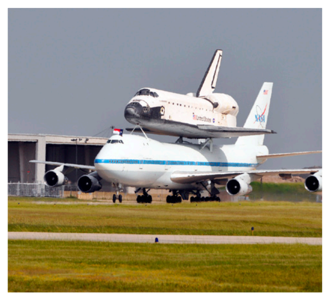
SEPTEMBER 2015 | FINAL



PHOTOS COURTESY OF
HOUSTON AIRPORT SYSTEM

ELLINGTON AIRPORT
Master Plan Update

RICONDO®
& ASSOCIATES

HOUSTON
AIRPORTS

Ellington Airport

Master Plan Update

PREPARED FOR:

Houston Airport System

September 2015

PREPARED BY:

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Ricondo & Associates, Inc. (R&A) prepared this document for the stated purposes as expressly set forth herein and for the sole use of the Houston Airport System and its intended recipients. The techniques and methodologies used in preparing this document are consistent with industry practices at the time of preparation.

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1. Introduction

The Houston Airport System (HAS) owns and operates three airports in the Houston area: William P. Hobby Airport, George Bush Intercontinental Airport/Houston, and Ellington Airport (collectively, the Airport System). Each airport has a unique role within the Airport System, and they collectively provide a full range of aviation activity to serve the Houston region:

- William P. Hobby Airport (hereinafter referred to as the Airport or HOU) is located approximately 7 miles southeast of downtown Houston. HOU is the airport of choice for many business travelers because of its proximity to downtown Houston and the availability of low-cost airline service to many United States destinations. The Airport is a key airport in Southwest Airlines' route system, and accommodates a significant amount of corporate aviation activity. In 2012, HOU was the 32nd busiest airport in the United States in terms of total numbers of enplaned passengers and the 44th busiest in terms of aircraft operations.[1]
- George Bush Intercontinental Airport/Houston (IAH) is located approximately 23 miles north of downtown Houston, and is the region's primary commercial service airport. IAH is dominated by the hubbing activity of United Airlines, and is the international gateway to Houston for commercial airline traffic. In 2012, IAH was the 11th busiest airport in the United States in terms of total numbers of enplaned passengers.[2]
- Ellington Airport (EFD) is located approximately 15 miles southeast of downtown Houston, and meets a wide range of the region's noncommercial aviation needs. EFD accommodates a significant amount of small general aviation aircraft activity. It is home to the Texas Air National Guard, the U.S. Army National Guard, the U.S. Coast Guard, and the National Aeronautics and Space Administration (NASA). It is also the site of the annual Wings Over Houston Airshow.

This Master Plan Update builds upon the Airport Master Plan which was completed in May 2004. This document is organized in 10 sections, and includes summaries of the detailed analyses and assessments associated with the Ellington Airport Master Plan Update. The remainder of this section provides a general statement regarding HAS' vision for the Airport and the goals of the Master Plan Update, as well as a summary of the Master Plan Update. The remaining nine sections present existing conditions at the Airport,

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[1] Federal Aviation Administration, *Preliminary CY 2012 Passenger Boarding and All-Cargo Data*, http://www.faa.gov/airports/planning_capacity/passenger_allcargo_stats/passenger/, accessed July 9, 2013.

[2] Federal Aviation Administration, *Preliminary CY 2012 Passenger Boarding and All-Cargo Data*, http://www.faa.gov/airports/planning_capacity/passenger_allcargo_stats/passenger/, accessed July 9, 2013.

including a brief Airport history; the forecasts of aviation demand at the Airport; demand/capacity and facility requirements; a strategy for implementing the recommended improvements; an airport environs development framework plan; an overall Airport development plan; a financial analysis, an environmental overview identifying issues associated with the strategy, as well as an airport layout drawing:

- Section 1 – Introduction
- Section 2 – Inventory of Existing Conditions
- Section 3 – Aviation Demand Forecasts
- Section 4 – Facility Requirements
- Section 5 – Alternatives Development
- Section 6 – Airport Environs (Off-Airport) Development Framework Plan
- Section 7 – Airport Development Plan
- Section 8 – Implementation Plan
- Section 9 – Funding Plan
- Section 10 – Environmental Overview

1.1 Master Plan Update Goals

The goals for the Airport Master Plan Update were established through various coordination meetings with the HAS Planning Department during the initial stages of the master planning process. These goals were refined as the Master Plan Update was being prepared, and as the planning team and the HAS Planning Department interacted with various tenants and City Departments. Goals from the 2004 Master Plan were also reviewed.

The overarching goal of the Master Plan Update is to ensure that natural market forces are not constrained in the future by facilities or operational limitations. As a result, the role of the Airport within the Houston Airport System is driven by HAS's mandate to expand EFD's role as a Spaceport, aircraft manufacturing, or any number of non-traditional aeronautical functions. Specific goals that were established to guide the EFD Master Plan Update are summarized below:

- Prepare a master plan that synergizes with the certification, development and operation of EFD as a Spaceport,
- Identify optimal land uses and prepare for future revenue enhancement opportunities, and;
- Elevate perception(s) of EFD

1.2 Summary of Master Plan Update

The Master Plan was initiated with the vision setting process in the fall of 2011. The technical analysis was started in early 2012 and preliminary conclusions reached in 2014. A series of workshops were held to present analyses methodologies and preliminary findings to stakeholders. Workshop presentation materials are provided in **Appendix B**. A public meeting was held in March 2015 to present findings to and obtain input from the community. Public meetings presentation materials are provided in **Appendix C.** Comments were addressed and included in the Master Plan Update.

This Master Plan Update addressed potential activity and related improvements through 2030. Recommendations included short, intermediate and long-term development to accommodate the growth that could occur. Some elements of airport development, such as new runways, can take 10 to 15 years to put in place once the need is identified. However, it is prudent for an airport to update its master plan periodically to ensure that planning initiatives respond to contemporary market conditions.

This Master Plan Update was designed so that projects could be initiated when demand dictates the need for development. The forecasts identify one timeline in which development could occur, however, if activity does not materialize as quickly as forecast, the development envisioned by this master plan would be delayed accordingly. Conversely, if growth were to accelerate, projects could be initiated prior to the timeline associated with the master plan forecasts. The need for implementation of various projects is based on actual activity reaching specific Planning Activity Levels (PAL) identified in the study. HAS would monitor aviation activity at HOU annually to determine whether activity is tracking as projected and which projects from the master plan should be programmed into the Airport’s five-year Capital Improvement Program (CIP) based on that activity.

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2. Inventory of Existing Conditions

The inventory of the physical, operational, and functional characteristics of Ellington Airport (the Airport or EFD) forms the basis for identifying and developing elements of the Airport Master Plan Update. The inventory information presented in this section also provides the basis for evaluating existing facilities and determining future facility requirements for the Airport. Information on the following topics is presented in this section:

- General Airport Information
- Airfield Facilities
- Airspace Environment
- Airport Support Facilities
- Airport Tenant Facilities
- Airport Access and Parking Facilities
- Environmental Inventory
- Land Use Compatibility
- Utility Infrastructure

2.1 General Airport Information

2.1.1 AIRPORT LOCATION

Exhibit 2-1 depicts the location of the three airports operated by the Houston Airport System (HAS), including Ellington Airport. EFD is located in Harris County, Texas, within the City of Houston, approximately 15 miles southeast of downtown Houston. William P. Hobby Airport is located approximately 7 miles to the northeast. George Bush Intercontinental Airport/Houston (IAH) is located approximately 23 miles north of downtown Houston.

Regional freeway access to the Airport is provided via Interstate 45 (I-45, which is also known as the Gulf Freeway), State Highway (SH) 3 and the Sam Houston Tollway/Beltway 8. Other arterial roads in the vicinity of the Airport include Dixie Farm Road, Scarsdale Boulevard, and Farm to Market Road (FM) 2351.

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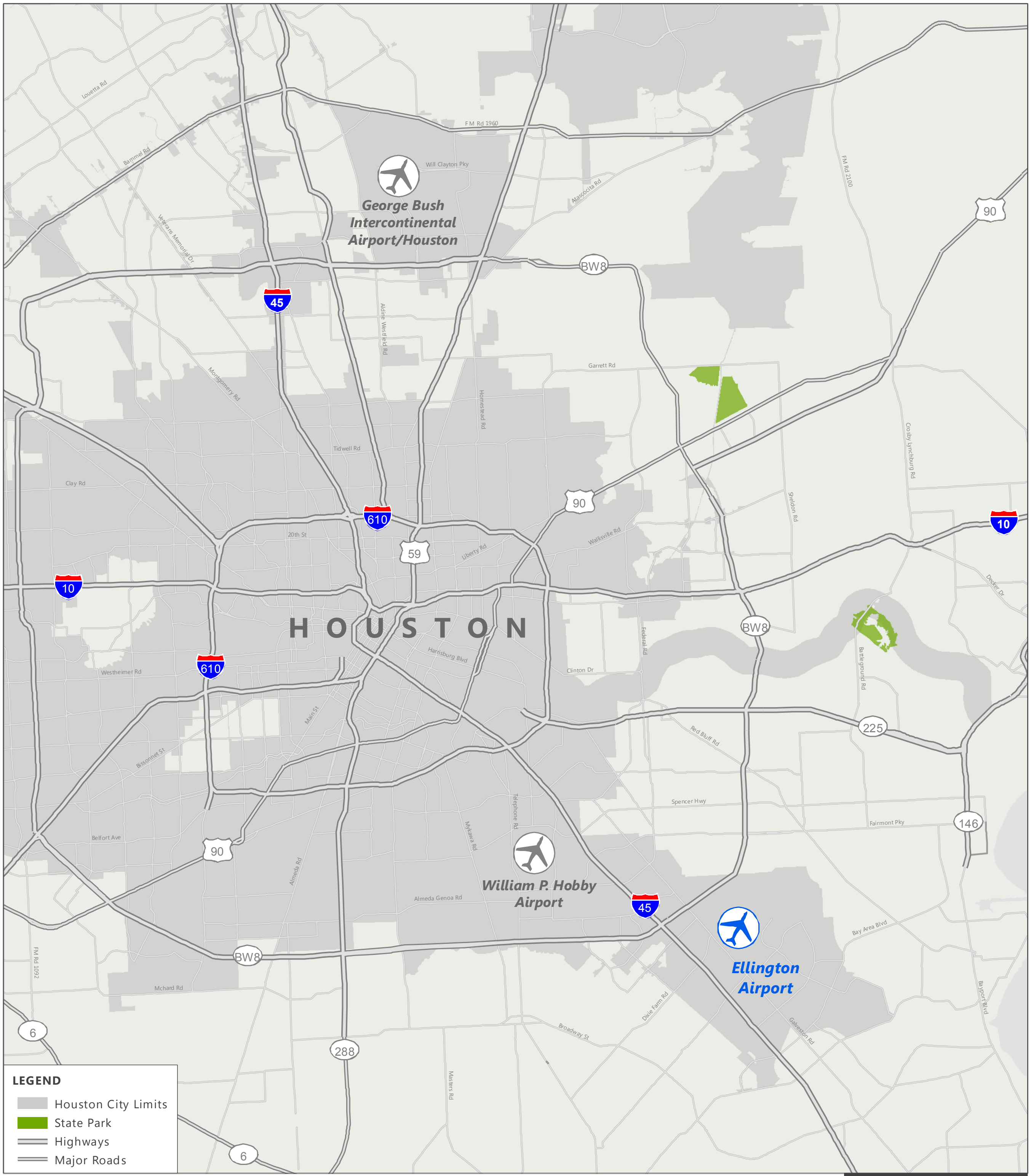

SOURCES: Environmental Systems Research Institute, 2010 (base map); Jacobs Engineering Group, Inc., 2013 (municipal boundary).
PREPARED BY: Ricondo & Associates, Inc., November 2013.

EXHIBIT 2-1

Houston Airport System Airports

Z:\Houston\1-EFD\EFD Master Plan 2012\02_Inventory\GIS Exhibits\Exhibit_2-1_HAS_Airports_042814.mxd

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2.1.2 AIRPORT HISTORY

Ellington Field was constructed in 1917 as a location for pilot and navigator training. It was the nation's first training site for aerial bombing. The training site was located on 1,280 acres of land and was named in honor of Lieutenant Eric Lamar Ellington, an army aviator who was killed in an aircraft crash in 1913. The training site was closed after World War I, in 1920, but was reopened in 1940 when the U.S. Congress authorized a program to rebuild it as one of 10 strategic defense bases in the nation.

Ellington Field was the only strategic defense base on the Gulf Coast; given its location, it was crucial to the defense of the Houston Ship Channel, the ports of Galveston and Houston, and the petrochemical refineries in the region. In 1947, Ellington Field became Ellington Air Force Base and continued to be operated as a training base for thousands of pilots, navigators, and bombardiers during World War II. From the 1950s to the 1970s, the base was used for air reservist, air guardsmen, and U.S. Navy, U.S. Marines, and aviation student training. The training base was deactivated in 1976.

From 1976 to 1984, a United States Air Force caretaker unit oversaw maintenance of the base. Thereafter, Ellington Field was acquired by the City of Houston to be operated as a municipal airport. In January 2009, Ellington Field was renamed Ellington Airport. It currently serves as Texas Air National Guard (TxANG), United States Army National Guard (ARNG), United States Coast Guard (USCG), and National Aeronautics and Space Administration (NASA) training facilities, as well as serving a variety of general aviation (GA) tenants.[3],[4]

2.1.3 AIRCRAFT ACTIVITY AND BASED AIRCRAFT DATA

Approximately 106,000 aircraft operations were conducted at the Airport in 2012, as shown in **Table 2-1**. Approximately 60 percent of those operations were conducted by GA aircraft, which include air taxis. NASA operations accounted for approximately 8 percent of operations in 2012, and military operations accounted for approximately 25 percent of operations

Table 2-1: 2012 Aircraft Operations

	AIR CARRIER	AIR TAXI	GENERAL AVIATION	NASA	MILITARY	TOTAL
Number of Aircraft Operations	--	8,827	61,683	8,335	27,197	106,042
Percentage of Total	0%	8.3%	58.2%	7.9%	25.6%	100.0%

SOURCE: Houston Airport System *Statistical Report*. Accessed October 2013; http://www.fly2houston.com/TrafficStats.
PREPARED BY: Ricondo & Associates, Inc., January 2014.

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[3] National Aeronautics and Space Administration, *Ellington Field: A Short History, 1917-1963,* February 1999. Accessed January 2104; http://www.jsc.nasa.gov/history/ellington/Ellington.pdf.

[4] Texas Archival Resources Online, Ellington Field research collection, 1917-2009. Accessed January 2104; https://library.rice.edu/collections/WRC/finding-aids/manuscripts/0547.

As shown in **Table 2-2**, in 2012, 237 aircraft were based at the Airport.

Table 2-2: Based Aircraft at the Airport

	2012
FIXED-WING AIRCRAFT	
Single-engine Piston	140
Multiengine Piston	25
Jet	40
Total Fixed-Wing Aircraft	205
HELICOPTERS	8
GLIDERS	1
MILITARY	23
TOTAL BASED AIRCRAFT	237

SOURCE: Federal Aviation Administration, *Form 5010-1, Airport Master Record for Year 2012,* October 2013.
PREPARED BY: Ricondo & Associates, Inc., March 4, 2014.

2.1.4 AIRPORT REFERENCE CODE

The Airport Reference Code (ARC) is a designation that generally classifies an airport according to its ability to accommodate certain categories of aircraft operations on the airfield. Assignment of an ARC does not limit the types of operations that can occur at an airport, but rather, the ARC is used to broadly identify various planning and design parameters that help ensure safe operations at an airport. The ARC is most often determined by Aircraft Approach Category (AAC) and Airplane Design Group (ADG) for aircraft using or expected to use the airport on a regular basis (at least 500 operations per year); however, the Federal Aviation Administration (FAA) also considers local characteristics when determining an airport's ARC. The AAC is designated by a letter (A through D) representing approach speed, and the ADG is designated by a Roman numeral (I through VI) based on wingspan and tail height. The ARC is written as the combination of the AAC and the ADG, separated by a hyphen.

As reported by HAS, the Airport has an ARC of D-IV, which means that aircraft with wingspans up to 171 feet and runway approach speeds up to 165 knots can be accommodated on the airfield. Examples of ADG IV aircraft include the Boeing 757, the Boeing 767, the McDonnell Douglas DC-8, the McDonnell Douglas DC-10, and the McDonnell Douglas MD-11. The Airport currently accommodates a wide variety of aircraft operations. Based and itinerant GA aircraft include small single-engine and multiengine aircraft (ARC A-I and B-I), and corporate turboprops and jets (ARC B-II, C-I, and C-II). Commercial charter activity, primarily for sporting events, is provided by air carrier jet aircraft, such as the Boeing 757. Other large aircraft that operate at the Airport include NASA and military aircraft. These aircraft may be as large as the Boeing 747 (ARC D-V).

Runways 17R-35L and 4-22 are designed to accommodate ARC D-IV aircraft. Runway 17L-35R can only accommodate helicopters and small aircraft belonging to AACs A and B and ADGs I and II. Only

Runways 17R-35L and 4-22 are certified for commercial air carrier use under Title 14, Code of Federal Regulations, Part 139 (14 CFR Part 139).

2.1.5 METEOROLOGICAL CONDITIONS

Wind and weather conditions influence airport operations by affecting runway use and the percentage of time aircraft can operate under certain flight rules. Observations of weather conditions, such as wind direction and speed, visibility, and cloud ceiling at Ellington Airport were used to evaluate general weather conditions and runway wind coverage.

2.1.5.1 General Weather Conditions

Weather conditions fall under two categories: visual meteorological conditions (VMC) and instrument meteorological conditions (IMC). VMC occur when the prevailing visibility is greater than or equal to 3.0 statute miles *and* the cloud ceiling is 1,000 feet above ground level (AGL) or higher. During VMC, pilots operate under visual flight rules (VFR), essentially using visual means to maintain separation from other aircraft, objects, terrain, etc.

IMC occur when the prevailing visibility is less than 3.0 statute miles *or* the cloud ceiling is lower than 1,000 feet AGL. During IMC, pilots operate under instrument flight rules (IFR), relying on FAA Air Traffic Control (ATC) to provide separation guidance from other aircraft and terrain. Operating under IFR requires additional pilot training and aircraft certifications beyond those required for operating under VFR. Pilots can operate under IFR in VMC.

To evaluate the weather conditions at Ellington Airport, information was obtained from the automated weather station located at the Airport. Data for this station were recorded by the National Climatic Data Center (NCDC) for the 10-year period between 2003 and 2012, and consist of 70,212 hourly observations.

At Ellington Airport, VMC and IMC were observed during approximately 85.7 percent and 14.3 percent of the hourly observations, respectively.

2.1.5.2 Runway Wind Coverage

Wind patterns have a significant effect on runway use at an airport, as aircraft typically take off and land into the wind to minimize required runway length. When wind direction is not directly aligned with the runway(s), pilots calculate a crosswind component to determine if a runway is usable. FAA Advisory Circular (AC) 150/5300-13A, *Airport Design*, recommends that runway(s) at an airport achieve at least 95 percent wind coverage, evaluated based on a period of at least 10 consecutive years. To evaluate the runway wind coverage at Ellington Airport, the NCDC information mentioned above was used. Runways 17L-35R, 17R-35L, and 4-22 were evaluated independently and collectively; however, as Runways 17L-35R and 17R-35L are oriented in the same direction, they are considered a single runway for the purposes of determining runway wind coverage. Crosswind components of 10.5 knots, 13 knots, 16 knots, and 20 knots were evaluated to determine the runway wind coverage percentages for all Runway Design Codes (RDCs).

Review of the NCDC wind data determined that the combined wind coverage provided by all runways at Ellington Airport is greater than 97.7 percent for all weather conditions, VMC, and IMC at all four calculated crosswind components (10.5, 13, 16, and 20 knots). This runway coverage exceeds the FAA's recommendation of 95 percent for all runways at an airport.

Individually, Runways 17L-35R and 17R-35L exceed the FAA wind coverage recommendations for all weather conditions, VMC, and IMC at all four crosswind components (10.5, 13, 16, and 20 knots). Runway 4-22 meets the FAA wind coverage recommendations for all weather conditions, VMC, and IMC at crosswind components of 13, 16, and 20 knots; however, Runway 4-22 alone does not meet the wind coverage recommendations during all weather conditions, VMC, and IMC at a 10.5 knot crosswind component. **Exhibits 2-2**, **2-3**, and **2-4** summarize the wind coverage for the Airport's runways under varying weather conditions.

2.2 Airfield Facilities

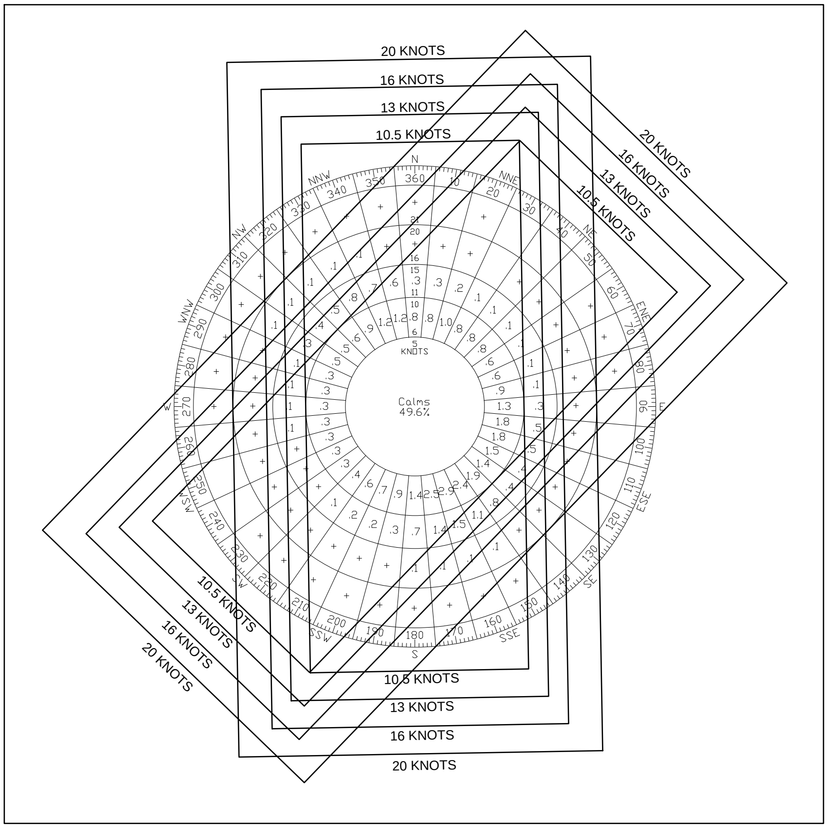
EFD is a joint use (civilian and military) facility and one of a few airfields built around World War I that is still used today for military training operations. The Airport occupies approximately 2,300 acres. The landscape is flat, with a field elevation of 32.7 feet above mean sea level (MSL). The airfield includes two parallel runways and one crosswind runway and is split into four quadrants, as shown on **Exhibit 2-5**:

- The *Northwest Quadrant* encompasses the Ellington Field Joint Reserve Base (EFJRB), and is off Airport property. This quadrant was, therefore, not included in the analyses conducted for this Master Plan Update.
- The *Southwest Quadrant* encompasses the GA areas south of the EFJRB, as well as some NASA facilities.
- The *Northeast Quadrant* is the triangular area between Runways 17R-35L and 4-22. Runway 17L-35R and several taxiways are also located in the Northeast Quadrant.
- The *Southeast Quadrant* is a vacant area located southwest of Runway 4-22.

2.2.1 RUNWAYS

Exhibit 2-5 also depicts the existing three runways at the Airport. The two parallel runways have a runway centerline-to-centerline separation of 2,600 feet. Runway 17R-35L, the primary runway and the longer of the two, is 9,001 feet long and 150 feet wide. Runway 17L-35R is 4,609 feet long and 80 feet wide. Runway 4-22 is a crosswind runway that is 8,001 feet long and 150 feet wide. Two decommissioned runways are used as Taxiways B and D.

ALL WEATHER WIND ROSE



WIND COVERAGE TABLE

CROSSWIND COMPONENT	RUNWAY COVERAGE			
	Runway 17	Runway 35	Runway 4	Runway 22
10.5 knots (12 mph)	79.8%	67.1%	71.1%	69.3%
	97.3%		90.8%	
	98.3%			
13 knots (15 mph)	81.1%	68.0%	74.1%	73.4%
	99.4%		98.0%	
	99.7%			
16 knots (18.4 mph)	81.2%	68.2%	74.7%	74.2%
	99.8%		99.4%	
	99.9%			
20 knots (23 mph)	81.2%	68.3%	75.0%	74.5%
	100.0%		100.0%	
	100.0%			

SOURCES: National Climatic Data Center, 3505 Format Surface Hourly Observations (2003 - 2012), November 2013; Ricondo & Associates, Inc., December 2013.
PREPARED BY: Ricondo & Associates, Inc., December 2013..

EXHIBIT 2-2

NORTH 0 Not To Scale

All Weather
Wind Rose and Runway Coverage Table

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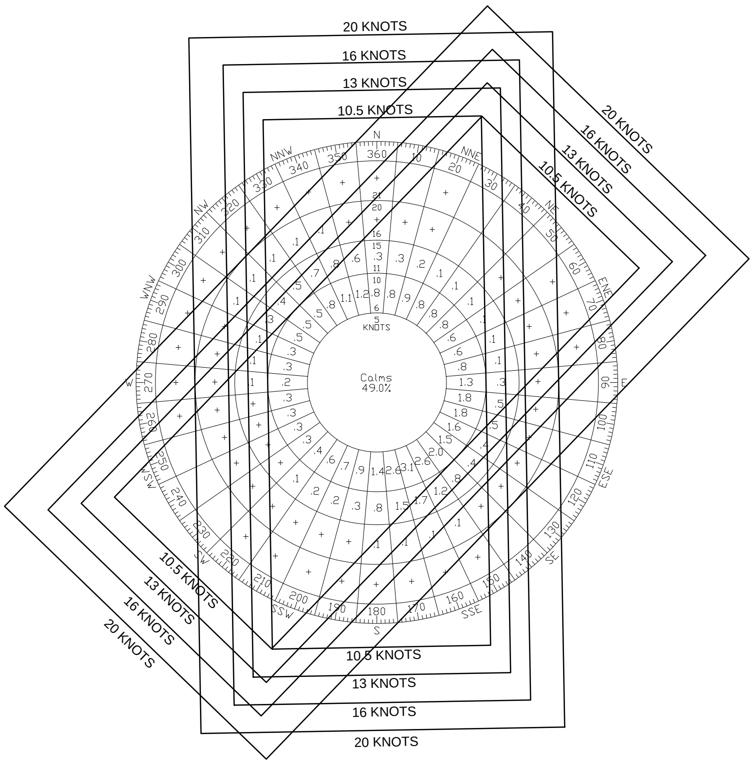
VISUAL METEOROLOGICAL CONDITIONS WIND ROSE



Ceiling at or above 1,000' and visibility greater than or equal to 3 statute miles

WIND COVERAGE TABLE

CROSSWIND COMPONENT	RUNWAY COVERAGE			
	Runway 17	Runway 35	Runway 4	Runway 22
10.5 knots (12 mph)	80.7%	65.7%	70.1%	69.5%
	97.4%		90.6%	
	98.5%			
13 knots (15 mph)	82.0%	66.5%	73.1%	73.9%
	99.5%		98.0%	
	99.8%			
16 knots (18.4 mph)	82.2%	66.7%	73.7%	74.7%
	99.8%		99.4%	
	99.9%			
20 knots (23 mph)	82.2%	66.8%	73.9%	75.0%
	100.0%		100.0%	
	100.0%			

SOURCES: National Climatic Data Center, 3505 Format Surface Hourly Observations (2003 - 2012), November 2013; Ricondo & Associates, Inc., December 2013.
PREPARED BY: Ricondo & Associates, Inc., December 2013..

EXHIBIT 2-3

NORTH 0 Not To Scale

Visual Meteorological Conditions Wind Rose and Runway Coverage Table

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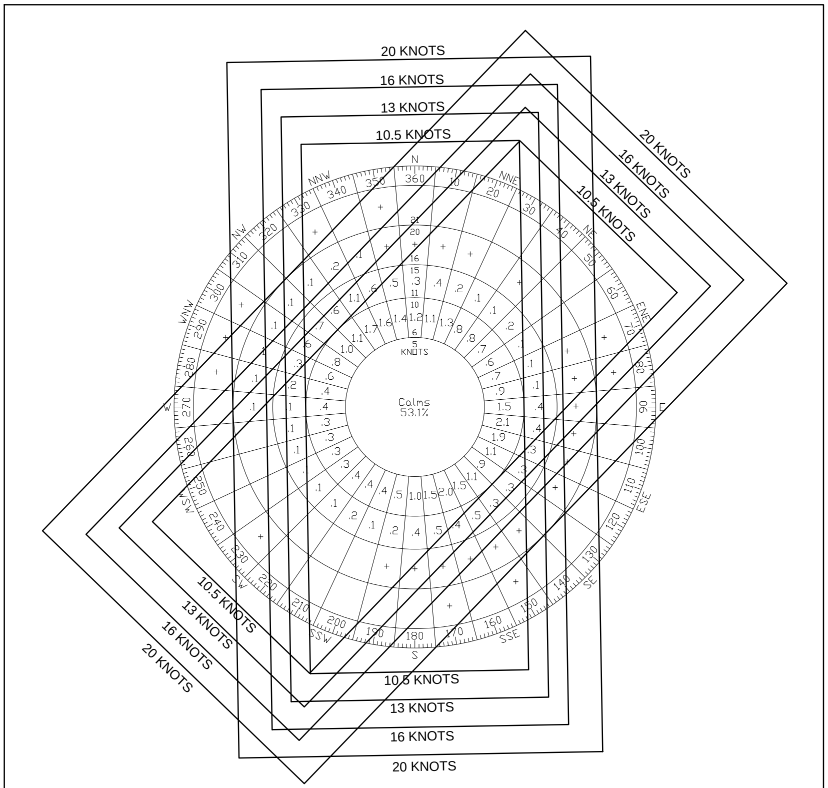
INSTRUMENT METEOROLOGICAL CONDITIONS WIND ROSE



Ceiling below 1,000 feet and/or visibility less than 3 statute miles

WIND COVERAGE TABLE

CROSSWIND COMPONENT	RUNWAY COVERAGE			
	Runway 17	Runway 35	Runway 4	Runway 22
10.5 knots (12 mph)	74.0%	75.4%	77.2%	68.1%
	96.4%		92.2%	
	97.7%			
13 knots (15 mph)	75.3%	76.7%	80.2%	70.7%
	98.9%		97.7%	
	99.4%			
16 knots (18.4 mph)	75.5%	77.2%	80.8%	71.4%
	99.6%		99.2%	
	99.8%			
20 knots (23 mph)	75.5%	77.5%	81.2%	71.7%
	99.9%		99.9%	
	100.0%			

SOURCES: National Climatic Data Center, 3505 Format Surface Hourly Observations (2003 - 2012), November 2013; Ricondo & Associates, Inc., December 2013.
PREPARED BY: Ricondo & Associates, Inc., December 2013..

EXHIBIT 2-4

NORTH 0 Not To Scale

Instrument Meteorological Conditions Wind Rose and Runway Coverage Table

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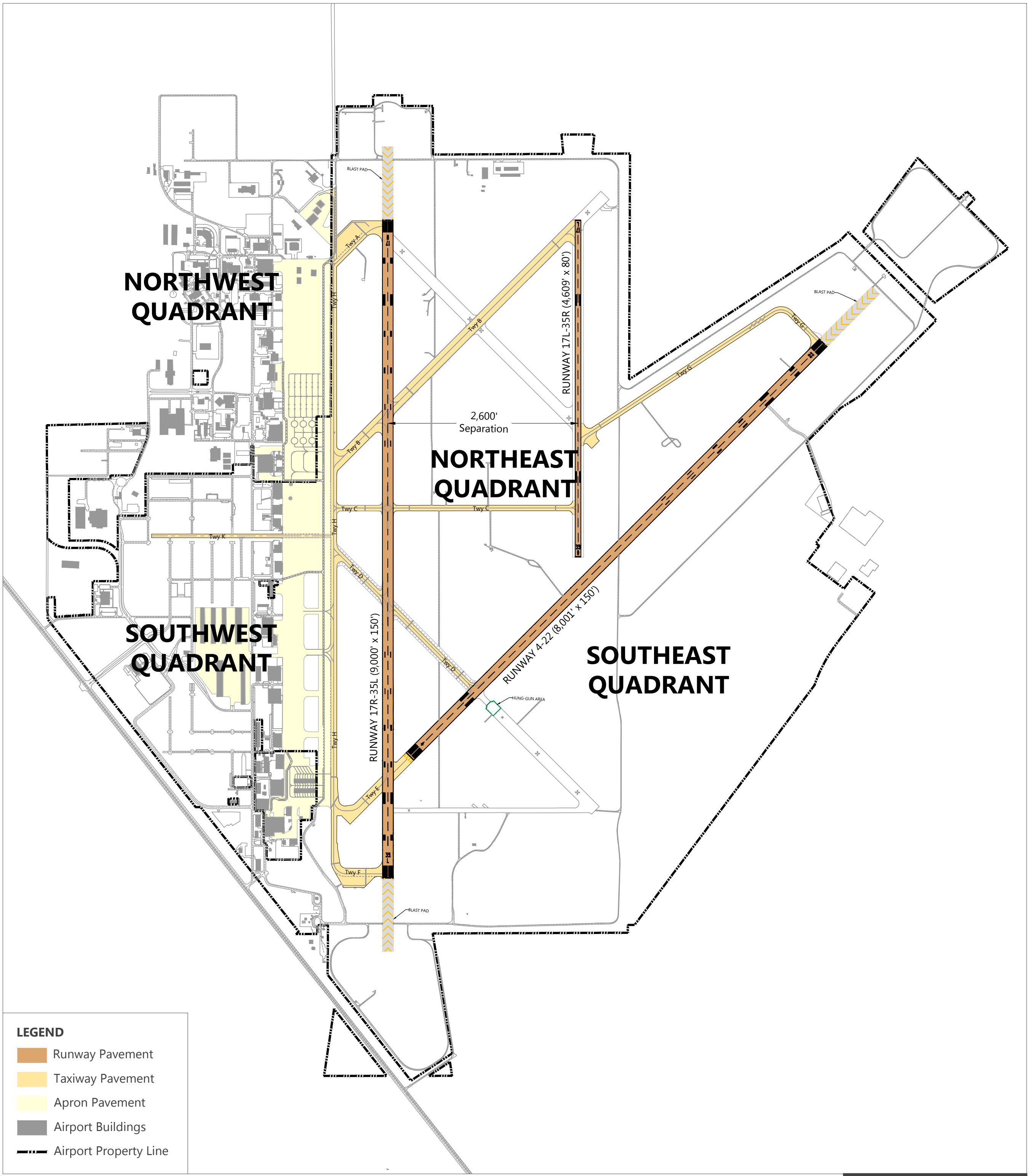

SOURCES: Ellington Draft Airport Layout Plan, Ricondo & Associates, March 2014; Houston Airport System, March 2014.
PREPARED BY: Ricondo & Associates, Inc., March 2014.

EXHIBIT 2-5

NORTH 0 2,000 ft.

Airfield Facilities

Drawing: \\ricondo.com\public\Dallas\Project\Houston Airport System\Ellington Airport\2014 Master Plan Update\02 - Data Collection and Inventory\2-Exhibits\CAD\Exhibit 2-5_Existing Runways.dwg Layout: Existing Runway Plotted: Sep 9, 2015, 11:33AM

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2.2.1.1 Runway 17R-35L

As depicted on **Exhibit 2-6**, Runway 17R-35L (9,001 feet long and 150 feet wide) has blast pads on both ends that are 1,000 feet long and 150 feet wide. The runway surface is grooved concrete and the runway has precision instrument markings. The RDC for Runway 17R-35L is D-IV-4000. In addition to the AAC and the ADG, the RDC also includes the approach visibility minimum, which is expressed in runway visual range (RVR) values in feet. The visibility minimum is derived from the runway's instrument approach procedures. This RDC corresponds to aircraft with maximum approach speeds of 165 knots, wingspans between 118 feet and 171 feet, tail heights between 45 and 60 feet, and an approach visibility minimum of 4,000 feet.

The load bearing capacity of a runway measures the strength of the runway pavement and its capacity to support loads at an average level of activity. It is expressed in terms of gross aircraft weight and varies with the type and size of landing gear (single wheel, double wheel, double tandem wheel, or dual double tandem wheel). The load bearing capacity of Runway 17R-35L is 100,000 pounds for single-wheel landing gear, 190,000 pounds for double wheel landing gear, 590,000 pounds for double tandem wheel landing gear, and 800,000 pounds for dual double tandem wheel landing gear.[5]

Arresting systems are installed on each runway end for use by military jets in the event of an aborted takeoff or aircraft failure during landing that would impede stopping capabilities. The systems installed at EFD consist of a cable laid across the runway, which can only accommodate military jet aircraft equipped with an arresting hook. One cable is located 1,500 feet south of the Runway 17R end, and the other is located 1,850 feet north of the Runway 35L end.

A hold pad is located on each runway end. On Runway 17R, the hold pad is adjacent to the military apron near the north end of the runway, and on Runway 35L, the hold pad is located near the south end on Taxiway H. Runway 17R is used mainly by the military and NASA; GA aircraft use the runway to a lesser extent, when other runways are being maintained or rehabilitated or when specifically requested by GA pilots. Aircraft arriving on Runway 17R are given several exit options: Taxiway B, C, D, E, or F. Taxiway H and its extension, Taxiway F, is the only full-length parallel taxiway for Runway 17R-35L. Aircraft arriving on Runway 35R can use Taxiway E, D, C, B, or A to access the GA facilities or the military, USCG, and NASA aprons.

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[5] Airnav.com, accessed December 2013.

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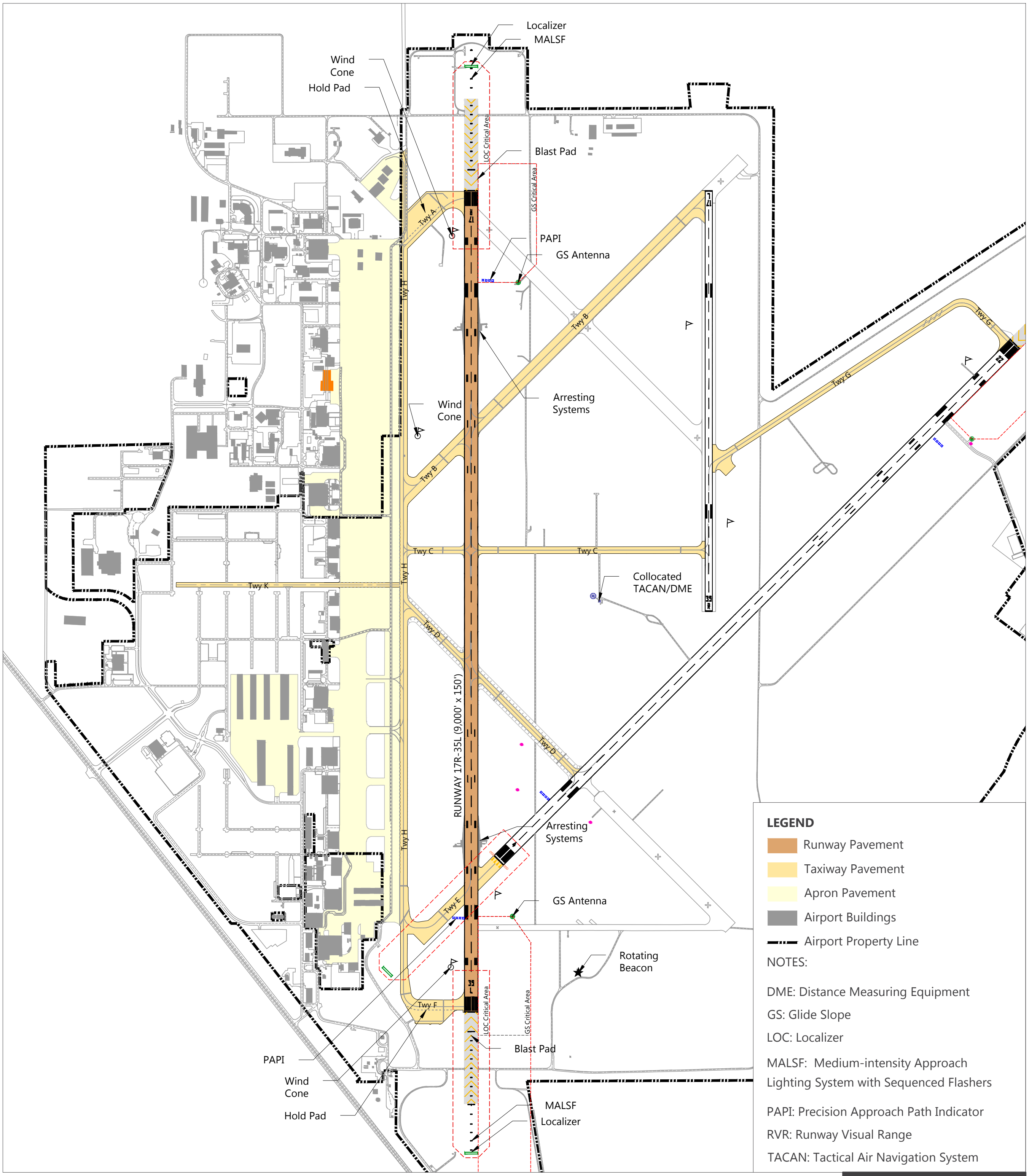

SOURCES: Ellington Draft Airport Layout Plan, Ricondo & Associates, March 2014; Houston Airport System, March 2014.
PREPARED BY: Ricondo & Associates, Inc., March 2014.

EXHIBIT 2-6

Runway 17R-35L and Associated Facilities

Drawing: \\ricondo.com\public\Dallas\Project\Houston Airport System\Ellington Airport\2014 Master Plan Update\02 - Data Collection and Inventory\2-Exhibits\CAD\Exhibit 2-6_17R-35L.dwg Layout: 17R-35L Plotted: Sep 9, 2015, 11:50AM

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2.2.1.2 Runway 17L-35R

As depicted on **Exhibit 2-7**, Runway 17L-35R is 4,609 feet long and 80 feet wide. Its surface is concrete. The runway has visual markings. The RDC for Runway 17L-35R is B-II-VIS (VIS indicates visual approaches only). This RDC corresponds to aircraft with maximum approach speeds of 120 knots, wingspans between 49 feet and 79 feet, and tail heights between 20 and 30 feet.

The load bearing capacity of this runway is 24,000 pounds for single-wheel landing gear, 63,000 pounds for double wheel landing gear, 145,000 pounds for double tandem wheel landing gear, and 300,000 pounds for dual double tandem wheel landing gear[6].

Runway 17L-35R is operated as a GA visual runway in the daytime only. However, at night, military aircraft use the runway for nighttime training. The portion of Runway 17L-35R between Taxiways G and C is used as a taxiway for aircraft landing on Runway 4 and exiting the runway onto Taxiway G.

Aircraft landing on Runway 17L exit on Taxiway C to access the apron areas on the west side of the Airport. Aircraft arriving on Runway 35R use Taxiway B.

2.2.1.3 Runway 4-22

As depicted on **Exhibit 2-8**, Runway 4-22 is 8,001 feet long and 150 feet wide. It is constructed with continuously reinforced and grooved concrete. Runway 22 has precision approach markings whereas Runway 4 has nonprecision approach markings. The RDC for Runway 4-22 is D-IV-1800.

Runway 4-22 has a load bearing capacity of 100,000 pounds for single-wheel landing gear, 164,000 pounds for dual-wheel landing gear, 300,000 pounds for dual-tandem wheel landing gear, and 668,000 pounds for dual double tandem wheel landing gear. Similar to Runway 17R-35L, arresting barriers are located at either end of Runway 4-22 for use by military aircraft; an arresting gear cable is located 1,496 feet southwest of the Runway 22 end, and another cable is located 1,563 feet northeast of the Runway 4 end.

Aircraft arriving on Runway 4 can exit the runway at Taxiway D or G. Taxiway E is an extension of Runway 4-22 and is used by departing aircraft taxiing to Runway 4 and aircraft arriving on Runway 22 to access the apron area on the west side of the Airport. Aircraft arriving on Runway 22 can exit the runway on Taxiway D or roll out to the end of the runway onto Taxiway E to reach the apron area.

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[6] Airnav.com, accessed December 2013.

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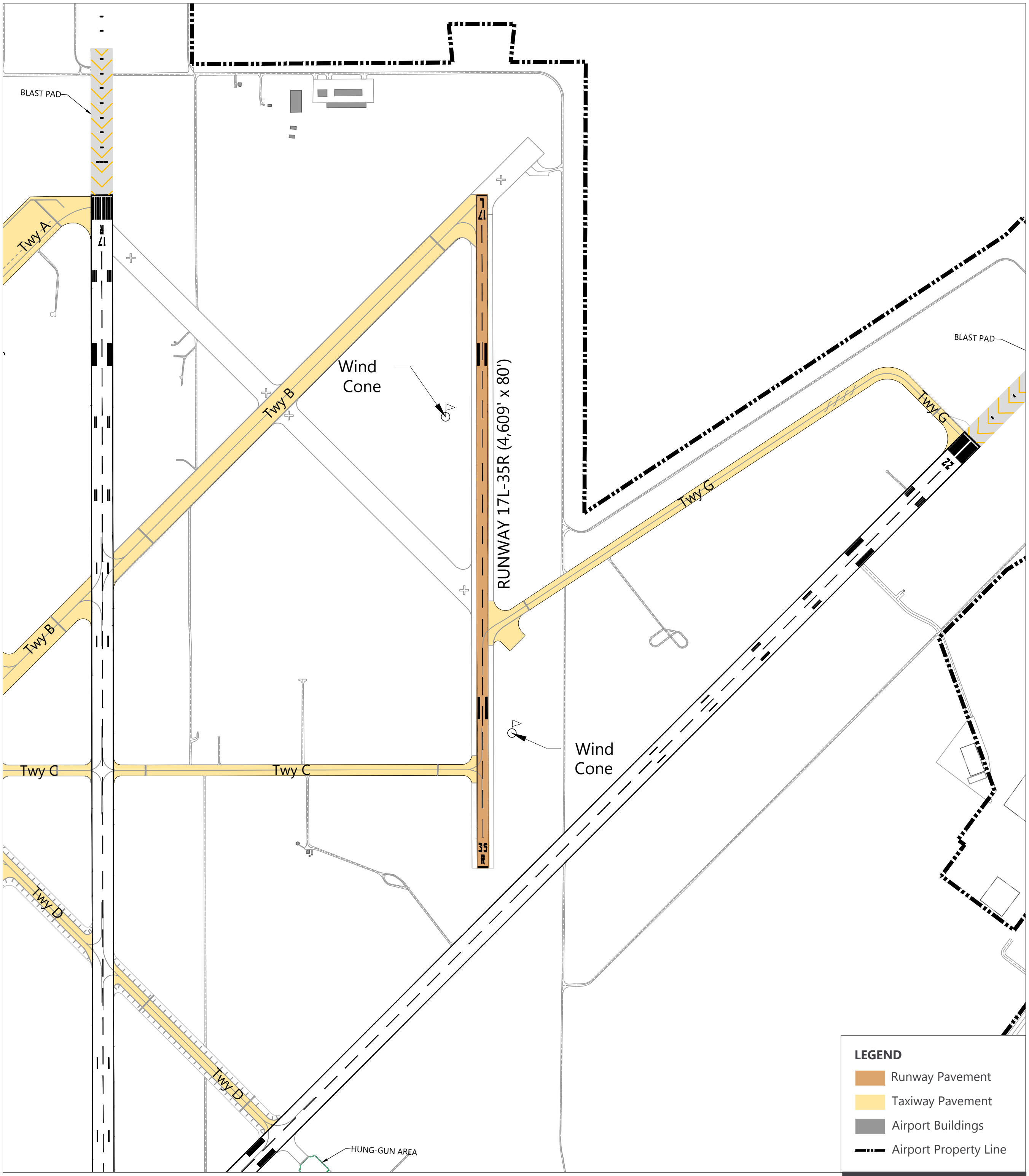

SOURCES: Ellington Draft Airport Layout Plan, Ricondo & Associates, March 2014; Houston Airport System, March 2014.
PREPARED BY: Ricondo & Associates, Inc., March 2014.

EXHIBIT 2-7

NORTH 0 1,000 ft.

Runway 17L-35R and Associated Facilities

Drawing: \\ricondo.com\public\Dallas\Project\Houston Airport System\Ellington Airport\2014 Master Plan Update\02 - Data Collection and Inventory\2-Exhibits\CAD\Exhibit 2-7_17L-35R.dwg Layout: 17L-35R Plotted: Sep 9, 2015, 11:55AM

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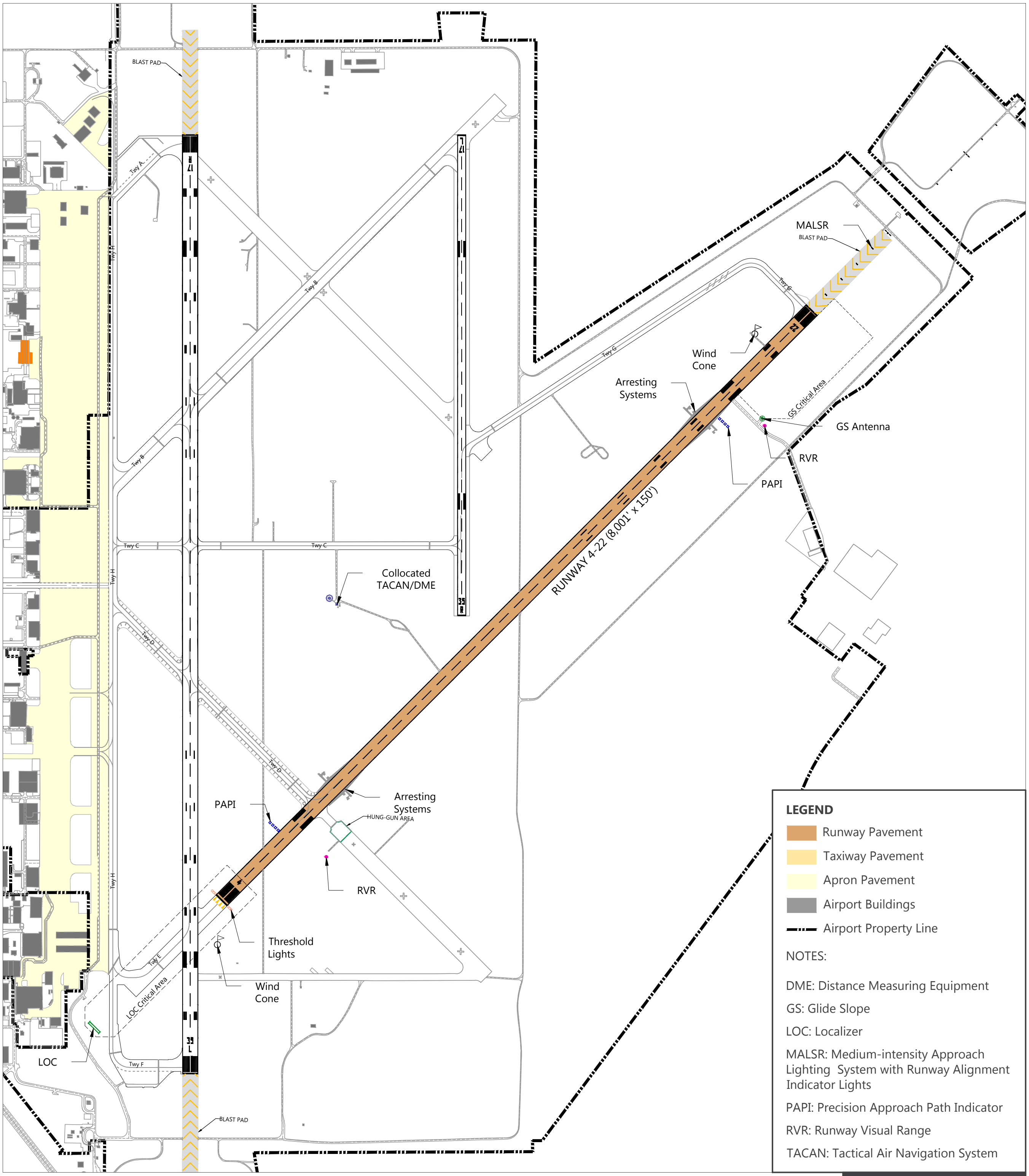

LEGEND

🟧 Runway Pavement

🟨 Taxiway Pavement

🟨 Apron Pavement

⬛ Airport Buildings

-·-·- Airport Property Line

NOTES:

DME: Distance Measuring Equipment

GS: Glide Slope

LOC: Localizer

MALSR: Medium-intensity Approach Lighting System with Runway Alignment Indicator Lights

PAPI: Precision Approach Path Indicator

RVR: Runway Visual Range

TACAN: Tactical Air Navigation System

SOURCES: Ellington Draft Airport Layout Plan, Ricondo & Associates, March 2014; Houston Airport System, March 2014.
PREPARED BY: Ricondo & Associates, Inc., March 2014.

EXHIBIT 2-8

NORTH 0 1,400 ft.

Runway 4-22 and Associated Facilities

Drawing: \\ricondo.com\public\Dallas\Project\Houston Airport System\Ellington Airport\2014 Master Plan Update\02 - Data Collection and Inventory\2-Exhibits\CAD\Exhibit 2-8_4-22.dwg Layout: 4-22 Plotted: Sep 9, 2015, 12:18PM

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2.2.1.4 Runway Characteristics Summary

Table 2-3 summarizes the characteristics described above for each runway and presents the runway end and touchdown zone elevations.

Table 2-3: Runway Characteristics

	RUNWAY		
DESCRIPTION	**17R-35L**	**17L-35R**	**4-22**
Length (feet)	9,001	4,609	8,001
Width (feet)	150	80	150
Runway Composition	Grooved Concrete	Concrete	Grooved Concrete
Runway End Elevation (feet)	17R: 32.0 35L: 27.6	17L: 31.3 35R: 30.0	4: 26.1 22: 30.4
Touchdown Zone Elevation (feet)	17R: 32.0 35L: 27.6	None	4: 30.4 22: 30.7
Runway Markings	Precision	Visual	Precision
Runway Design Code	D-IV-4000	B-II-VIS	D-IV-1800
Load Bearing Capacity (000 pounds)			
Single Wheel	100	24	100
Dual Wheel	190	63	164
Dual Tandem Wheel	590	145	300
Dual Double Tandem Wheel	800	300	668

SOURCES: FAA AVN Datasheet System, Detail for Ellington Airport accessed December 26, 2012; FAA, *Digital Airport/Facility Directory*, effective November 15, 2012, to January 10, 2013.

PREPARED BY: Ricondo & Associates, Inc., December 2012.

2.2.1.5 Runway Design Criteria

The FAA-recommended runway design criteria for ARC B-II and D-IV aircraft are presented in **Table 2-4**, along with existing runway specifications at the Airport. As shown, the runways currently meet the recommended design criteria, expect for the pavement of ADG IV runway shoulders and runway blast pads. According to the latest FAA AC on airport design (150/5300-13A), paved shoulders are required for runways accommodating ADG IV through ADG VI aircraft. Therefore, Runways 17R-35L and 4-22 do not meet FAA standards, as their shoulders are currently not paved. Additionally, a runway accommodating ARC B-II aircraft should have a blast pad that is 95 feet wide and 150 feet long, while the blast pad associated with a runway accommodating ARC D-IV aircraft should be 200 feet wide and 200 feet long. Runways 17R, 35L, and 22 are equipped with blast pads that meet the length requirement, but not the width requirement. The Runway 4, 17L, and 35R ends do not have blast pads.

Table 2-4: Runway Design Criteria

RUNWAY DESIGN ELEMENTS	ARC D-IV DESIGN CRITERIA (FEET) DESIGN CRITERIA	RUNWAY 17R-35L	RUNWAY 4-22	ARC B-II DESIGN CRITERIA FOR VISUAL RUNWAY (FEET) DESIGN CRITERIA	RUNWAY 17L-35R
Runway Width	150	150	150	75	80
Runway Shoulder Width	25	- [1/]	- [1/]	10	37.5
Runway Shoulder Pavement [2/]	Paved	Not Paved	Not Paved	No Requirement	Paved
Runway Blast Pad:					
Width	200	150 - 150	150 - 0	95	-
Length	200	1,000 -1,000	1,000 - 0	150	-
Runway Centerline to:					
Taxiway Centerline	400	740	- [3/]	240	- [3/]
Aircraft Parking Area	500	890	- [4/]	250	- [4/]

NOTES:

1/ Runway does not have paved shoulders.

2/ According to the recent FAA update of the Advisory Circular on airport design, the shoulders of ADG IV runways must be composed of asphalt.

3/ Runway does not have a full-length taxiway parallel to its centerline.

4/ There is no aircraft parking area in the proximity of the runway.

SOURCES: Federal Aviation Administration, Advisory Circular 150/5300-13A (Change 1), *Airport Design*, February 2014; Ricondo & Associates, Inc., May 2015.

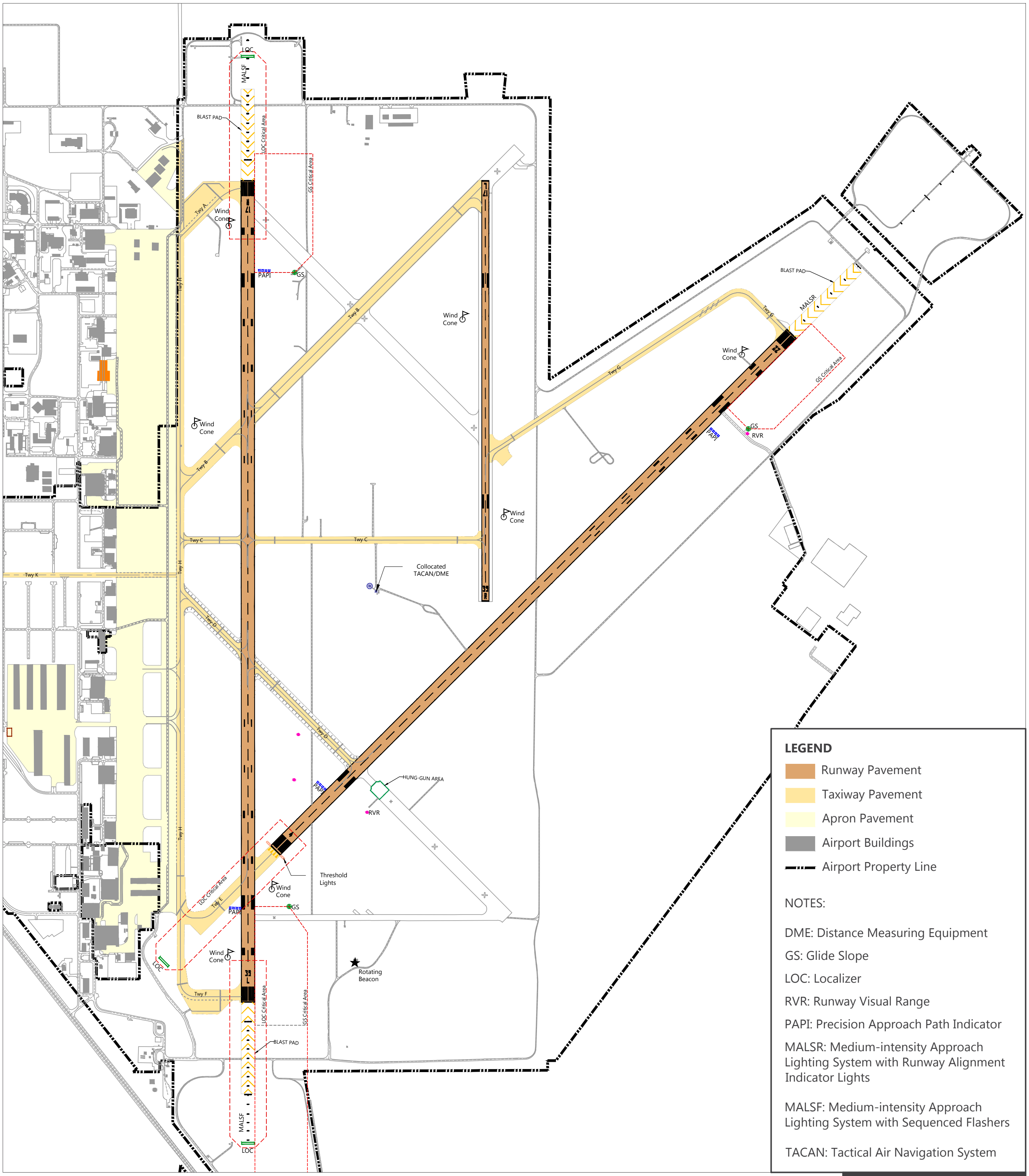
PREPARED BY: Ricondo & Associates, Inc., May 2015.

2.2.2 NAVIGATIONAL AIDS AND LIGHTING SYSTEMS

The following subsections describe the navigational aids and lighting systems for each runway at the Airport. Their locations are depicted on **Exhibit 2-9**.

2.2.2.1 Tactical Air Navigation System

To support military aircraft navigation, the Airport is equipped with a tactical air navigation system (TACAN). The TACAN transmitter is located south of Taxiway C, along its midpoint. The information provided by a TACAN is the same as the civilian very high frequency (VHF) omnidirectional range (VOR) and distance measuring equipment (DME) combination: azimuth and slant range distance. However, TACAN information is transmitted over an ultrahigh frequency (UHF) band of frequencies. Its use requires TACAN airborne equipment and it does not operate through conventional VOR equipment.



LEGEND

🟧 Runway Pavement

🟨 Taxiway Pavement

▭ Apron Pavement

▇ Airport Buildings

-·-·- Airport Property Line

NOTES:

DME: Distance Measuring Equipment

GS: Glide Slope

LOC: Localizer

RVR: Runway Visual Range

PAPI: Precision Approach Path Indicator

MALSR: Medium-intensity Approach Lighting System with Runway Alignment Indicator Lights

MALSF: Medium-intensity Approach Lighting System with Sequenced Flashers

TACAN: Tactical Air Navigation System

SOURCES: Ellington Draft Airport Layout Plan, Ricondo & Associates, March 2014; Houston Airport System, March 2014.
PREPARED BY: Ricondo & Associates, Inc., March 2014.

EXHIBIT 2-9

NORTH 0 1,600 ft.

Navigational Aids and Lighting Systems

Drawing: \\ricondo.com\public\Dallas\Project\Houston Airport System\Ellington Airport\2014 Master Plan Update\02 - Data Collection and Inventory\2-Exhibits\CAD\Exhibit 2-9_EFD Navaids.dwg Layout: 8.5x11P Plotted: Sep 9, 2015, 01:42PM

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2.2.2.2 Distance Measuring Equipment

DME provides slant range distance information for aircraft in flight. It can be used both by aircraft transitioning through the area and by aircraft landing at Ellington Airport. At the Airport, the DME is collocated with the military TACAN.

2.2.2.3 Instrument Landing System

An instrument landing system (ILS) is a ground-based instrument approach system that provides precision guidance to pilots upon the final approach for landing in conditions of limited or reduced visibility. An ILS is designed to provide an approach path for exact alignment and descent of an aircraft on final approach to a runway. ILS components provide the following information:

- Lateral and vertical guidance with a localizer and glide slope antenna, respectively,
- Range information with a marker beacon and/or DME, and
- Visual information with approach lighting systems (ALS), touchdown zone lights (TDZL), and runway edge and centerline lights.

There are three categories of ILS approaches based on the RVR and the decision height available:

- A Category I (CAT I) ILS approach has a decision height not less than 200 feet above touchdown zone elevation and an RVR not less than 1,800 feet.
- A CAT II ILS approach has a decision height of 100 feet and an RVR not less than 1,200 feet.
- A CAT III ILS is further divided into CAT IIIa, CAT IIIb, and CAT IIIc:
    - CAT IIIa approaches have no decision height minimums and an RVR not less than 700 feet.
    - CAT IIIb and CAT IIIc approaches have no decision heights and lower RVR minimums than CAT IIIa approach minimums. CAT II and CAT III ILS approaches require special crew training and certification, as well as aircraft certification.

Three CAT I ILSs are installed at Ellington Airport, and provide precision instrument approach capability for landings in poor weather conditions on Runways 17R, 35L, and 22. ILS approach procedures to all three runway ends are designed both for pilots executing a rapid descent from high altitudes, such as military jets, and for aircraft operating at traditional descent rates, such as civilian air carrier aircraft and GA aircraft.

Table 2-5 summarizes the specifications of each published ILS approach available at the Airport.

Table 2-5: Instrument Landing System Approach Specifications

RUNWAY	PUBLISHED INSTRUMENT APPROACH	APPROACH MINIMUMS [1/]	DA
17R	(HI) ILS CAT I	200/40 [2/]	231
35L	(HI) ILS CAT I	200/40	228
22	(HI) ILS CAT I	200/18	230

NOTES:

DA - Decision altitude (in feet above mean sea level)

(HI) ILS CAT I – High Altitude Instrument Landing System Category I

1/ Minimums are lowest available on each runway - Ceiling (feet above ground level) / visibility (runway visual range).

2/ HAS plans to upgrade the Runway 17R approach lighting system at the Airport to decrease the visibility minimums to a runway visual range of 2,400 feet.

SOURCE: Federal Aviation Administration, Digital Terminal Procedures. Accessed November 2012.
PREPARED BY: Ricondo & Associates, Inc., November 2013.

An ILS is an approach aid that emits electronic signals to aircraft. Electronic signals are prone to interference from buildings, aircraft on the ground, and other objects. To protect the signals sent by the ILS components, a critical area is established for the localizer and glideslope antennas to keep aircraft and vehicles from interfering with the navigation signals emitted. The critical areas are required to be clear of objects and smoothly graded. These critical areas are shown on Exhibit 2-9.

2.2.2.4 Approach Lighting Systems

The complexity of the several runway lighting systems varies based on the types of approaches available on a particular runway. ALSs provide visual information, runway alignment, height perception, roll guidance, and horizon references to assist pilots in the transition from instrument flight to visual flight for landing. At Ellington Airport, Runways 17R, 22, and 35L are equipped with an ALS. Runway 22 is equipped with a medium-intensity approach lighting system with runway alignment indicator lights (MALSR), which is the FAA standard for CAT I precision runways. Runways 17R and 35L are equipped with a medium-intensity approach lighting system with sequenced flashers (MALSF). It should be noted that HAS plans to upgrade the Runway 17R MALSF to a MALSR and, therefore, decrease the visibility minimums for approaches to that runway. Runway 17L-35R is not equipped with runway lighting, which makes the runway unusable by GA aircraft at night.

2.2.2.5 Precision Approach Path Indicator

A precision approach path indicator (PAPI) is installed past the Runway 17R, 35L, 4, and 22 ends to provide visual approach slope information to pilots during the approach phase of flight. This glide path information not only helps the pilot establish a stabilized approach, but also provides obstacle clearance. PAPI lights are visible from approximately 5 miles during the day and 20 miles or more at night. PAPIs are typically sited on the left side of the runway, left of the aim point markers that correspond to the point where the glide path intercepts the runway surface. **Table 2-6** presents the distance between the threshold and the PAPI on each runway end.

Table 2-6: Precision Approach Path Indicator Locations along the Runway

RUNWAY END	GLIDE SLOPE ANGLE (DEGREES)	THRESHOLD CROSSING HEIGHT (FEET)	DISTANCE BETWEEN LANDING THRESHOLD AND PRECISION APPROACH PATH INDICATOR (FEET)
17R	3.00	52	992
35L	3.00	54	1,030
4	3.04	50	941
22	3.00	54	1,030

SOURCES: Jeppessen Approach Charts, accessed February 26, 2014; Ricondo & Associates, Inc., November 2013.
PREPARED BY: Ricondo & Associates, Inc., February 2014.

2.2.2.6 Windsock

Seven windsocks are installed in the vicinity of the runway ends to provide wind direction and speed information to pilots during landing. Five of the windsocks are lighted.

2.2.2.7 Runway Lights

Runway Edge Lights

Runway edge lights are used to outline the edges of runways during periods of darkness or restricted visibility. These light systems are classified according to the intensity or brightness they are capable of producing: high-intensity runway lights (HIRL), medium-intensity runway lights (MIRL), or low-intensity runway lights (LIRL). HIRLs are installed on Runways 4-22 and 17R-35L. There are no runway edge lights on Runway 17L-35R.

Runway Centerline Lights

Runway centerline lights are installed on some precision approach runways along the runway centerline to facilitate landing under adverse visibility conditions. Both Runways 4-22 and 17R-35L are equipped with centerline lights.

Touchdown Zone Lights

Touchdown zone lights are installed on some precision approach runways to indicate the touchdown zone when pilots are landing in adverse visibility conditions. These lights consist of two rows of transverse light bars installed symmetrically about the runway centerline. The Runway 22, 17R, and 35L approach ends are equipped with TDZLs.

2.2.2.8 Taxiway Edge Lights

All Airport taxiways except Taxiway B east of Runway 17R-35L are equipped with taxiway edge lights, which are used to outline the edges of taxiways during periods of darkness or restricted visibility.

2.2.2.9 Transmissometer

Transmissometers are used to measure the RVR, which is the distance a pilot should be able to see down the runway upon touchdown. Transmissometers are installed along the runway for which they provide information. The RVR is used to determine whether visibility conditions permit a certain type of instrument approach. Two transmissometers provide touchdown and rollout RVR information for approaches to Runway 22.

2.2.2.10 Rotating Beacon

The Airport is equipped with a rotating beacon, located east of the Runway 35L end. The beacon emits alternating white and green flashes, indicating a lighted land airport. The Airport beacon is a visual navigational aid for use during nighttime operations. Operation of the Airport beacon during daylight hours may indicate that ground visibility is less than 3 miles and/or the ceiling is less than 1,000 feet AGL.

2.2.2.11 Navigational Aids and Lighting Systems Summary

Table 2-7 summarizes the runway navigational aids and lighting systems at EFD.

Table 2-7: Navigational Aids, Approach Aids, and Lighting Systems

	RUNWAYS					
	17R	**35L**	**17L**	**35R**	**4**	**22**
APPROACH TYPE						
Precision	√	√				√
Nonprecision					√	
Visual			√	√		
APPROACH AIDS						
Localizer	√	√			√	√
Glideslope	√	√				√
TACAN	√	√			√	√
Runway Visual Range						√
NAVIGATIONAL AIDS						
Distance Measuring Equipment	√	√				√
Rotating Beacon	√	√	√	√	√	√
APPROACH LIGHTING SYSTEMS						
Medium Intensity Approach Light System with Runway Alignment Indicator Lights						√
Medium Intensity Approach Lighting System with Sequenced Flashers	√	√				
Precision Approach Path Indicator	√	√			√	√
RUNWAY LIGHTING						
High Intensity Runway Edge Lights	√	√			√	√
Runway Alignment Indicator Lights						√
Touchdown Zone Lights	√	√				√
Runway Centerline Lights	√	√			√	√
TAXIWAY LIGHTING	√	√	√	√	√	√

SOURCE: Jeppesen Sandersen, *Airport and Instrument Approach Charts*. Accessed February 2014.
PREPARED BY: Ricondo & Associates, Inc., February 2014.

2.2.3 AIRFIELD SAFETY AND PROTECTION AREAS

Safe and efficient Airport operations require that certain areas on or near the Airport are clear of objects/obstructions or restricted to those objects functionally necessary, such as lights and navigational aids. FAA design standards for the various airfield safety and protection areas, as they relate to the Airport, are presented in this subsection. The airfield safety and protection areas in place at the Airport are presented below and depicted on **Exhibit 2-10**.

2.2.3.1 Runway Safety Area

The runway safety area (RSA) is a rectangular area centered on the runway centerline. Under normal (dry) conditions, the RSA surface is capable of supporting aircraft without causing structural damage to the aircraft or injury to its occupants if the aircraft were to inadvertently leave the paved runway surface. To serve this function, the FAA requires RSAs to be (a) cleared and graded, (b) drained by grading or storm sewers to prevent water accumulation, and (c) free of objects, except those that need to be located in the RSA because of their function (e.g., approach lighting).

Based on FAA design criteria for ARC D-IV runways, the RSA for Runways 17R-35L and 4-22 should be 500 feet wide (i.e., 250 feet on either side of the runway centerline) and extend 1,000 feet beyond the runway ends. Design criteria for ARC B-II visual runways (Runway 17L-35R) require an RSA with a width of 150 feet that extends 300 feet beyond the runway ends. The RSAs associated with each runway are depicted on Exhibit 2-10.

2.2.3.2 Runway Object Free Area

The runway object free area (ROFA) is a rectangular area centered on the runway centerline; it is required to be clear of objects protruding above the nearest point on the RSA, with the exception of those objects that are essential to air navigation or aircraft ground maneuvering.

For ARC D-IV runways (Runways 17R-35L and 4-22), ROFAs must be 800 feet wide (i.e., extending 400 feet on either side of the runway centerline) and extend 1,000 feet beyond the runway ends. For ARC B-II runways (Runway 17L-35R), the ROFA must be 500 feet wide and extend 300 feet beyond each runway end. The ROFA length beyond the end of the runway never exceeds the standard RSA length beyond the runway end. The OFAs associated with each runway are depicted on Exhibit 2-10.

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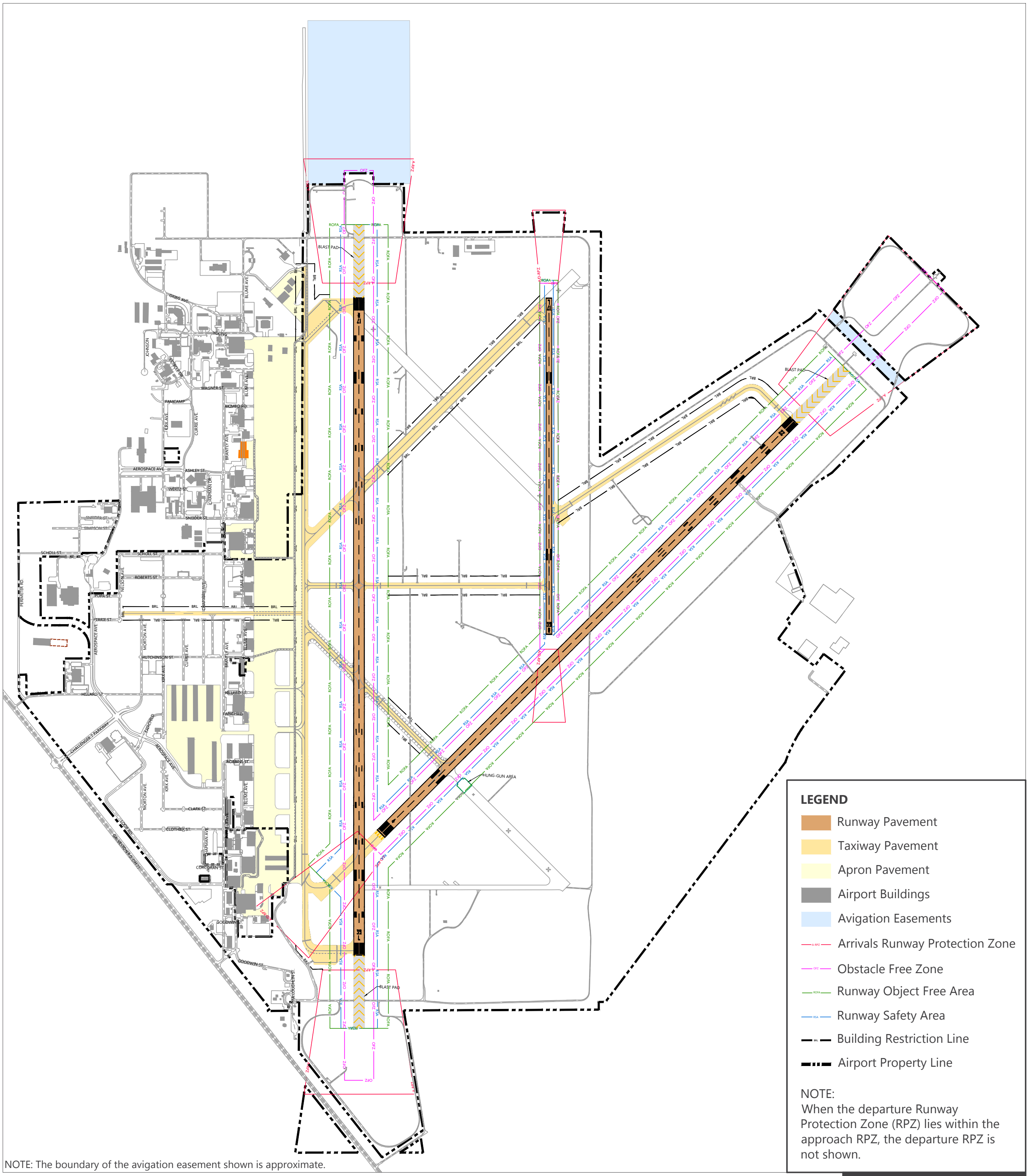

NOTE:
When the departure Runway Protection Zone (RPZ) lies within the approach RPZ, the departure RPZ is not shown.

NOTE: The boundary of the avigation easement shown is approximate.

SOURCES: Ellington Draft Airport Layout Plan, Ricondo & Associates, March 2014; Houston Airport System, March 2014; CHPlanning Ltd, October 2012 (Runway Protection Zone and Avigation Easements Data).
PREPARED BY: Ricondo & Associates, Inc., March 2014.

EXHIBIT 2-10

NORTH

0 2,000 ft.

Runway Protection Areas

Drawing: \\ricondo.com\public\Dallas\Project\Houston Airport System\Ellington Airport\2014 Master Plan Update\02 - Data Collection and Inventory\2-Exhibits\CAD\Exhibit 2-10_RPA.dwg Layout: 8.5x11P Plotted: Sep 9, 2015, 01:51PM

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2.2.3.3 Obstacle Free Zone

The obstacle free zone (OFZ) is the three-dimensional airspace along the runway and extended runway centerline that is required to be clear of obstacles to protect an aircraft's transition from ground to airborne operations (and vice versa).

Airports with nonprecision instrument approach procedures are only required to comply with the runway component of the OFZ criteria, while airports with precision instrument approach procedures or approach lighting systems are required to comply with additional requirements. FAA criteria prohibit taxiing, parked aircraft, and object penetrations within OFZs, except for frangible navigational aids with fixed locations. Applicable elements of the Airport's OFZ are described as follows:

- **Runway OFZ** – The runway OFZ is a volume of airspace centered above the runway. In general, the required runway OFZ is 400 feet wide for runways serving large aircraft, such as Runways 17R-35L and 4-22, and between 120 feet and 300 feet wide for runways serving small aircraft (the Runway 17L-35R OFZ is 250 feet wide). All runway OFZs extend 200 feet beyond the runway ends.
- **Inner-approach OFZ** – The inner-approach OFZ is a volume of airspace centered on the approach area that applies only to runways equipped with an ALS. Therefore, the inner-approach OFZ only applies to Runways 17R, 35L, and 22 at EFD. The inner-approach OFZ begins 200 feet from the runway threshold and extends 200 feet beyond the last unit in the ALS. It has the same width as the runway OFZ and rises at a slope of 50:1 away from the runway end. Any objects that penetrate the inner-approach OFZ are listed on the Airport Obstruction Chart.
- **Inner-transitional OFZ** – The inner-transitional OFZ is a defined volume of airspace along the sides of the runway and inner-approach OFZ. It applies only to runways with approach visibility minimums less than 0.75 statute mile. Several instrument approaches published for Runway 22 have visibility minimums less than 0.75 statute mile. Therefore, Runway 22 is the only runway at the Airport subject to inner-transitional OFZ object clearance restrictions. Any objects that penetrate the inner-transitional OFZ are listed on the Airport Obstruction Chart.

Applicable OFZs are depicted on Exhibit 2-10.

2.2.3.4 Runway Protection Zone

The runway protection zone (RPZ) is a trapezoidal area centered on the extended runway centerline. The length and width of the RPZ are contingent on the size of aircraft operating on the runway as well as the type of approach (i.e., visual or instrument) and the available approach minima, and vary for the approach and departure RPZs. The RPZs are designed to enhance the protection of people and property on the ground. To achieve this goal, the FAA recommends that the airport operator own or otherwise control the property in the RPZ. This area should be free of land uses that create glare and smoke and the FAA recommends that airport operators keep the RPZs clear of incompatible land uses, specifically residences, fuel storage facilities, and places of public assembly (e.g., churches, schools, office buildings, and shopping centers). The FAA recently added a requirement that public roadways are no longer permitted inside the RPZ.

All RPZ trapezoids begin 200 feet beyond the threshold of a runway (landing threshold in the case of a displaced threshold). The standard dimensions of the approach RPZs are set forth in **Table 2-8**.

Table 2-8: Runway Protection Zone Standard Dimensions

RUNWAY	INNER WIDTH (FEET)	OUTER WIDTH (FEET)	LENGTH (FEET)
17R	1,000	1,510	1,700
35L	1,000	1,510	1,700
22	1,000	1,750	2,500
4	500	1,010	1,700
17L	500	700	1,000
35R	500	700	1,000

SOURCE: Federal Aviation Administration, Advisory Circular 150/5300-13A (Change 1), *Airport Design*, February 2014;
PREPARED BY: Ricondo & Associates, Inc., May 2015.

Exhibit 2-10 depicts the existing RPZs at the Airport. Only the approach RPZs are depicted because the departure RPZs at the Airport are within the approach RPZs. Currently, Runways 4, 17L, and 35R are the only runways whose approach RPZs entirely fall within the Airport property boundary. The approach RPZs for Runways 17R, 35L, and 22 are partially located outside the Airport property boundary and their existing conditions are described as follows:

- There is an avigation easement for the land located outside Airport property, but inside the Runway 17R approach RPZs. This area does not have incompatible structures.
- There is an avigation easement for the drainage canal located in the Runway 22 approach RPZ, but outside Airport property.
- Several structures belonging to NASA are located within the Runway 4 approach RPZ.
- The Runway 35L approach RPZ intersects Old Galveston Road, a four-lane public roadway running west of the Airport. This roadway provides access to the west side of the Airport and is within the approach Runway 35L RPZ for a distance of approximately 270 feet.

2.2.4 TAXIWAY NETWORK

The Airport's three runways are served by nine taxiways and one taxilane, providing aircraft access between the runways and aircraft parking areas. As shown on **Exhibit 2-11**, Taxiways A, B, C, D, and E all extend eastward from Taxiway H. Taxiway K extends to the west into a currently undeveloped area. It is planned to provide aircraft access for future Airport tenants. Taxilane J provides access to the existing HAS-owned aircraft hangar storage facilities. Taxiway H, an apron edge taxiway, is parallel to Runway 17R-35L. It is the only full-length parallel taxiway at the Airport. Taxiway F, an extension of Taxiway H, continues to the Runway 35L end. Taxiways A and F each provide a hold pad prior to entering the runway. Taxiway G provides access to and from Runways 17L-35R and 4-22.

As previously discussed, the runway design criteria that apply to the Airport are based on ARC B-II aircraft for Runway 17L-35R and ARC D-IV aircraft for Runways 17R-35L and 4-22. The taxiway object free area (TOFA) requirements and the taxiway safety area requirements are based on the runway design criteria. At the Airport, all taxiways meet the TOFA width requirement of 259 feet and 131 feet for ADG IV and II, respectively. Likewise, all taxiways meet the taxiway safety area width requirements of 171 feet and 79 feet for ADG IV and II, respectively. However, the runway design criteria are only based on the wingspan and tail height of the design aircraft. To account for the dimensions of the aircraft landing gear that are essential to evaluate taxiways, different categories have been established for taxiways. **Table 2-9** presents the FAA taxiway dimensional design criteria for taxiway design group (TDG) 5, which is the TDG associated with the largest ADG IV aircraft. Therefore, all taxiways except Taxiway K, which is limited to ARC B-II aircraft, must comply with TDG 5 standards. Taxilane J, the only taxilane at the Airport, can accommodate ARC C-III aircraft.

The taxiway network at the Airport can accommodate ADG IV (TDG 5) aircraft operations, although not all taxiways meet the latest ADG IV standards. A number of taxiways are located on decommissioned runway pavement, which results in several discrepancies in pavement design requirements. Similar to ADG IV runway shoulders, the latest update of AC 150/5300-13A, *Airport Design*, requires that taxiways accommodating ADG IV to ADG VI aircraft have paved shoulders. Taxiway D is the only taxiway at the Airport with paved shoulders, and it complies with TDG 5 design criteria. All other ADG IV taxiways have no paved shoulders and, therefore, do not meet FAA requirements for shoulder pavement.

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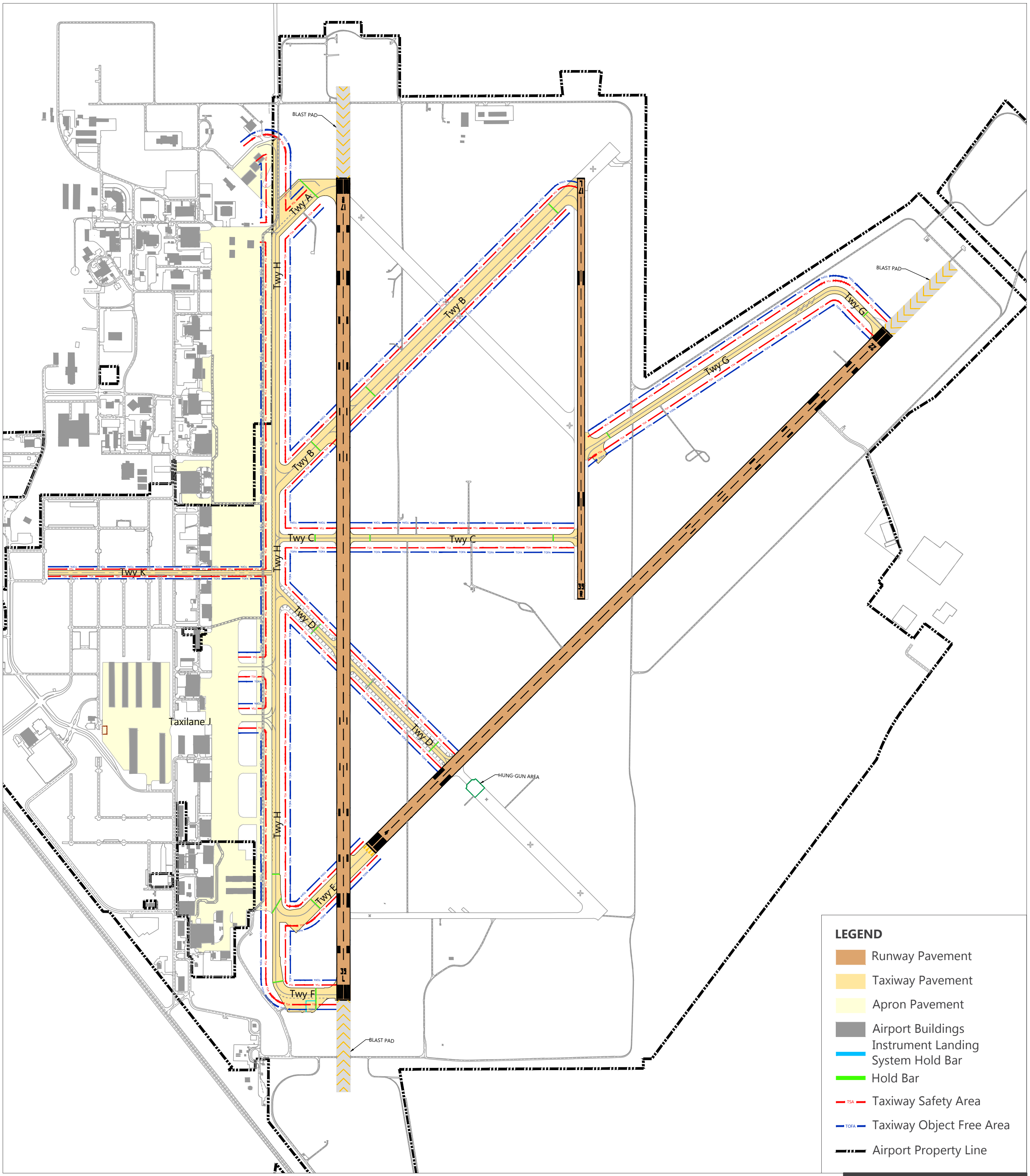

SOURCES: Ellington Draft Airport Layout Plan, Ricondo & Associates, March 2014; Houston Airport System, March 2014.
PREPARED BY: Ricondo & Associates, Inc., March 2014.

EXHIBIT 2-11

NORTH 0 1,600 ft.

Taxiway and Taxilane Network

Drawing: \\ricondo.com\public\Dallas\Project\Houston Airport System\Ellington Airport\2014 Master Plan Update\02 - Data Collection and Inventory\2-Exhibits\CAD\Exhibit 2-11_Taxiway Layout.dwg Layout: 8.5x11P Plotted: Sep 9, 2015, 01:57PM

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Table 2-9: Taxiway Design Criteria

BASED ON AIRPLANE DESIGN GROUP	
TAXIWAY DESIGN ELEMENTS	**ADG IV DESIGN CRITERIA (FEET)**
Taxiway Safety Area	171
Taxiway Object Free Area	259
Taxiway Centerline to:	
Parallel Taxiway/Taxilane Centerline	215
Fixed or Movable Object	129.5
Taxilane Centerline to:	
Parallel Taxiway/Taxilane Centerline	198
Fixed or Movable Object	112.5
BASED ON TAXIWAY DESIGN GROUP	
TAXIWAY DESIGN ELEMENTS	**TDG 5 DESIGN CRITERIA (FEET)**
Taxiway Width	75
Taxiway Shoulder Width	25
Taxiway/Taxilane Centerline to Parallel Taxiway/Taxilane Centerline	240 [1/]

NOTE:

1/ Use 240 feet and not 215 feet or 198 feet when 180 degree turns between parallel taxiways are required.

SOURCES: Federal Aviation Administration, Advisory Circular 150/5300-13A (Change 1), *Airport Design*, February 2014; Ricondo & Associates, Inc., May 2015.

PREPARED BY: Ricondo & Associates, Inc., May 2015.

2.2.5 APRON AREAS

The apron areas at the Airport are all located on the west side, west of Taxiway H. As shown on **Exhibit 2-12**, the apron is divided into three sections: the northernmost section is reserved for military aircraft, the southernmost section is used by NASA, and the section in between is public-use apron, which is used by GA aircraft. Exhibit 2-12 also provides the acreage of each apron section.

Nonmilitary aircraft are stored and parked on either the GA apron or in one of the storage hangars located on the airfield.

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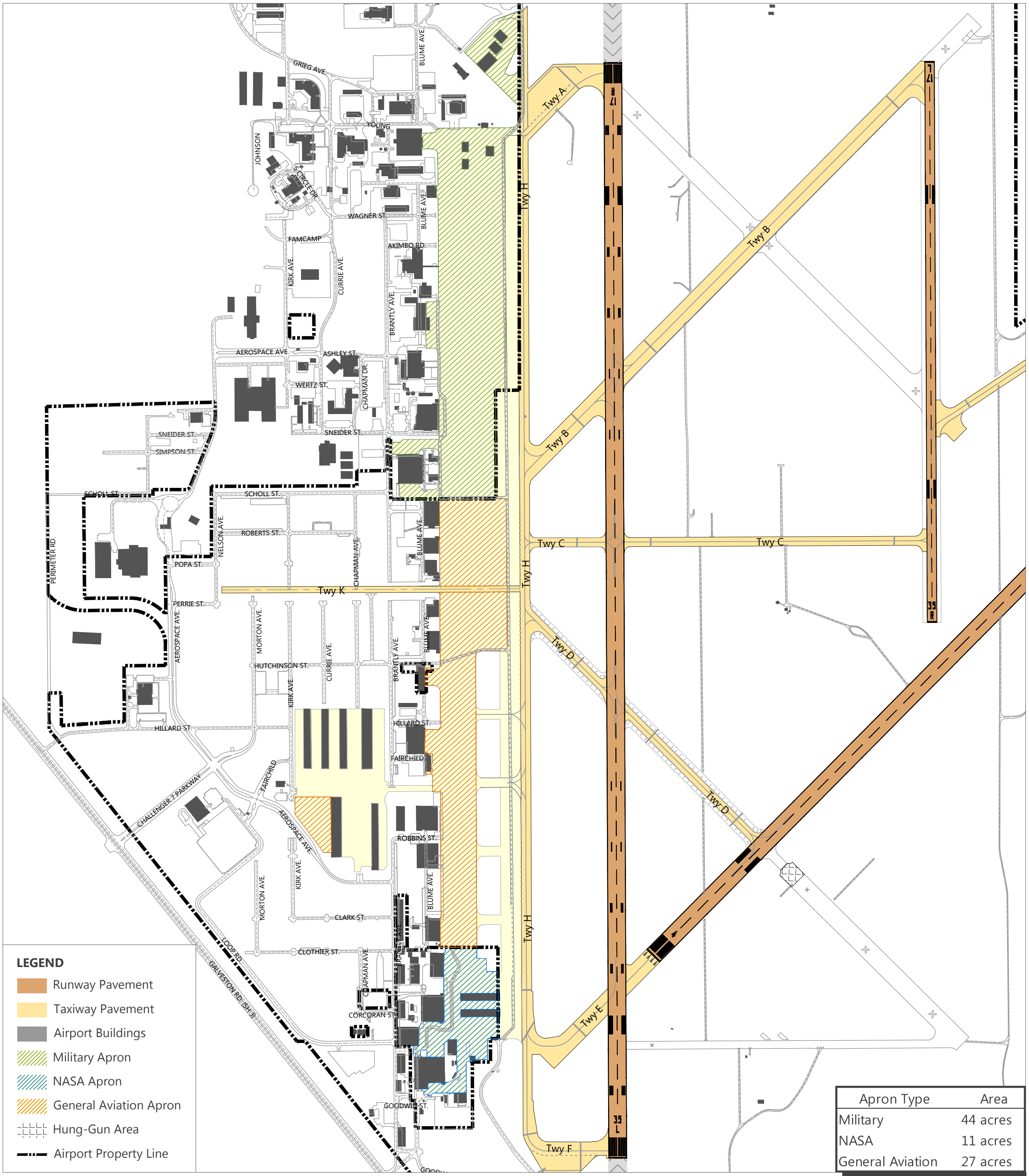

Apron Type	Area
Military	44 acres
NASA	11 acres
General Aviation	27 acres

SOURCES: Ellington Draft Airport Layout Plan, Ricondo & Associates, March 2014; Houston Airport System, March 2014; Ricondo & Associates, Inc., March 2014.
PREPARED BY: Ricondo & Associates, Inc., March 2014.

EXHIBIT 2-12

Apron Areas

Drawing: \\ricondo.com\public\Dallas\Project\Houston Airport System\Ellington Airport\2014 Master Plan Update\02 - Data Collection and Inventory\Exhibits\CAD\Exhibit 2-12_Apron Areas.dwg Layout: 8.5x11 Plotted: Sep 14, 2015, 09:21AM

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2.2.6 HUNG-GUN AREA

An area immediately south of Runway 4-22, along the Taxiway D extended centerline, is designated as a hung-gun area (see Exhibit 2-12). An aircraft 'hung-gun' occurs when an armed weapon malfunctions during flight and does not release; in this scenario, the aircraft must immediately return to base to resolve the hung-gun issue.

2.2.7 SERVICE ROADS

The service roads that provide access to the airfield are only accessible through security gates. They are used to facilitate maintenance and security, monitor and maintain navigational aids on the airfield, secure and repair the perimeter fence, and access the military facilities located on the north side of the Airport and the fuel storage complex located on the south side of the Airport. The service roads are constructed of asphalt and are mostly 10 to 12 feet wide; the service roads along Taxiway H and leading to the fuel storage complex are 20 to 24 feet wide. The service roads that follow the perimeter of the Airport and those providing access to the navigational aids are currently in good condition, with limited pavement cracking and wear.

2.3 Airspace Environment

The structure of the airspace in the vicinity of the Airport and the flight procedures used by aircraft arriving at and departing from the Airport influence aircraft routings to and from the Airport. This section describes the various FAA ATC facilities serving the terminal airspace surrounding the Airport, the airspace structure, the procedures used in that airspace, and the airspace interactions with William P. Hobby Airport (HOU).

2.3.1 AIR TRAFFIC CONTROL FACILITIES

Three facilities provide ATC services for the pilots of aircraft arriving at, departing from, or overflying the immediate area of the Airport. These facilities include the Air Route Traffic Control Center (ARTCC), Terminal Radar Approach Control (TRACON), and Airport Traffic Control Tower (ATCT). The role of these facilities is to facilitate the safe, efficient, and expeditious movement of air traffic.

The FAA Houston ARTCC is located at Bush Intercontinental Airport/Houston (IAH) and provides ATC services to pilots of aircraft operating on IFR flight plans within controlled airspace during the en route phase of flight. The en route phase of flight is generally defined as the period when aircraft are operating between origin and destination terminal areas.

The Houston TRACON is also an FAA facility located at IAH. This facility provides radar control services to pilots of aircraft arriving to and departing from civilian airports in the regional service area and to aircraft operating under VFR in and around the Class B airspace associated with IAH and HOU. The Houston TRACON transfers arriving aircraft under its control to Ellington Airport ATC, which issues clearances for aircraft to land. Similarly, the ATCT clears aircraft to take off and then transfers these departures to the Houston TRACON, if applicable. Finally, the Airport ATC controls the movement of aircraft on the airfield and other aircraft that may be transitioning through the Class D airspace surrounding the Airport.

2.3.2 AIRSPACE STRUCTURE

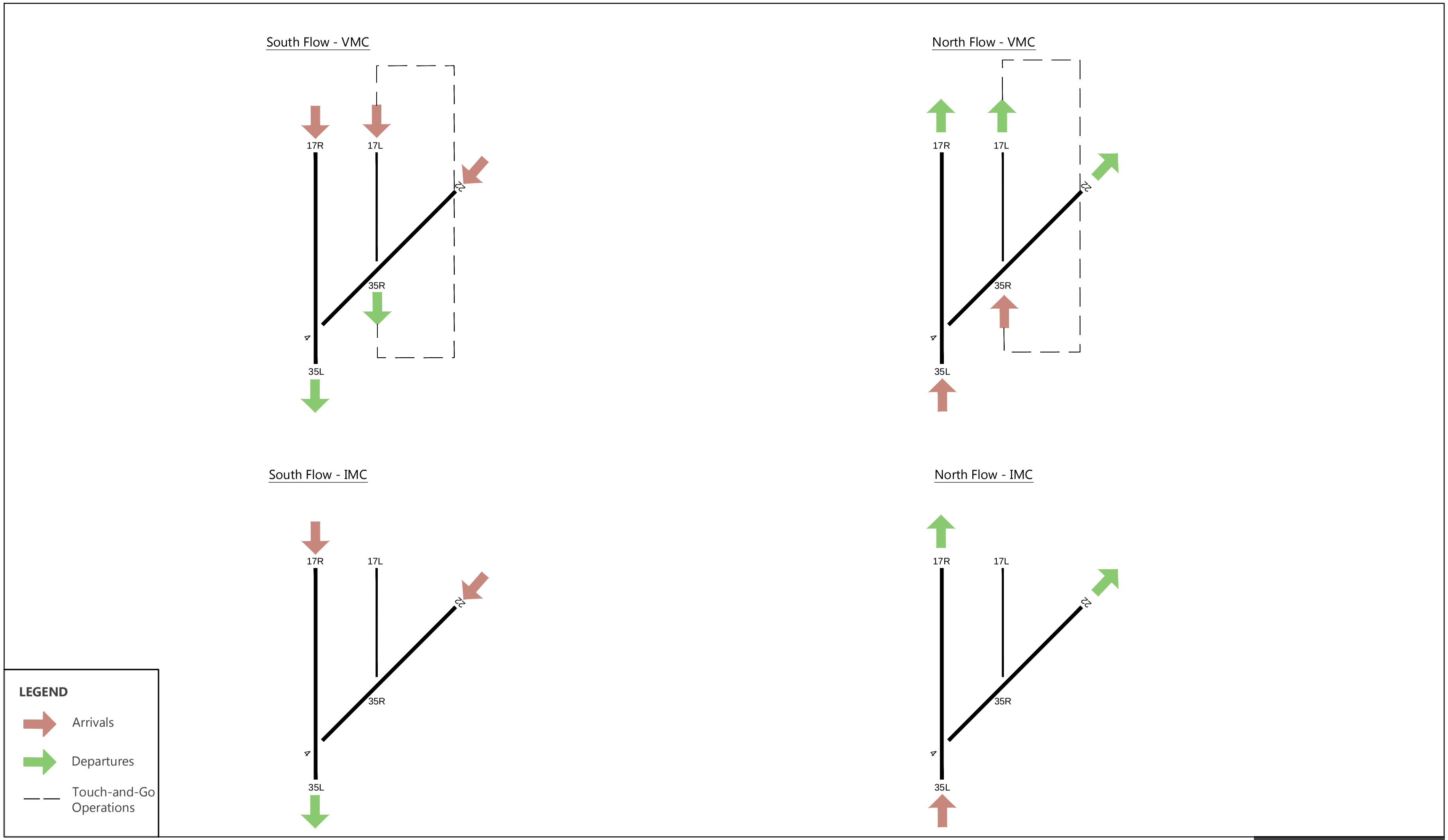
Airspace operating procedures depend on the types of approaches available for each runway and on the overall airfield configuration. At Ellington Airport, Runways 17R, 35L, and 22 have instrument approach procedures, including precision instrument approaches, such as ILS, a localizer (LOC), and LOC/DME, and nonprecision instrument approaches, such as an Area Navigation global positioning system (RNAV GPS) and a TACAN. Runway 4 has nonprecision instrument approaches (RNAV GPS and TACAN) and Runway 17L-35R is a visual runway that primarily serves touch-and-go training activity. Runway 17R-35L is the only runway with a full length parallel taxiway. No partial parallel taxiways are available for Runways 17L-35R and 4-22. Taxiways E and G provide access to the Runway 4 and Runway 22 thresholds, respectively. Runway 4-22 has one exit: Taxiway D. Taxiway B provides access to the Runway 17L threshold and Taxiway C is the only westbound exit available for Runway 17L-35R.

2.3.3 RUNWAY USE OPERATING CONFIGURATIONS

All runways at the Airport are available for aircraft arrivals and departures. However, the characteristics of the runways, such as length, width, location, and associated Airport noise abatement procedures, define how the runways are used. **Exhibit 2-13** depicts the two primary runway use configurations at EFD in IMC and VMC. These configurations are designated as South Flow and North Flow.

Each aircraft operation may not occur during a specific flow configuration because of a variety of operational factors, such as wind direction or speed, the aircraft origin/destination, or the airfield condition. At the Airport, Runway 17R-35L is the primary runway in north and south flows, but the crosswind component may restrict the use of that runway. The following aircraft groups must use Runway 4-22 if the crosswind component reaches:

- 10.5 knots: A-I and B-I aircraft must depart on the crosswind runway.
- 13.0 knots: A-II and B-II aircraft must depart on the crosswind runway.
- 16.0 knots: A-III, B-III, C-I through C-III, and D-I thought D-III aircraft must depart on the crosswind runway.
- 20.0 knots: A-IV, B-IV, C-IV, and D-IV aircraft must depart on the crosswind runway.



SOURCE: Ricondo & Associates, Inc., January 2014.
PREPARED BY: Ricondo & Associates, Inc., January 2014.

EXHIBIT 2-13

NORTH

0 Not to Scale

Runway Use Configurations

Drawing: \\ricondo.com\public\Dallas\Project\Houston Airport System\Ellington Airport\2014 Master Plan Update\02 - Data Collection and Inventory\EFD_Exh_RWY_Use_Config.dwg Plotted: Sep 14, 2015, 09:25AM

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2.3.3.1 South Flow

South Flow is the predominant runway use configuration at EFD. Based on conversations with EFD ATC personnel, approximately 85 percent of all aircraft operations at the Airport occur in South Flow, on Runways 17R, 17L, and 22. When the airfield is operated in South Flow, departing aircraft are assigned to Runway 17L or 17R and arriving aircraft are typically assigned to Runway 17L, 17R, or 22. In South Flow, most aircraft operations, including all operations using instrument approach procedures, occur on Runways 17R and 22, while Runway 17L accommodates small GA aircraft and military helicopters conducting touch-and-go training operations. No departures occur on Runway 17L in IFR conditions, and if the crosswind component prevents the use of Runway 17R, Runway 22 is used for arrivals and departures.

2.3.3.2 North Flow

In North Flow, which occurs at the Airport approximately 15 percent of the time, aircraft use Runways 35L, 35R, and 4. Departing aircraft are assigned to Runway 35L or 4. All ILS approach operations occur on Runway 35L and other operations occur on Runways 35R, 35L, and 4 for both visual and instrument operations. Runway 35R is mainly used for touch-and-go operations.

2.3.4 TAXI ROUTES

ATC is responsible for the safe, efficient, and expeditious flow of surface traffic in the airfield movement areas. The movement areas consist of runways, taxiways, and safety areas of the Airport, which are used for aircraft taxiing/hover taxiing, takeoff, and landing. Apron parking areas are not considered movement areas and activity in these areas is the responsibility of the tenant and aircraft/vehicle operator. However, specific approval for entry onto the movement areas must be obtained from ATC personnel.

2.3.4.1 South Flow

In VMC, aircraft depart from Runways 17R and 17L. In IMC, aircraft depart from Runway 17R if the crosswind component does not restrict the use of that runway (i.e., if wind speed does not reach the limits discussed earlier). If the crosswind component does not allow departures on Runway 17R, departures in south flow use Runway 22. To reach the Runway 17R threshold, aircraft use Taxiways H and A. To reach the Runway 17L threshold, aircraft use Taxiway B. To reach the Runway 22 threshold, aircraft use Taxiway C, then Runway 17L-35R, and finally Taxiway G.

2.3.4.2 North Flow

In VMC, aircraft depart on Runway 35L and perform touch-and-go operations on Runway 35R when the crosswind component does not restrict use of the parallel runways. In IFR conditions, Runway 35L is the primary runway when the crosswind component allows the use of that runway. If the crosswind speed is over the limits discussed previously, Runway 4 is used for departures in IMC. Small aircraft only are affected by crosswinds between 10.5 and 16.0 knots. If the crosswind speed is more than 20 knots, all aircraft depart on Runway 4. To reach the Runway 35L threshold, aircraft use Taxiways H and F. To reach the Runway 4 threshold, aircraft use Taxiways H and E. As no taxiway reaches the Runway 35R departure threshold, it was assumed that Runway 35L is only used for touch-and-go operations in north flow and in VFR conditions.

2.3.5 INSTRUMENT FLIGHT RULE ARRIVAL PROCEDURES

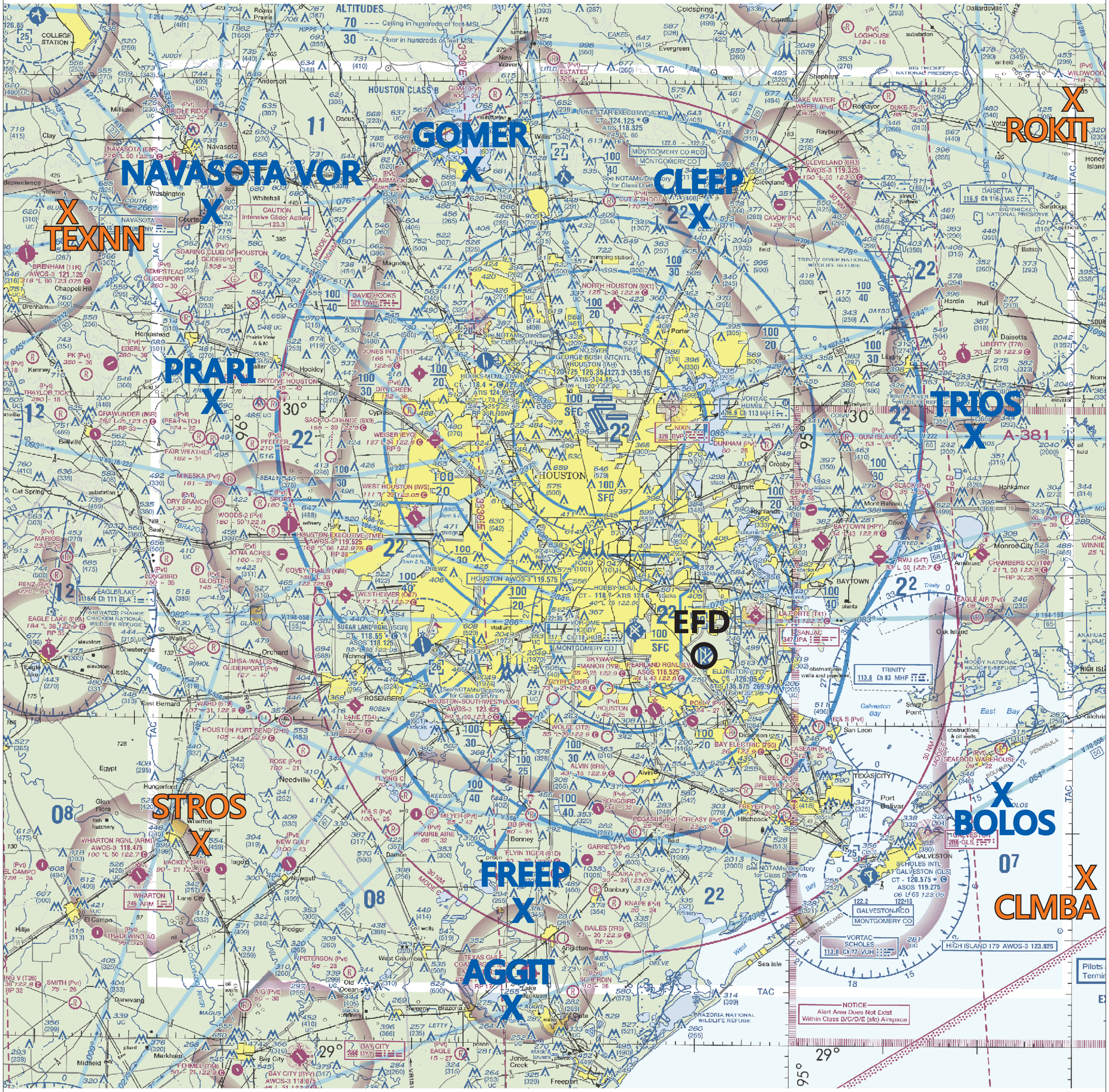
EFD is a satellite airport for the purposes of FAA ATC services, as it shares approach control airspace and services with other Houston area airports, including IAH and HOU. As mentioned previously, approach control services for the region are provided by the Houston TRACON at IAH.

The Houston TRACON airspace is structured so that arriving aircraft can safely and efficiently transition from the en route environment to the approach control environment. The role of the TRACON is also to deliver arriving aircraft from the approach control airspace to the airfield proper. The Houston TRACON controls arriving aircraft by issuing instructions, known as radar vectors. A radar vector is a heading issued to an aircraft to provide navigational guidance for the pilot. The Houston TRACON also issues altitude clearances to position arriving aircraft in the proper traffic flow prescribed for aircraft landing at the Airport. External conditions may alter these traffic flows (weather and traffic conditions permitting), but ATC will always attempt to deliver arriving aircraft to the Airport via the most expeditious routing possible.

The ATCT at EFD is a military facility and is consequently not operated by the FAA. Therefore, unlike other airfields controlled by FAA personnel, FAA personnel at the Houston TRACON do not have access to IFR aircraft information after the aircraft has been transferred to EFD ATC. To transfer an IFR aircraft to EFD ATC, and allow this aircraft to initiate an approach to the Airport, communication is required between EFD ATC and the Houston TRACON to ensure that the previous IFR flight has landed. The transfer usually occurs prior to the aircraft reaching the final approach fix or 7.0 nautical miles from the Airport, whichever occurs first. Therefore, a minimum separation of 7.0 nautical miles is imposed between two consecutive aircraft conducting IFR approaches, to allow the trailing aircraft to cross the final approach fix after the leading aircraft has landed. These conditions impose a limit on the IFR throughput rate at the Airport, which can affect Airport capacity, especially if the number of IFR aircraft operations increases.

Aircraft are transitioned from the en route phase of flight by the Houston ARTCC to the Houston TRACON just prior to the aircraft reaching the ROKIT intersection, the CLMBA intersection, the STROS intersection, or the TEXNN intersection. These intersections are depicted on **Exhibit 2-14** and are used as follows:

- Aircraft arriving from Milwaukee, Chicago, Kansas City, and areas in the northeastern United States arrive over the ROKIT intersection. HOU arrivals share this arrival fix with aircraft destined for IAH and EFD. Aircraft destined for these airports cross the ROKIT intersection at least 5 nautical miles in-trail of each other. Turbojets cross the ROKIT intersection at 10,000 feet above MSL. Turboprops and piston-powered aircraft are assigned lower altitudes. HOU arrivals are then vectored toward the southwest for either a visual or instrument approach.
- The CLMBA intersection serves aircraft arrivals at HOU from the southeast and Gulf regions of the United States. Aircraft flights originating in cities such as Miami, Jacksonville, and New Orleans arrive at the Airport via the CLMBA intersection. Aircraft destined for the Airport cross the CLMBA intersection at 10,000 feet above MSL and 5 nautical miles in-trail separation. Aircraft are radar vectored to the west for either a visual or instrument approach to the Airport.



LEGEND

- 🟧 Airspace ARRIVAL Gates
- 🟦 Airspace DEPARTURE Gates
- ○ Ellington (EFD) Airport

SOURCE: skyvector.com, 2012.
PREPARED BY: Ricondo & Associates, Inc., CHPlanning, Ltd., May 2012.

EXHIBIT 2-14

NORTH 0 Not to Scale

Airspace Arrivals and Departures Gates

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- Aircraft originating from the southwestern United States, Mexico, or southwest Texas use the arrival stream flying over the STROS intersection. Arrivals from cities such as Los Angeles, Phoenix, and San Antonio use this routing. Turbojet aircraft are assigned an altitude of 10,000 feet above MSL, while turboprops and piston-powered aircraft are assigned lower altitudes. Arriving aircraft are vectored toward the east to the appropriate traffic pattern component for either a visual or instrument approach to the Airport.
- Aircraft arriving at the Airport from the Rocky Mountain region, the Pacific Northwest, and north Texas use the TEXNN intersection to enter the Houston TRACON airspace. Aircraft arriving from cities such as Dallas, Denver, and Salt Lake City use this routing. Aircraft destined for the Airport cross the TEXNN intersection at 10,000 feet above MSL and 5 nautical miles in-trail separation. Aircraft are radar vectored to the southeast for either a visual or instrument approach to the Airport.

2.3.6 INSTRUMENT FLIGHT RULE DEPARTURE PROCEDURES

Houston TRACON airspace is also reserved so that aircraft departing from the Airport can transition from the terminal environment to the en route environment. The departure procedures and airspace are based on radio navigational aids and radar vectors in areas referred to as departure corridors. Four departure corridors serve the Houston TRACON (i.e., the north, south, east, and west corridors, which correspond to the departure control positions in the Houston TRACON). There are preferred departure routings, referred to as departure gates, from the Houston TRACON based on aircraft destination, arrival aircraft traffic flows, and en route airspace requirements. These departure gates are also depicted on Exhibit 2-14. The Houston TRACON vectors departing aircraft toward these gates and provides separation from traffic arriving at and departing from the Houston area airports. The Houston TRACON and the Houston ARTCC have mutually agreed to these departure gates. Prior to these gates, the Houston TRACON transfers control of aircraft to the Houston ARTCC. Aircraft departing from the Airport share departure airspace with aircraft departing from both IAH and HOU.

- The airspace fixes defining the departure gates for the north departure corridor are the GOMER and CLEEP intersections. Aircraft departing from the Airport and destined for the Dallas/Fort Worth area and midwestern U.S. cities (e.g., Cincinnati, Chicago, and Kansas City) depart through the GOMER gate. Departures from the Airport destined for southeastern U.S. cities, such as Atlanta and Charlotte; mid-Atlantic Coast cities, such as Washington, D.C. and Philadelphia; and northeastern U.S. cities, such as New York and Boston depart through the CLEEP gate.
- The airspace fix defining the departure gates for the east departure corridor is the TRIOS intersection. The TRIOS departure gate is used by aircraft departing from the Airport and landing at Gulf Coast airports, such as those in New Orleans and Mobile, or Florida airports, for aircraft that can operate over water for extended periods.
- The airspace fixes defining the departure gates for the south departure corridor are the FREEP, BOLOS, and AGGIT intersections. Departures routed via the FREEP departure gate are generally destined for cities in the Rio Grande Valley, such as Brownsville and Harlingen, and cities in northern Mexico. Aircraft authorized to operate for extended periods over water and destined for cities such as Miami and Fort Myers or cities in the Caribbean are routed over the BOLOS departure

gate. Departures destined for central and southern Mexico, Central America, and South America are vectored by ATC to the AGGIT departure gate.

- The PRARI intersection and the Navasota VOR serve as departure gates for the west departure corridor. Aircraft departing from the Airport and destined for Texas cities, such as San Antonio; southern California cities, such as Los Angeles; and southwestern U.S. cities, such as Las Vegas and Phoenix, are vectored over the PRARI departure gate. The Navasota VOR departure gate serves northern California and Pacific Northwest cities (e.g., Oakland, Portland, and Seattle) and cities in the Rocky Mountain Region (e.g., Denver and Salt Lake City).

It is anticipated that the FAA Optimization of Airspace and Procedures in the Metroplex (OAPM) program will be implemented in August 2014. Improvements in the nation’s metroplexes will include more arrival and departure procedures involving RNAV, routings resulting in less mileage, procedures with fewer level-offs, as well as new arrival and departure gate names (however, the location of these gates will be the same as the existing ones). The OAPM for the Houston Metroplex is not anticipated to result in any operational changes at the Airport.

2.4 Airport Support Facilities

Airport support facilities provide services that are essential to maintaining safe and efficient Airport operations. Some of these facilities are located landside and include the ATCT and HAS Administration facilities. Others are located airside and include the Airfield Services (maintenance) Complex (ASC), the aircraft rescue and firefighting (ARFF) station, and the fuel storage complex. Airport support facilities at EFD are depicted on **Exhibit 2-15** and described in this section.

SOURCES: Ellington Draft Airport Layout Plan, Ricondo & Associates, March 2014; Houston Airport System, March 2014.
PREPARED BY: Ricondo & Associates, Inc., March 2014.

EXHIBIT 2-15

NORTH 0 2,000 ft.

Airport Support Facilities

Drawing: \\ricondo.com\public\Dallas\Project\Houston Airport System\Ellington Airport\2014 Master Plan Update\02 - Data Collection and Inven[illegible] Plotted: Sep 14, 2015, 09:42AM

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2.4.1 AIRPORT TRAFFIC CONTROL TOWER

The ATCT is located on the west side of the Airport, near mid-airfield and adjacent to Runway 17R-35L, as shown on **Exhibit 2-16**. Landside access is provided via Brantly Avenue, north of the Landmark Aviation main terminal building. The ATCT was constructed in 1955 by the U.S. Air Force and has about 250 square feet of cab space[7]. The observation height is about 87 feet above MSL and its overall height is approximately 112 feet above MSL, including appurtenances and antennas[8]. The ATCT was already in poor condition before Hurricane Ike damaged it beyond reasonable repair in 2008. As the existing ATCT is not considered salvageable for long-term use, a new ATCT is planned to be constructed in the parking lot for the existing ATCT. The new facility is expected to have an overall height of 143 feet above MSL[9], including antennas.

Currently, the ATCT is operated by the TxANG under contract with the U.S. Department of Defense (DOD) and an agreement with HAS, which owns and maintains the facility. The ATCT is operational 24 hours per day, 7 days per week. Dynamic Science, Inc., provides ATC and related services for certain NASA operations. Once the new ATCT is constructed, it is expected that an identical operating agreement will be executed between the TxANG, DOD, and HAS.

2.4.2 AIRCRAFT RESCUE AND FIREFIGHTING STATION

The ARFF station at EFD is located along the military apron. ARFF services are provided by the 147th TxANG ARFF unit, which owns and operates the ARFF equipment. TxANG ARFF station personnel provide the following services:

- Emergency response to aircraft incidents/accidents
- Emergency medical services to people on Airport property
- Structural response (fire alarms and fires)

An index based on the length of air carrier aircraft and average daily departures of air carrier aircraft qualifies each ARFF station. As EFD does not accommodate air carrier aircraft operations, the ARFF station at EFD is sized to meet 14 CFR Part 139.315 Index A requirements. [10]

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[7] City of Houston, Houston Airport System, *Request for Qualification for Architectural/Engineering Design Service, New Air Traffic Control Tower At Ellington Airport*, May 2010.

[8] City of Houston, Houston Airport System, *Request for Qualification for Architectural/Engineering Design Service, New Air Traffic Control Tower At Ellington Airport*, May 2010.

[9] AECOM, *Ellington Airport/Houston, Texas, Airport Traffic Control Tower, Exterior Elevations*, November 14, 2012.

[10] Title 14: Aeronautics and Space, Code of Federal Regulations, Part 139 – Certification of Airports, Subpart D –Operations, dated December 12, 2013, http://www.ecfr.gov/, accessed December 16, 2013.

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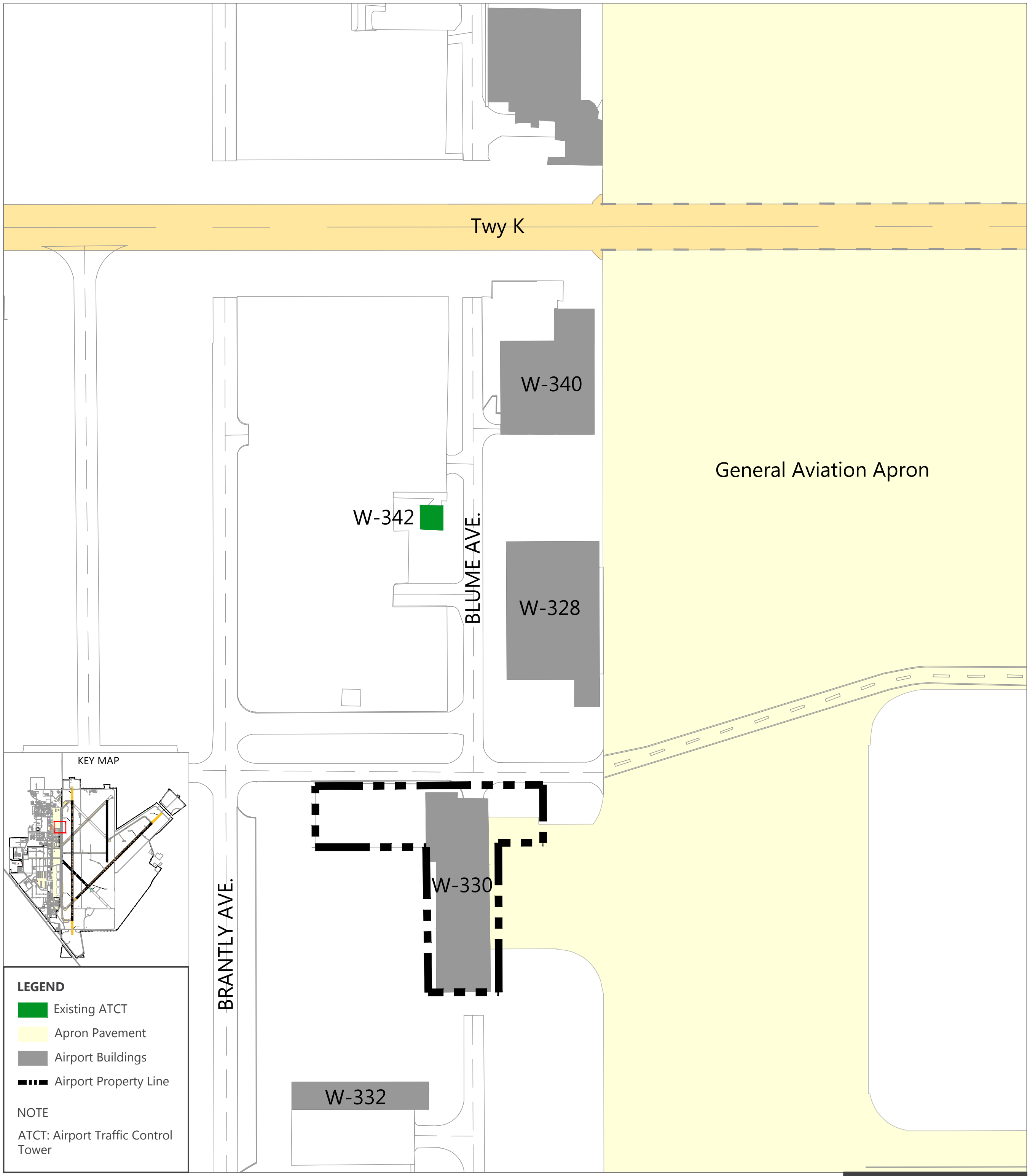

SOURCES: Ellington Draft Airport Layout Plan, Ricondo & Associates, March 2014; Houston Airport System, March 2014; Ricondo & Associates, Inc., March 2014.
PREPARED BY: Ricondo & Associates, Inc., March 2014.

EXHIBIT 2-16

NORTH 0 160 ft.

Airport Traffic Control Tower

Drawing: \\ricondo.com\public\Dallas\Project\Houston Airport System\Ellington Airport\2014 Master Plan Update\02 - Data Collection and Inven[illegible] Plotted: Sep 14, 2015, 09:49AM

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The 147th TxANG ARFF unit is equipped with three crash apparatuses, one vehicle used for structural response, one water tanker, and one rescue vehicle and trailer. The crash apparatuses are deployed as the first emergency response to aircraft incidents. The structural response vehicle is deployed for emergency fire response to facilities or buildings. The other units support the emergency fire apparatus in the event of rescue operations and water shuttling. **Table 2-10** describes EFD ARFF equipment, including the equipment model, water storage capacity, dry chemical capacity, and Airport response time to an emergency fire incident on the airfield. A combined total of 10 fire fighters typically staff these vehicles.

Table 2-10: ARFF Equipment

VEHICLE NUMBER	MODEL	EQUIPMENT	GALLONS OF WATER	GALLONS OF AFFF [1/]	RESPONSE TIME OR PURPOSE
C-4	TI-5000	Crash apparatus	1,500	205 450 pounds purple k	3 minutes
C-6	P-34	Crash apparatus	400	56	3 minutes
C-5	Oshkosh Striker	Crash apparatus	1,500	130 500 pounds purple k	3 minutes
E-12	P-22	Structural apparatus	500	50	3 minutes
T-10	P-18	Water tanker	2,000	N/A	When needed, Chief will drive
R-3	P-30	Rescue vehicle	N/A	N/A	N/A
N/A	N/A	Trailer	N/A	1,000	N/A

NOTE:

N/A = Not Applicable

1/ AFFF refers to aqueous film forming foam agent, which is used to extinguish fires.

SOURCE: Houston Airport System, April 2014.
PREPARED BY: Ricondo & Associates, Inc., April 2014.

2.4.3 AIRFIELD SERVICES COMPLEX

The ASC, located just north and east of Runway 17R-35L at the Airport, consists of buildings and facilities used to store, maintain, and repair a wide variety of equipment. As shown on **Exhibit 2-17**, the ASC consists of four separate buildings surrounded by a concrete paved surface. This surface area is used for a variety of activities, including vehicle and equipment maneuvering, vehicle parking, and storage.

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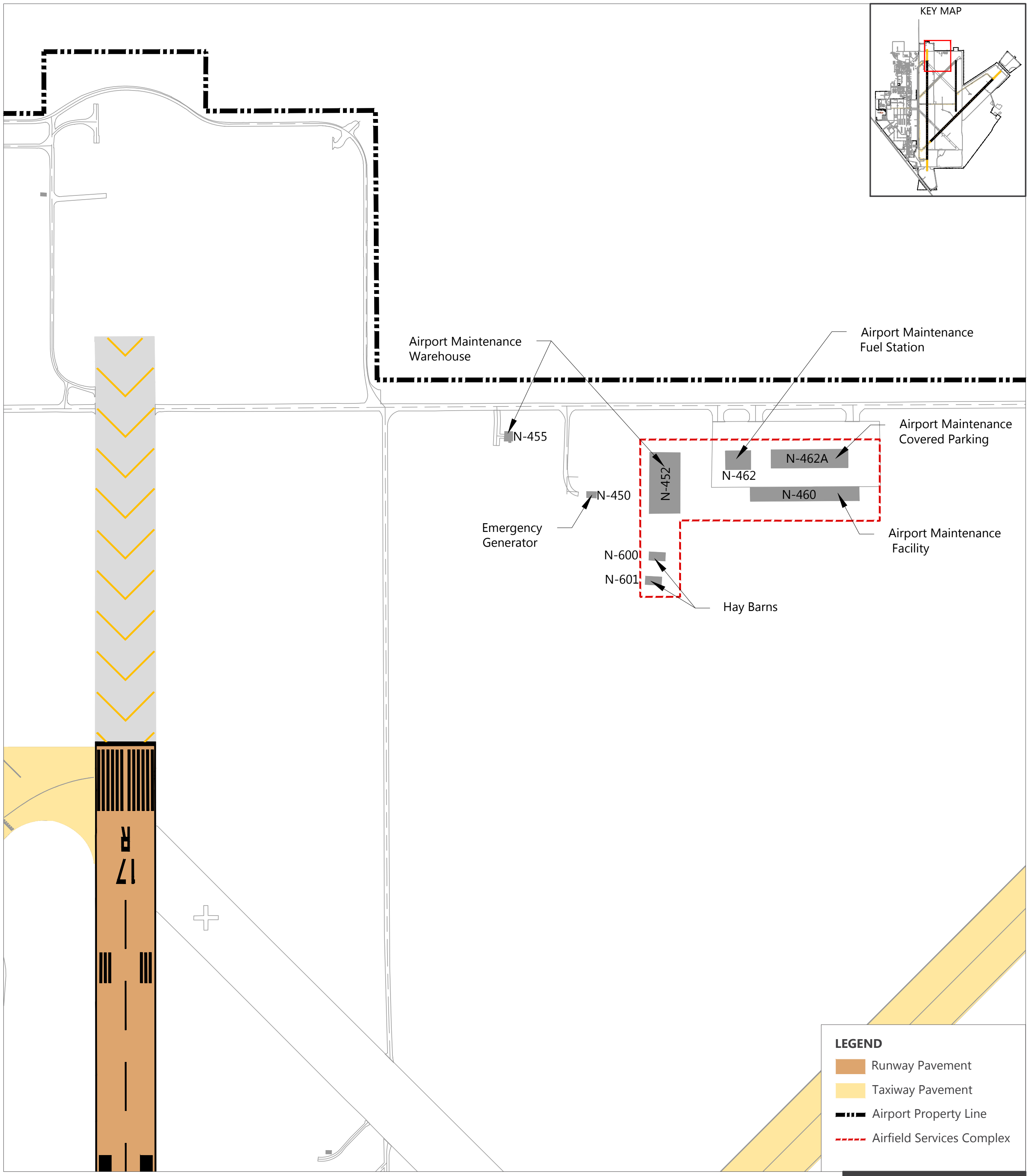

SOURCES: Ellington Draft Airport Layout Plan, Ricondo & Associates, March 2014; Houston Airport System, March 2014; Ricondo & Associates, Inc., March 2014.
PREPARED BY: Ricondo & Associates, Inc., March 2014.

EXHIBIT 2-17

Airfield Services Complex

Drawing: \\ricondo.com\public\Dallas\Project\Houston Airport System\Ellington Airport\2014 Master Plan Update\02 - Data Collection and Inven[illegible] Plotted: Sep 14, 2015, 09:55AM

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Building N-452 is an Airport maintenance warehouses. Building N-462 houses the fuel station and wash bay. Building N-462A houses the open-sided covered parking maintenance bay, which is used as an equipment servicing area. Enclosed maintenance is conducted in Building N-460, which consists of four bays that contain storage areas as follows:

- An airfield and grounds storage bay that stores equipment used to maintain landside and airfield pavements, roadways, and grassed grounds at the Airport.
- An equipment support storage bay used to store a variety of equipment serviced by an HAS contractor.
- A physical plant maintenance bay used to store building materials, mechanical and plumbing fixtures, and other equipment.
- An electrical equipment storage bay used to store building electrical supplies and equipment.

An emergency generator is located in Building N-450. Another Airport maintenance warehouse is located to the west in Building N-455. Two hay barns are also located in the ASC, in Buildings N-600 and N-601.

2.4.4 FUEL STORAGE FACILITIES

The EFD fuel farm is located in the southwest corner of Airport property. As depicted on **Exhibit 2-18**, the fuel farm consists of three fuel storage facilities adjacent to one another along McLoughlin Street. Access to the fuel farm is provided via McLoughlin Street through a secure gate. Fuel is delivered to the fuel storage facilities by tanker trucks. As no underground fuel lines or hydrant fueling systems are located at EFD, aircraft fueling is performed via fuel trucks. All storage tanks and pipelines are located above ground. Landmark Aviation and the TxANG are the two main fueling suppliers with tanks at the fuel farm. A self-service fueling facility is planned to be completed in spring 2015. It will be located at the end of Taxilane J, and will have a capacity of 12,000 gallons of aviation gasoline (avgas).

Landmark Aviation operates the fuel farm's north and central fuel storage facilities, which have a combined storage capacity of 176,000 gallons. Landmark Aviation is the only fuel service provider at EFD and provides fuel for all tenants, except the military tenants. The northern fuel storage facility is accessed via a looped connector off the north side of McLoughlin Street, which reconnects with McLoughlin Street on the south side of the facility. The central fuel storage facility abuts a circular road that egresses from and ingresses onto McLoughlin Street, and then onto an airfield service road that enters the EFD airfield area. The TxANG operates the fuel farm's southern storage facilities, which consist of two 12,000-gallon horizontal tanks connected via pipes to a pumping station on the opposite side of McLoughlin Street.

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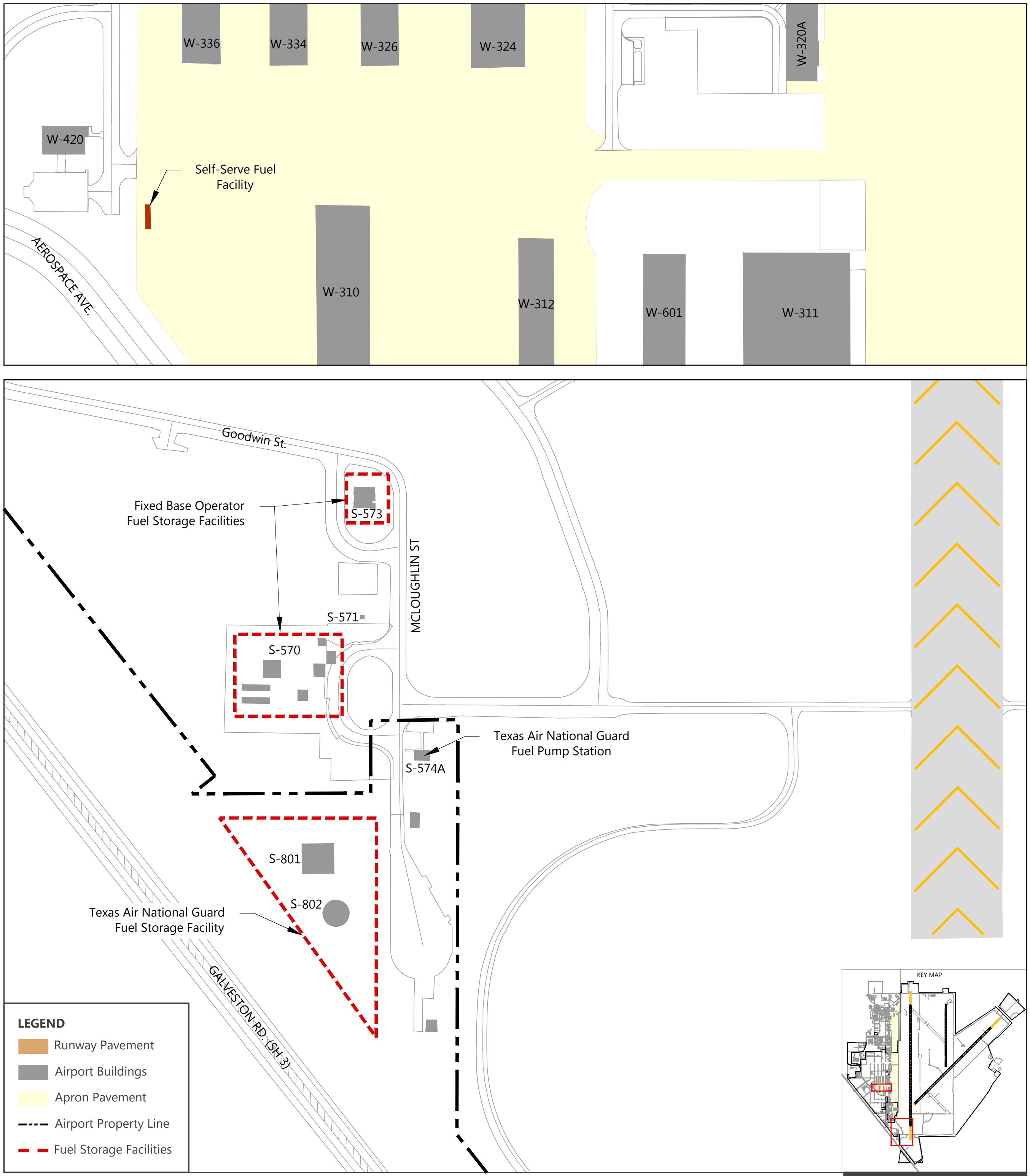

SOURCES: Ellington Draft Airport Layout Plan, Ricondo & Associates, March 2014; Houston Airport System, March 2014; Ricondo & Associates, Inc., March 2014.
PREPARED BY: Ricondo & Associates, Inc., March 2014.

EXHIBIT 2-18

NORTH

0 20 ft.

Fuel Storage Facilities

Drawing: \\ricondo.com\public\Dallas\Project\Houston Airport System\Ellington Airport\2014 Master Plan Update\02 - Data Collection and Inventory\2-Exhibits\CAD\Exhibit 2-18_FuelFacility.dwg Layout: Existing Site Plotted: Sep 29, 2015, 01:20PM

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Table 2-11 provides a breakdown of the general aviation (non-military) fuel storage capacity by provider, tank size, and fuel truck capacity.

Additionally, a number of smaller above-ground fuel storage tanks serve backup generators for the various navigational aids on the airfield. Two underground storage tanks are located at the ASC for fueling maintenance vehicles and ground support equipment (GSE). These fuel tanks are maintained by HAS through an outside contract.

Fuel flowage at EFD in 2012 amounted to approximately 3,142,000 gallons (excluding military activity), of which approximately 920,000 gallons were Jet-A fuel, 132,000 gallons were avgas, and 2,090,000 gallons were JP8 fuel.[11]

Table 2-11: General Aviation Fuel Storage Capacity

PROVIDER	FUEL TANK (GALLONS)	FUEL TRUCK (GALLONS)	TOTAL
	JET A		
Landmark Aviation	30,000	5,000	
Landmark Aviation	12,000	5,000	
Landmark Aviation	12,000		
	54,000	**10,000**	**64,000**
	AVGAS		
Landmark Aviation	12,000	750	
Landmark Aviation		1,200	
HAS Self-Serve Fueling Facility	12,000		
	24,000	**1,950**	**25,950**
	JP 8		
Landmark Aviation	30,000	5,000	
Landmark Aviation	20,000	5,000	
Landmark Aviation	20,000	5,000	
Landmark Aviation	20,000	5,000	
Landmark Aviation	20,000		
	110,000	**20,000**	**130,000**

SOURCES: Houston Airport System, April 2014; Landmark Aviation (formerly Southwest Airport Services), April 2014.
PREPARED BY: Ricondo & Associates, Inc., April 2014.

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[11] Houston Airport System, Finance Division, *Revenue Accounting*, June 2013.

2.4.5 DEICING OPERATIONS

Aircraft deicing involves spraying deicing or anti-icing chemicals on the aircraft before takeoff to ensure a safe takeoff in icing conditions.

A deicing pad is located on the Runway 35L hold pad. It is equipped with infrastructure to process and store deicing fluid runoff from deicing operations. However, no deicing fluid storage tanks are located at EFD. As the system has not been used recently, it would need to be evaluated to determine its current condition. However, according to discussions with Airport staff, there is currently no need for a deicing facility at the Airport.

2.4.6 HAS ADMINISTRATION

HAS Administration offices are located in Building W-440 on Aerospace Avenue. Building W-440 consists of approximately 21,000 square feet and contains HAS offices and meeting areas. A portion of the administrative property, including a section of the parking lot, was recently reclaimed for the new USCG Regional Command Center. Building W-440 also houses office space for the Houston Police Department-(HPD).

2.4.7 U.S. CUSTOMS AND BORDER PROTECTION

U.S. Customs and Border Protection (CBP) regulations govern landing requirements and procedures for private aircraft arriving into the United States. Private aircraft entering the United States from a foreign country have to go through CBP inspection at their first U.S. stop. In general, the first landing of a private aircraft entering the United States from a foreign country will be at a:

- Designated international airport,
- Landing rights airport, if permission to land has been granted, or
- Designated user fee airport, if permission to land has been granted.

Ellington Airport is considered a user fee airport, as there are currently no permanent CBP services offered at the Airport. CBP inspection services are available for nonprecleared private aircraft arrivals,[12] the CBP can process international general aviation and cargo aircraft arrivals on demand. The Airport is also eligible for the arrival of precleared private aircraft flights,[13] which means that an aircraft that has been precleared at its origin does not need to go through CPB inspection when it lands at EFD. Currently, nine airports in Canada, four airports in the Caribbean, and two airports in Ireland offer preclearance services.[14]

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[12] http://www.cbp.gov/linkhandler/cgov/travel/private_flyers/airport_inspection.ctt/airport_inspection.pdf

[13] http://www.nbaa.org/ops/intl/customs-regulatory/customs/preclearance/airports.php

[14] http://www.cbp.gov/xp/cgov/toolbox/contacts/preclearance/preclear_locations.xml

2.5 Airport Tenant Facilities

Airport tenant facilities are typically located landside with airside access. Tenants include general aviation, government, and commercial organizations.

2.5.1 GENERAL AVIATION FACILITIES

General aviation tenant facilities are located on the west side of the Airport, midfield. As depicted on **Exhibit 2-19**, the general aviation tenant facilities consist of multiple buildings managed by a fixed base operator (FBO), a flight school, aircraft parking areas, and hangars for itinerant and based aircraft, including three hangars used by private corporate business operators (CBOs). These facilities are described below.

2.5.1.1 Fixed Base Operator

One full-service FBO, Landmark Aviation, is located on-Airport and provides services such as aircraft fueling for itinerant and based aircraft. Additional services provided through Landmark Aviation are:

- Aircraft, airframe, and engine maintenance is provided by subtenant JR Helicopter & Aircraft Services, Inc.
- Charter operations, aircraft management and acquisition services, and jet membership are provided by Starbase Aviation, a subsidiary of Landmark Aviation.
- Simulator training provided through AV Flight Simulation, and;
- Aircraft storage (although limited).

Landmark Aviation operates the following buildings:

- Building W-320A, the main terminal complex, located south of the ATCT, at the intersection of Brantly Avenue and Hillard Street. This building houses the terminal facility and offices, as well as the Flying Tigers flight school. The two-level main terminal hangar building was constructed in 2008 and provides a total of approximately 35,000 square feet of covered space, split into 22,500 square feet for protected aircraft storage and 12,500 square feet for office and maintenance space.
- Building W-322 (Hangar A) for aircraft storage.
- Buildings W-601, W-311, and W-602 (Hangars B, C, and D) for aircraft storage.
- Building S-390 (Hangar E), where aircraft maintenance is conducted.
- Buildings W-352 and W-354 (Hangars F and G), where Starbase Aviation operates.
- Building W-322, where Av Flight Simulation operates.

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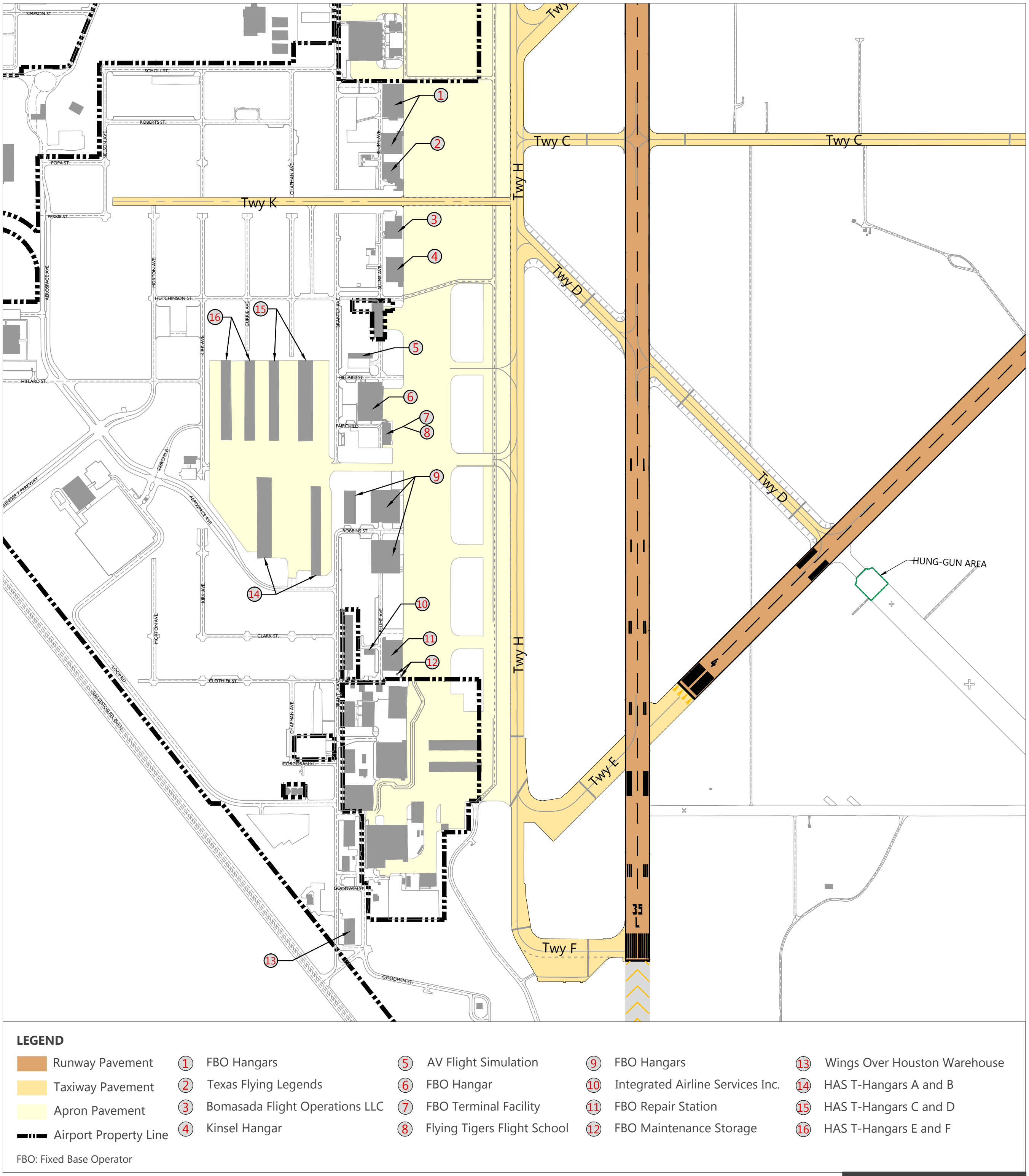

SOURCES: Ellington Draft Airport Layout Plan, Ricondo & Associates, March 2014; Houston Airport System, March 2014; Ricondo & Associates, Inc., March 2014.
PREPARED BY: Ricondo & Associates, Inc., March 2014.

EXHIBIT 2-19

NORTH

0 2,000 ft.

General Aviation Tenant Facilities

Drawing: \\ricondo.com\public\Dallas\Project\Houston Airport System\Ellington Airport\2014 Master Plan Update\02 - Data Collection and Inventory\2-Exhibits\CAD\Exhibit 2-19_ Airport Tenant Facilities.dwg Layout: 8.5x11P Plotted: Sep 29, 2015, 01:13PM

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2.5.1.2 Flight School

Flying Tigers is the sole flight school operating at the Airport. The Flying Tigers flight training program operates in conjunction with Lee College in Baytown, Texas. The flight school currently operates 10 single-engine and two multiengine aircraft. Student pilots conduct single-engine training in Grumman Cheetah, Cessna 172, and American General Tiger aircraft. The Light Sport Tecnam P92 and Piper Arrow aircraft are used for complex training, and the Grumman GA-7 and Beechcraft Duchess aircraft are used for multiengine aircraft training. The flight school parks its aircraft north of the NASA apron and operates from the Landmark Aviation main terminal complex.

2.5.1.3 Aircraft Parking

Itinerant aircraft parking areas are located predominantly on the apron area between the Landmark Aviation facilities and Taxiway H. These areas provide apron and parking space for transient aircraft, while allowing convenient access to taxiways, runways, FBO fueling facilities, and ground transportation services. As shown on **Exhibit 2-20**, itinerant aircraft parking areas front the FBO and CBO facilities, including the former ARFF station and ATCT.

Based aircraft parking areas provide apron and parking space for aircraft owned by local businesses or pilots. HAS offers 22 tiedown positions in the southwest corner of the T-hangar area of the Airport.

2.5.1.4 Aircraft Hangars

A variety of hangars at the Airport are used for aircraft storage, full-service maintenance, and other aircraft support services.

HAS Hangars

Hangar units are individual aircraft parking facilities primarily used for the permanent storage of aircraft. HAS owns and leases six hangar buildings at the Airport. These hangar buildings are located between Kirk Avenue and Brantly Avenue, west of the Landmark Aviation terminal building. The combined hangar buildings provide a total of approximately 176,000 square feet of storage space and consist of:

- 66 small hangar units (1,482 square feet per unit), divided among four buildings (W-336, W-334, W-326, and W-312), provide a total of approximately 100,000 square feet of storage space.
- 24 large hangar units (3,188 square feet per unit), divided between two buildings (W-324 and W-310), provide a total of approximately 76,000 square feet of storage space.

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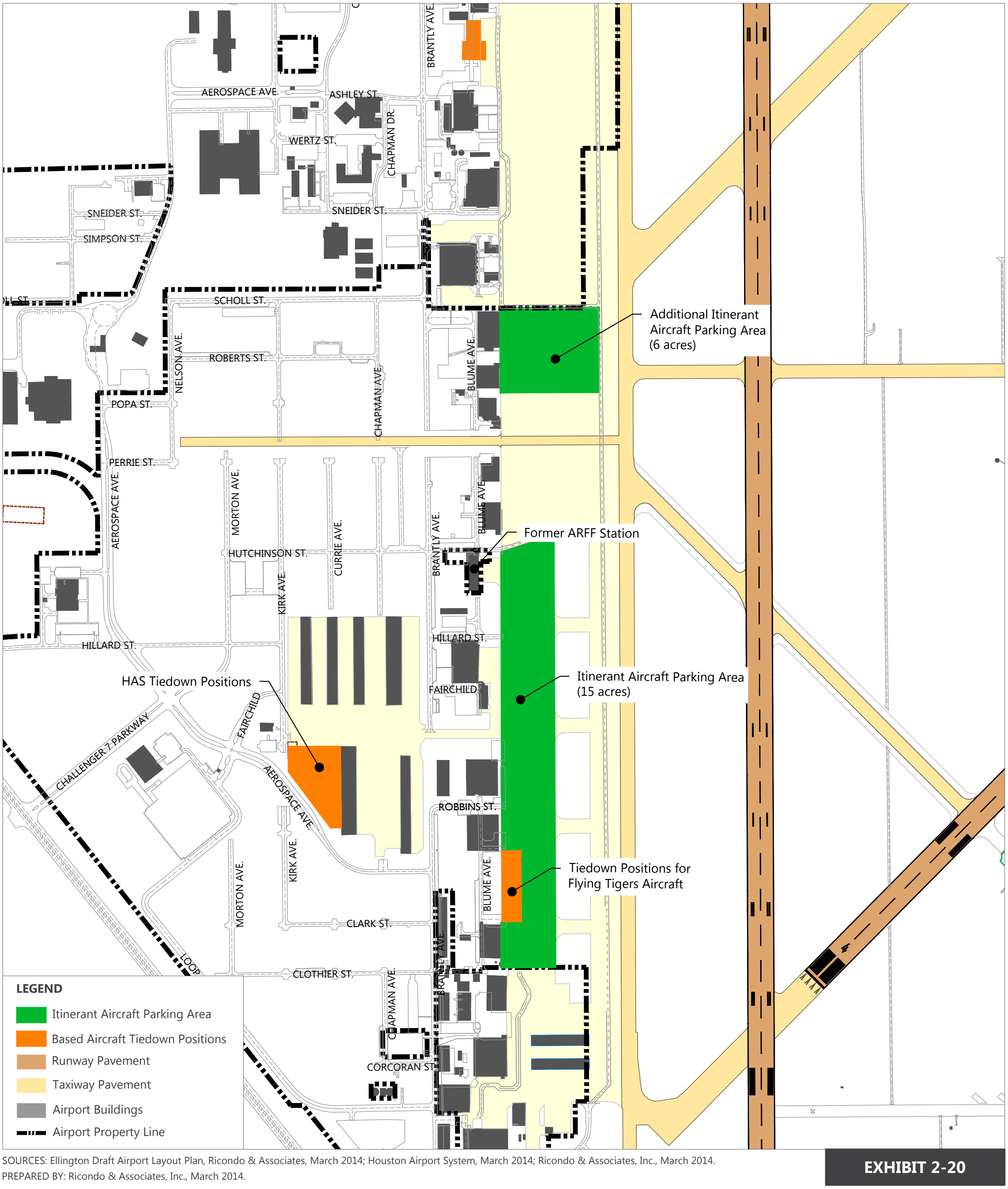

SOURCES: Ellington Draft Airport Layout Plan, Ricondo & Associates, March 2014; Houston Airport System, March 2014; Ricondo & Associates, Inc., March 2014.
PREPARED BY: Ricondo & Associates, Inc., March 2014.

EXHIBIT 2-20

NORTH 0 800 ft.

Aircraft Parking Areas

Drawing: \\ricondo.com\public\Dallas\Project\Houston Airport System\Ellington Airport\2014 Master Plan Update\02 - Data Collection and Inven[illegible] Plotted: Sep 14, 2015, 10:12AM

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Private/Corporate Hangars

Corporate hangars are used by private corporate entities to store large high-performance aircraft; aviation support and maintenance services are provided. Three hangars are used by CBOs at the Airport:

- Building W-328: Kinsel Industries
- Building W-340: Bomasada Flight Operations
- Building W-350: Texas Flying Legends Museum

2.5.2 GOVERNMENT FACILITIES

As depicted on **Exhibit 2-21**, government tenants at the Airport include NASA, the FAA, and three active military units that form the (EFJRB): the U.S. ARNG, the TxANG, and the USCG. These three tenants own their respective properties within the Airport boundary and are not bound by land lease agreements with HAS.

2.5.2.1 National Aeronautics and Space Administration

NASA operations take place in two locations at the Airport. One of NASA's locations, consisting of three buildings and a parking area, is on the southeast edge of the EFJRB. The largest building is known as NASA 990. The other site is in the southwest corner of the Airport, along Taxiway H, where NASA has multiple buildings, consisting mostly of hangars used to store, maintain, and support a variety of aircraft based at the Airport. NASA also conducts astronaut flight training at the Airport, in the T-38 aircraft, and conducts weather reconnaissance observations using two WB57 aircraft.

NASA also operates the Neutral Buoyancy Laboratory in the Sonny Carter Training Facility on off-Airport land adjacent to the eastern Airport boundary. One building, however, is located on Airport property.

2.5.2.2 Federal Aviation Administration

The FAA controls approximately 2 acres inside the TxANG property on the Airport, from which it operates a Common Air-Route Surveillance Radar; this is an unmanned facility used to control airspace within and around the borders of the United States.

2.5.2.3 Texas Air National Guard

The TxANG is the host for the EFJRB, which occupies approximately 213 acres in the northwest corner of the Airport, according to the *Master Plan for Space Utilization* at EFJRB, dated April 2009.[15]

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[15] CH2MHill, *Master Plan for Space Utilization at EFJRB*, April 2009,

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SOURCES: Ellington Draft Airport Layout Plan, Ricondo & Associates, March 2014; Houston Airport System, March 2014.
PREPARED BY: Ricondo & Associates, Inc., March 2014.

EXHIBIT 2-21

NORTH 0 1,200 ft.

Military and Government Facilities

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In 2008, the TxANG transitioned from the 147th Fighter Wing Squadron to the 147th Reconnaissance Wing. As a result, TxANG property assets shifted from mission support of F-16 aircraft to two Combatant Command (COCOM) missions. The two Combatant Command missions are the Predator MQ-1 unmanned aerial vehicle (UAV) and Air Sovereignty Missions, supported by four F-16 aircraft. These Combatant Command missions are further supported by two missions in the relocation of the 272th Engineering Installation Squadron and the integration of the Air Support Operations Squadron. To accommodate this transition and fulfill its new operational command missions, the EFJRB underwent facility reconfiguration. The Predator MQ-1 UAV and the future MQ-9 do not require extensive maintenance and supply facilities, unlike the F-16 aircraft requirements. However, they do require more robust reconnaissance operations. The MQ-9 is larger than the MQ-1 and has the ability to carry weapons; as such, it will require additional support facilities compared to the MQ-1.

2.5.2.4 United States Army National Guard

The U.S. ARNG leases approximately 20 acres of the EFJRB from the TxANG. The ARNG primarily supports and operates AH-64 Apache helicopters.

2.5.2.5 United States Coast Guard

The USCG is a responsive operational force that supports the roles of maritime homeland security and national defense, and manages domestic disasters. At EFD, the USCG occupies approximately 12 acres leased from the TxANG in the southeast corner of the TxANG property, where it operates Dauphin helicopters. Additionally, the USCG Regional Command Center is located on a parcel of land of approximately 75 acres, southwest of the EFJRB. The building encompasses approximately 100,000 square feet of space and more than 350 people are employed in the various divisions of the Command Center, in Investigative Services, Electronic Support, the Public Affairs Department, and the Regional Civil Rights Office.

2.5.3 COMMERCIAL FACILITIES

Commercial activity has been growing at the Airport. The Orion Group leases approximately 15 acres at the intersection of Challenger 7 Parkway and Aerospace Avenue. On this 15-acre site is located a 28,500-square-foot four-story building, the Grumman Building, in which several companies lease office space.

As a result of the damage caused by Hurricane Ike in 2008, there are plans to relocate the Lone Star Flight Museum, currently located in Galveston, Texas, to EFD within a few years. The relocation will provide the museum with a larger space and modern amenities, along with a theatre and restaurant. Approximately 50,000 people visit the museum annually.[16]

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[16] http://www.chron.com/news/houston-texas/article/Air-museum-s-move-to-Ellington-will-attract-more-2134231.php

2.6 Airport Access and Parking Facilities

2.6.1 REGIONAL ACCESS

The Airport is accessible via three major roadways: Interstate 45 (Gulf Freeway), Beltway 8 (Sam Houston Tollway) and State Highway 3, which are shown on **Exhibit 2-22**. The primary access to the Airport is via Dixie Farm Road (FM 1959), which connects State Highway 3 and Interstate 45.

Each key roadway providing regional access to the Airport is described as follows:

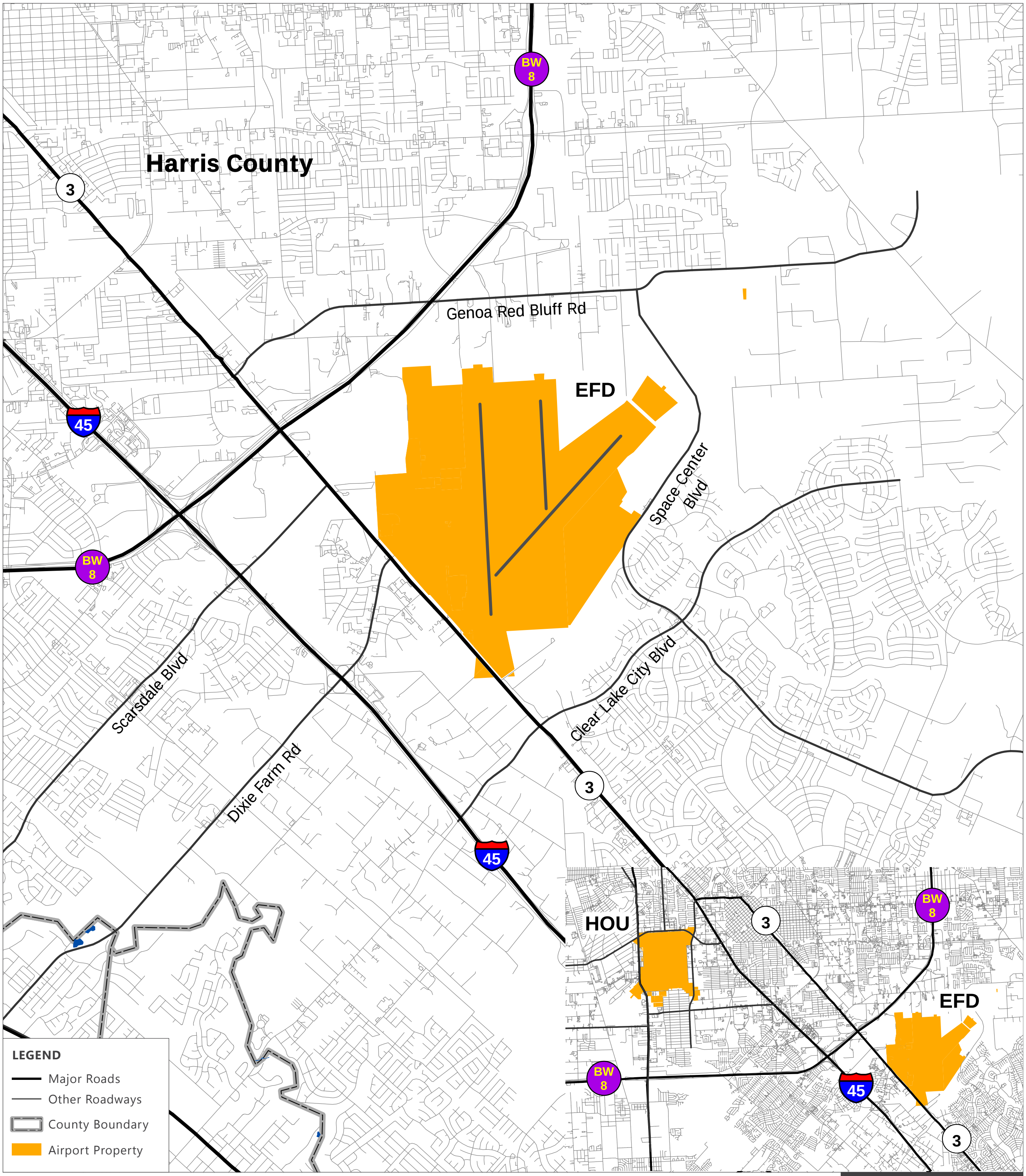
- Interstate 45 – This north-south freeway provides regional access to the Airport and the surrounding area. Direct access to the Airport is provided via Scarsdale Boulevard and Dixie Farm Road.
- Beltway 8 (Sam Houston Tollway) – This toll road runs along the northwest portion of the Airport and provides access to the Airport via State Highway 3.
- State Highway 3 (Old Galveston Road) – This north-south freeway generally forms the western boundary of the Airport. Access to the Airport is provided via intersections with Challenger 7 Parkway, Hillard Street, and Brantly Avenue along State Highway 3.
- Dixie Farm Road (Farm to Market Road 1959) – This road provides primary access from Interstate 45, and intersects with State Highway 3 and Challenger 7 Parkway at the main airport entrance.

The characteristics of these roadways are summarized in **Table 2-12**.

Table 2-12: Regional Access

ROADWAY	CLASSIFICATION	NUMBER OF LANES	MEDIAN	SIGNAL LOCATIONS	COMMENTS
Interstate 45	Freeway/Expressway	8	Yes	N/A	Has median high occupancy vehicle lane
State Highway 3	Major Thoroughfare	5	No	Conklin Lane Scarsdale Boulevard (Farm to Market Road 2553) Dixie Farm Road (Farm to Market Road 1959) Brantly Avenue Clear Lake City Boulevard Pineloch Drive	Raised median constructed in some sections
Beltway 8 (Sam Houston Tollway)	Freeway/Expressway	4 - 8	Yes	N/A	Tollway serves as outer beltway surrounding the City of Houston
Dixie Farm Road (FM 1959)	Major Thoroughfare	5	No	State Highway 3 Kensington Place Interstate 45	Has continuous center median lanes and provides direct access to the Airport

SOURCE: UrbanCore Collaborative, Inc., August 2012.
PREPARED BY: UrbanCore Collaborative, Inc., August 2012.



SOURCES: Houston-Galveston Area Council, Houston Airport System (OASIS), STARMap, May 2012.
PREPARED BY: UrbanCore Collaborative, Inc., August 2012.

EXHIBIT 2-22

NORTH 0 6,250 ft.

Regional Accessibility

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2.6.2 LOCAL ACCESS

Direct access to Ellington Airport is provided via Clear Lake City Boulevard and Brantly Avenue on the south, Space Center Boulevard on the east, and State Highway 3 (Old Galveston Road) on the west. Challenger 7 Parkway (extension of Dixie Farm Road) serves as the primary access to the general aviation areas, whereas Hillard Street and Brantly Avenue are secondary access roads. These access roads are in fair to good condition. Exhibit 2-22 illustrates the layout of both the public and private use access roads at and around the Airport. Each local roadway is described below:

- Clear Lake City Boulevard – This east-west roadway is located along the southern edge of the Airport and provides access to the Airport via State Highway 3.
- Scarsdale Boulevard (FM 2553) – This east-west roadway is accessed via Interstate 45 and State Highway 3. Access to the Airport is provided via an intersection located slightly south of the Scarsdale Boulevard/State Highway 3 intersection.
- Challenger 7 Parkway – Along with Dixie Farm Road, this roadway provides primary access to the Airport. This roadway is accessible via State Highway 3 and Dixie Farm Road.
- Hillard Street – This two-lane roadway provides access to the Airport via the intersection with State Highway 3, and is located north of Challenger 7 Parkway.
- Brantly Avenue – Access to the Airport is provided via the intersection of Brantly Avenue and State Highway 3. This access point is the southernmost entrance to the Airport.

The characteristics of these roadways are summarized in **Table 2-13**.

Table 2-13: Local Access

ROADWAY	CLASSIFICATION	NUMBER OF LANES	MEDIAN	SIGNAL LOCATIONS	COMMENTS
Clear Lake City Boulevard	Major Thoroughfare	4	Yes	State Highway 3 El Camino Real Space Center Boulevard	Wide medians
Scarsdale Boulevard (FM 2553)	Major Thoroughfare	4	No	State Highway 3 Interstate 45	Has left turn bay lanes
Challenger 7 Parkway	Local Street	4	Yes	State Highway 3	Provides direct access to the southwest side of the Airport
Hillard Street	Local Street	2	No	N/A	Provides direct access to the southwest side of the Airport
Brantly Avenue	Local Street	2	No	State Highway 3	Provides direct access to the south side of the Airport

N/A = Not Applicable

SOURCES: UrbanCore Collaborative, Inc., August 2012; Ricondo & Associates, Inc., January 2014.
PREPARED BY: Ricondo & Associates, Inc., January 2014.

Table 2-14 lists major and minor intersections in the Airport vicinity, based on major thoroughfare classification, traffic volume, and direct accessibility to the Airport.

Table 2-14: Major/Minor Intersections in the Vicinity of the Airport

ROADWAY INTERSECTION	TYPE OF INTERSECTION	SIGNALS
State Highway 3 and Challenger 7 Parkway	Major	Yes
State Highway 3 and Brantly Avenue	Major	Yes
State Highway 3 and Scarsdale Boulevard (FM 2553)	Major	Yes
State Highway 3 and Clear Lake City Boulevard	Minor	Yes
Clear Lake City Boulevard and Space Center Boulevard	Minor	Yes

SOURCE: UrbanCore Collaborative, Inc., August 2012.
PREPARED BY: UrbanCore Collaborative, Inc., August 2012.

2.6.3 VEHICULAR TRAFFIC ON AIRPORT ACCESS ROADWAYS

The City of Houston maintains a traffic count database, which is updated periodically. **Table 2-15** provides the directional average daily traffic counts on Airport access roadways. The traffic counts will assist the transportation engineers in calculating the roadway levels of service based on forecasted demand. **Exhibit 2-23** identifies major and minor arterial roads accessing the Airport and major and minor intersections in the vicinity of the Airport. These arterial roadways and intersections have a major role in providing efficient access to the Airport.

Table 2-16 illustrates the directional 24-hour traffic counts on Airport access roadways conducted by a transportation consultant in April 2012. Gunda Corporation, LLC, conducted peak-period turning movement counts for four study area intersections during April 2012.

Exhibit 2-24 illustrates the traffic count locations identified by the City of Houston Geographic Information and Management System (GIMS) and turning movement counts by Gunda Corporation.

The majority of trips to and from the Airport are by private vehicles. The vast majority of passengers using the Airport are either employees or visitors to the tenant offices; the Airport does not provide rental car service.

Table 2-15: Traffic Count Locations (City of Houston Counts)

ROADWAY	DIRECTION	VEHICLE COUNT	AVERAGE DAILY TRAFFIC	LOCATION (CROSS STREET)
State Highway 3	Northbound Westbound	11,163 10,856	22,019	Genoa Red Bluff to Scarsdale Boulevard (FM 2553)
State Highway 3	Northbound Westbound	10,645 10,771	21,416	Scarsdale Boulevard (FM 2553) to Dixie Farm Road (FM 1959)
State Highway 3	Northbound Southbound	10,970 11,512	22,482	Dixie Farm Road (FM 1959) to Clear Lake City Boulevard
State Highway 3	Northbound Southbound	12,026 13,594	25,620	Clear Lake City Boulevard to El Dorado Boulevard
State Highway 3	Northbound Southbound	12,314 14,814	27,128	El Dorado Boulevard to N. Webster City Limit
Scarsdale Boulevard (FM 2553)	Eastbound Westbound	3,516 3,727	7,243	State Highway 3 to Gulf Freeway (I-45)
Dixie Farm Road (FM 1959)	Eastbound Westbound	8,247 8,149	16,396	State Highway 3 to Gulf Freeway (I-45)
Clear Lake City Boulevard	Eastbound Westbound	14,546 15,698	30,244	State Highway 3 to Gulf Freeway (I-45)
Clear Lake City Boulevard	Eastbound Westbound	13,791 15,845	29,636	El Camino Real to State Highway 3
Clear Lake City Boulevard	Eastbound Westbound	12,351 13,445	25,796	El Camino Real to Space Center Boulevard
Space Center Boulevard	Northbound Southbound	7,075 7,229	14,304	Genoa Red Bluff Road to Clear Lake City Boulevard
Genoa Red Bluff Road	Eastbound Westbound	10,306 9,995	20,301	Beltway 8 south to Space Center Boulevard

SOURCE: City of Houston Geographic Information and Management System Database, May 2012.
PREPARED BY: Urbancore Collaborative, Inc., August 2012.

Table 2-16: Traffic Count Locations (Consultant Counts)

ROADWAY	DIRECTION	VEHICLE COUNT	AVERAGE DAILY TRAFFIC	LOCATION
Brantly Avenue	Eastbound Westbound	684 545	1,229	East of State Highway 3
Challenger 7 Parkway	Eastbound Westbound	1,455 1,485	2,940	East of State Highway 3
Hillard Street	Eastbound Westbound	973 866	1,839	East of State Highway 3
Space Center Boulevard	Northbound Southbound	8,203 9,171	17,374	North of Village Dale Avenue

SOURCE: Gunda Corporation, LLC, April 2012.
PREPARED BY: UrbanCore Collaborative, Inc., April 2012.

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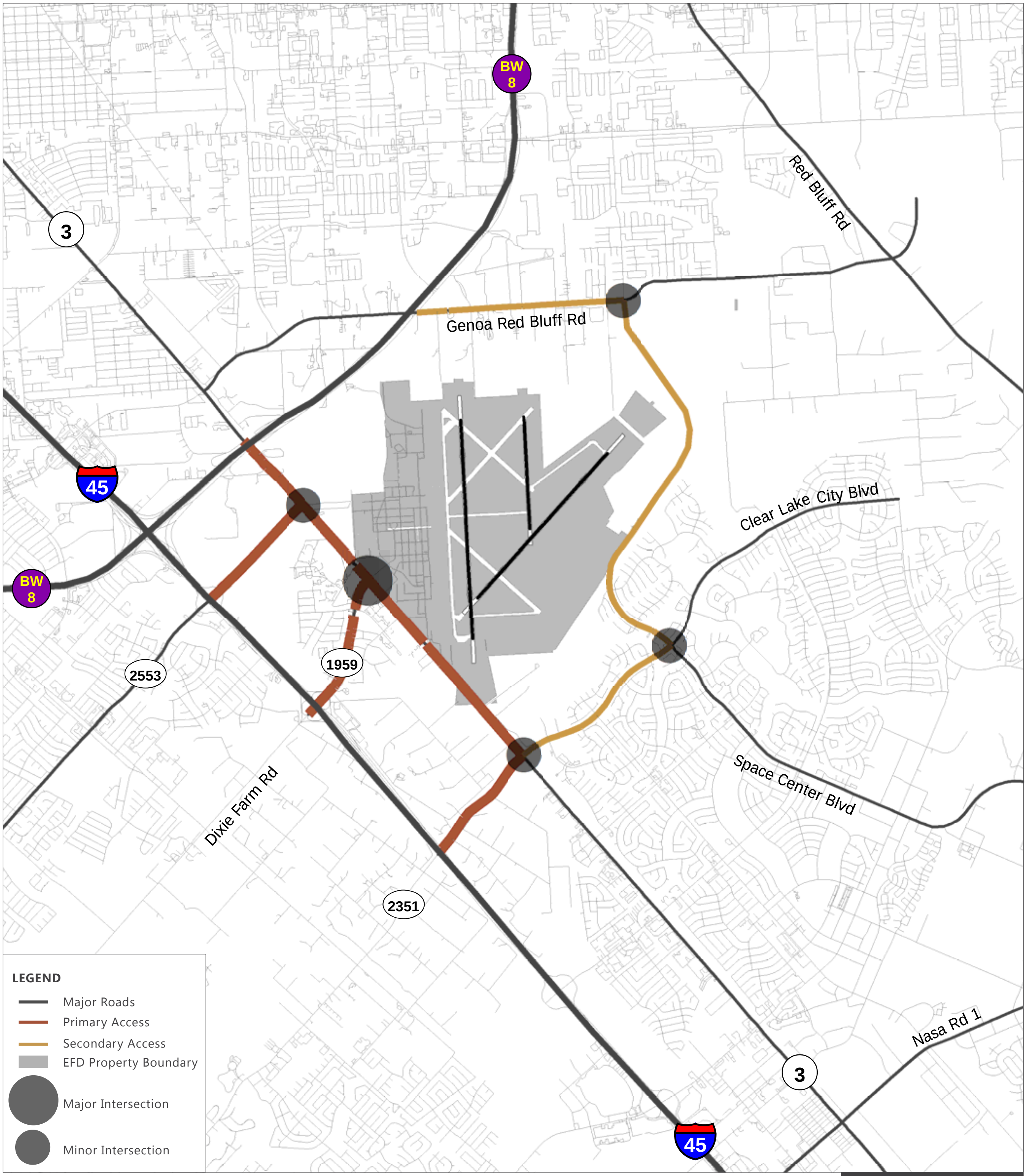

SOURCES: Houston-Galveston Area Council, Houston Airport System (OASIS), City of Houston (GIMS), STARMap, May 2012.
PREPARED BY: UrbanCore Collaborative, Inc., May 2012.

EXHIBIT 2-23

NORTH 0 3,000 ft.

Airport Access Roads

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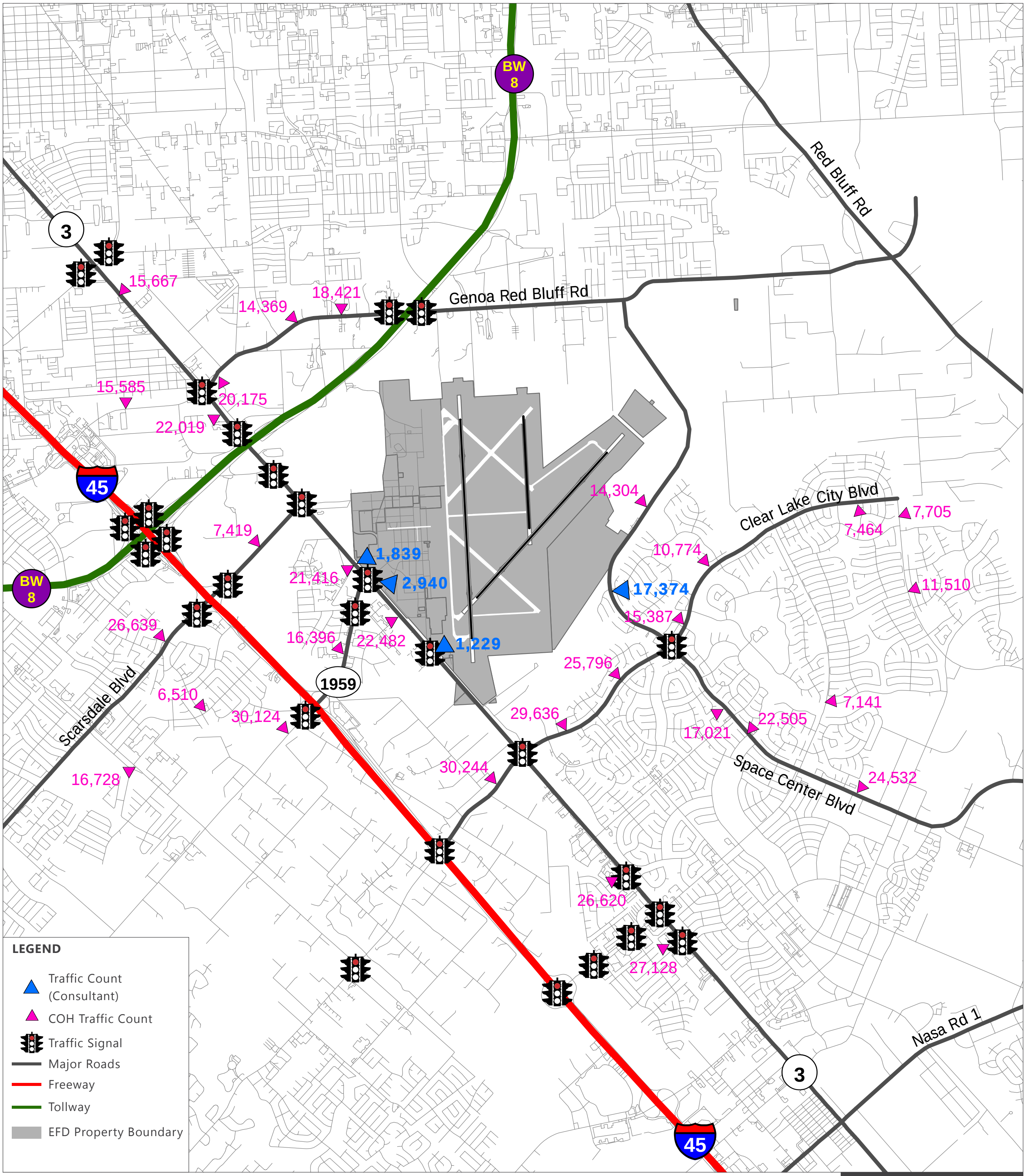

SOURCE: Houston-Galveston Area Council, Houston Airport System (OASIS), City of Houston (GIMS), GUNDA Corporation, STARMap, May 2012.
PREPARED BY: UrbanCore Collaborative, Inc., May 2012.

EXHIBIT 2-24

NORTH 0 6,000 ft.

Traffic Counts on Roadways Approaching the Airport

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2.6.4 PUBLIC TRANSPORTATION

Currently, the Airport is not served by public transit. However, there are three Park and Ride locations and one Park and Pool lot located in the vicinity. Information about these locations, as well as the bus routes operating through the Park and Ride facilities, are summarized in **Table 2-17.**

Table 2-17: Mass Transit Park Locations

NAME	LOCATION	SERVED BY METRO ROUTE
South Point Park & Ride	Beltway 8 and I-45 intersection area	297
Fuqua Park & Ride	Beltway 8 and I-45 intersection area	244, 247, 249
Bay Area Park & Ride	El Dorado Boulevard and El Camino Real Intersection area	246, 249
Bay Area Park & Pool	Bay Area Boulevard and I-45 intersection area	246, 249

SOURCE: Metropolitan Transit Authority of Harris County, May 2012
PREPARED BY: UrbanCore Collaborative, Inc., May 2012.

2.6.5 PARKING FACILITIES

Most Airport facilities have adjacent parking areas, which are considered nonpublic areas. The only public parking area currently available at the Airport is adjacent to the HAS Administration building**.** **Exhibit 2-25** presents the public parking area, the FBO parking areas, and the largest private parking area serving a nonmilitary facility at the Airport. There is currently no shortage of public or nonpublic parking spaces at the Airport.

2.7 Environmental Inventory

The goal of airport master planning is to set a long-term development program for an airport, identifying appropriate projects that are economically and environmentally feasible. Projects recommended in a Master Plan that are later approved for development then must be the subject of an assessment of environmental impacts under the National Environmental Policy Act of 1969 (NEPA), which requires the FAA to publicly disclose the environmental impacts expected to be caused by the proposed project. FAA Order 5050.4B, *Airport Environmental Handbook*, states that: “In approving the Federal actions necessary to support an airport development proposal, the approving FAA official must consider environmental effects as fully and as fairly as it does technical, economic, and other non-environmental considerations.” During the master planning process, a thorough environmental overview that identifies the potential environmental impacts of recommended projects in advance could prevent the airport development program from experiencing delays or cancelled projects.

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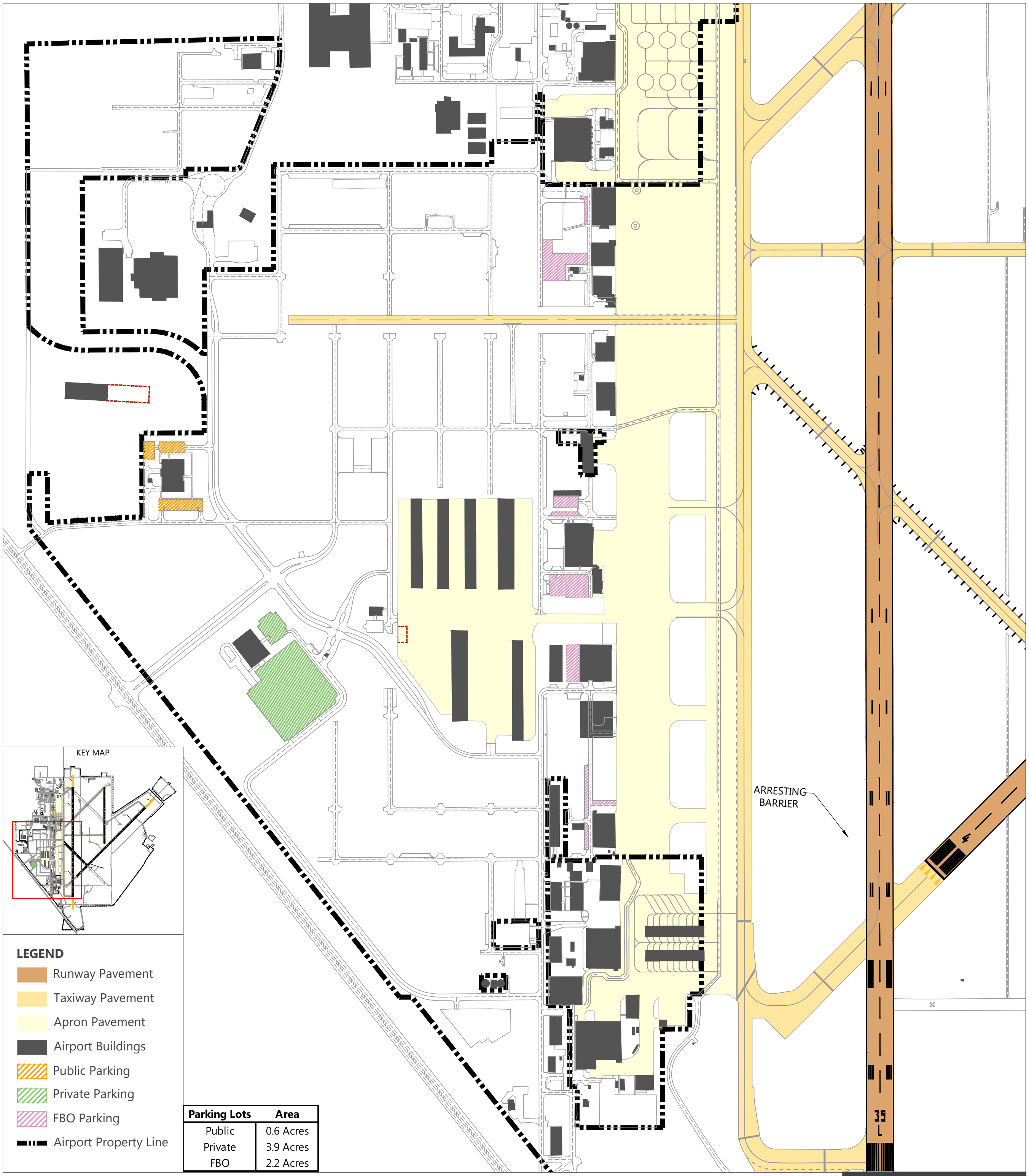
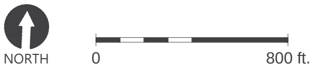


Parking Lots	Area
Public	0.6 Acres
Private	3.9 Acres
FBO	2.2 Acres

SOURCES: Ellington Draft Airport Layout Plan, Ricondo & Associates, March 2014; Houston Airport System, March 2014; Ricondo & Associates, Inc., March 2014.
PREPARED BY: Ricondo & Associates, Inc., March 2014.

EXHIBIT 2-25



Vehicular Parking Areas

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This environmental inventory identifies the current conditions of the natural and social environment in and around Ellington Airport, and the trends affecting environmental conditions. It provides background information for the Environmental Overview section of this Master Plan Update. In the overview section, the likely environmental impacts of the proposed airside and landside development projects for EFD are examined and potential mitigation measures are recommended, thus setting the stage for the NEPA process for projects approved for development. Many types of airport development projects have the potential to result in environmental impacts, including:

- Runway extensions
- Taxiway extensions and development
- New hangars
- Apron expansions
- Roadway development

This inventory section follows the guidelines in FAA Order 5050.4B, *Airport Environmental Handbook;* current conditions for 9 of the 21 environmental impact categories listed in the FAA Order are considered herein, as follows:

- Air Quality
- Floodplains
- Biotic Communities
- Wetlands
- Endangered and Threatened Species
- Cultural Resources
- Department of Transportation Act, Section 4(f) Lands
- Socioeconomic Conditions/Environmental Justice
- Hazardous Materials

The later Environmental Overview section addresses the potential environmental impacts of Master Plan alternatives for future development. The previously mentioned nine categories and the remaining 12 categories listed in the FAA Order are addressed. The 12 remaining categories are:

- Noise
- Compatible Land Use
- Water Quality
- Coastal Zone Management Program
- Coastal Barriers
- Wild and Scenic Rivers

- Farmlands
- Energy Supply and Natural Resources
- Light Emissions
- Solid Waste Impacts
- Construction Impacts
- Cumulative Impacts

Neither this environmental inventory nor the later Environmental Overview section of the Master Plan Update constitutes a NEPA document, such as an Environmental Assessment or Environmental Impact Statement. A limited degree of environmental analysis is provided herein for proposed Airport development projects. Projects receiving federal funding or approval that are later determined to be not categorically excluded from NEPA assessment would require additional environmental analysis and preparation of NEPA documents.

2.7.1 AIR QUALITY

Airports are "point" sources of air pollutants in that pollutants are emitted from a defined, relatively small area. Aircraft engines, GSE, electric generators, incinerators, fuel farms, shuttle buses, and automobiles all generate air pollutants at airports.

The Clean Air Act of 1970 sets National Ambient Air Quality Standards (NAAQS) for six criteria pollutants and requires states to identify regions where standards are not met. The U.S. Environmental Protection Agency (EPA) designates such regions as nonattainment areas. A state with a nonattainment area must prepare a State Implementation Plan (SIP) that sets forth programs to meet air quality standards by specified deadlines.

The Houston-Galveston-Brazoria region exceeds the NAAQS for ozone, a powerful oxidizer that harms the human respiratory system. The U.S. EPA designates the Houston-Galveston-Brazoria region as a "moderate" nonattainment area for ozone. The major contributors to ozone emissions in the Houston-Galveston-Brazoria region are industries and motor vehicles; each contributes about half of the region's total emissions of ozone precursor pollutants. The Houston-Galveston-Brazoria region meets the NAAQS for the other five criteria pollutants (sulfur oxides, nitrogen oxides, particulate matter greater than 10 microns in size, carbon monoxide, and lead).

The Clean Air Act Amendments of 1990 require federal agencies to ensure that their actions not only conform to SIPs, but also reduce the severity and number of violations of air quality standards and expedite attainment of the standards. Actions funded or approved by the FAA are subject to the General Conformity regulations of the Clean Air Act Amendments. To comply with the General Conformity regulations, projects in nonattainment areas must meet two criteria:

- The project's direct and indirect emissions of air pollutants not attaining national standards must be included in the SIP or be below *de minimis* emissions levels for the nonattainment area, and
- The project's emissions of each air pollutant not attaining the national standard must contribute less than 10 percent of the region's total emissions for that pollutant.

Ellington Airport is in the Houston-Galveston-Brazoria region, which is a nonattainment area for ozone, and, therefore, the General Conformity rules apply to EFD. The current Texas SIP includes Ellington Airport in its budget of air pollutant emissions, but new projects recommended in this Master Plan Update would need to demonstrate compliance with the SIP and be within its emissions budget.

If a project's total annual pollutant emissions (including indirect emissions) would be below *de minimis* levels and would not exceed 10 percent of the region's emissions, it is presumed to conform to the SIP and would not require further air quality analysis. Otherwise, it would require a conformity determination and a detailed pollution assessment, including dispersion analysis.

Few airport projects in nonattainment areas are large enough to require a detailed pollution assessment. However, more and more airport projects in the past decade have required determinations of air quality conformity through an emissions inventory and dispersion analysis.

2.7.2 FLOODPLAINS

Floodplains are areas adjoining inland and coastal waters that are occasionally flooded during rain or storm surge events. The 100-year floodplain is the area that has a 1.0-percent chance of flooding each year. Executive Order 11988, *Floodplain Management*, requires federal agencies to avoid or minimize activities that directly or indirectly result in developing floodplain areas.

The City of Houston is a participant in the National Flood Insurance Program by the Federal Emergency Management Agency (FEMA). FEMA publishes Flood Insurance Rate Maps displaying the 100-year floodplains in and around EFD, as shown on **Exhibit 2-26**. This exhibit shows that the southern part of the airfield is within the 100-year floodplain of Horsepen Bayou, which flows along the southern boundary of EFD.

2.7.3 BIOTIC COMMUNITIES

The unpaved parts of EFD are planted in grasses and mowed regularly. Plant species commonly found in the mowed airfield include St. Augustine grass (*Stenotaphrum secundatum*), Bermuda grass (*Cynodon dactylon*), brushy bluestem (*Andropogon glomeratus*), salt meadow cordgrass (*Spartina patens*) and aster (*Symphyotrichum drummondii*).

An area on Airport property at the northeast end of Runway 4-22 is mowed infrequently and shows characteristics of the native Texas prairie ecosystem: dense perennial grasses, especially brushy bluestem and salt meadow cordgrass, along with dense sod formation. This area also includes several wetlands.

In undeveloped lands off Airport property, scattered woodlots are dominated by sugarberry (*Celtis laevigata*) and Chinese tallow (*Sapium sebiferum*) trees, with water oak (*Quercus nigra*) and pecan trees (*Carya illinoinensis*) present. Old fields are dominated by brownseed paspalum (*Paspalum plicatulum*), Bermuda grass, and herbaceous plants, such as goldenrod (*Solidago canadensis*), and ragweed (*Ambrosia trifida*).

Wildlife seen on the Airport and surrounding areas includes birds, such as house sparrows (*Passer domesticus*), laughing gulls (*Larus atricilla*), and northern harriers (*Circus cyaneus*). Feral pigs have also been seen by Airport staff at EFD.

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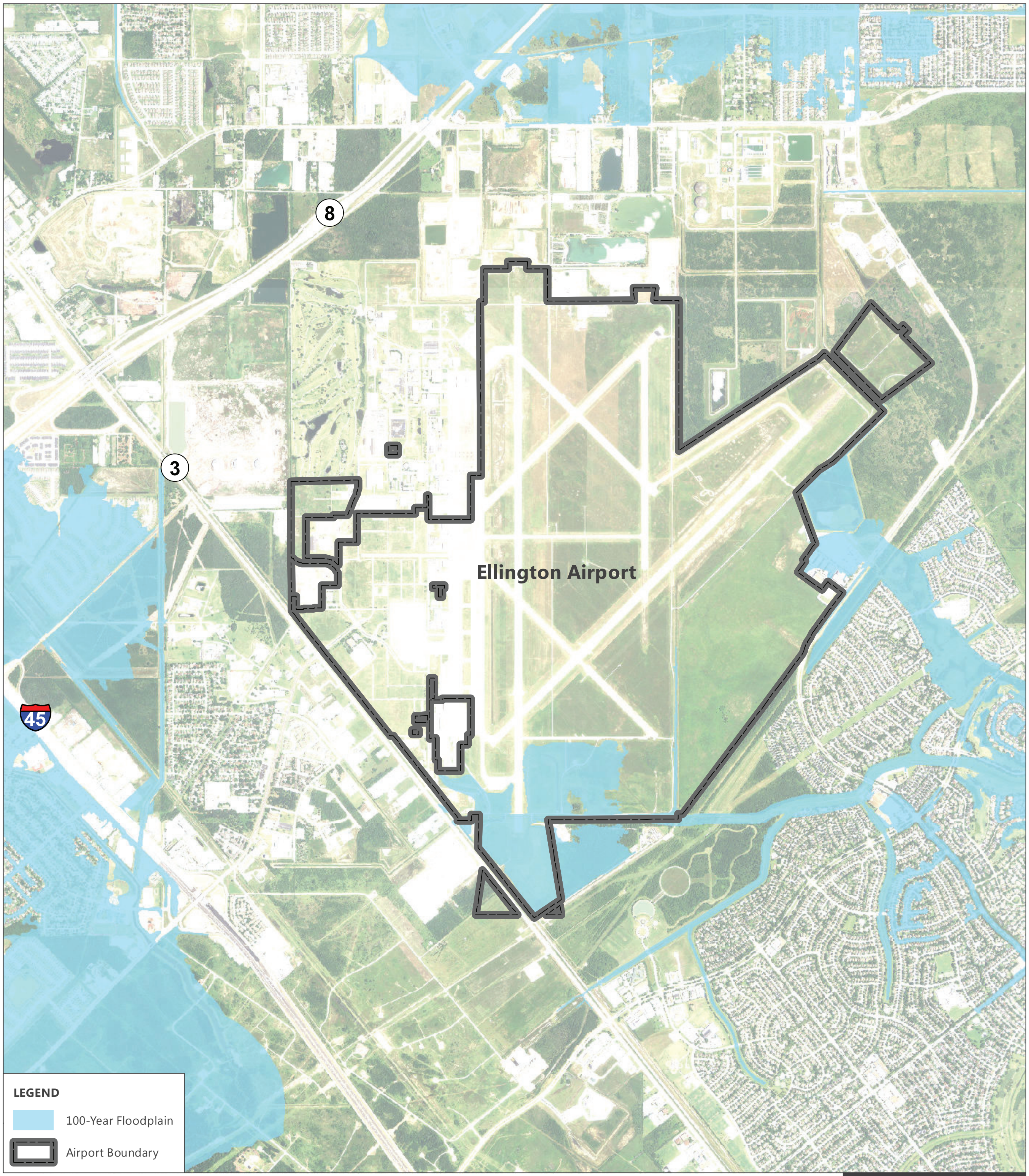

SOURCE: Federal Emergency Management Agency, Flood Insurance Rate Map No. 48201 C 0895L, revised June 18, 2007.
PREPARED BY: Quadrant Consultants Inc., February 2014.

EXHIBIT 2-26

100-Year Floodplain

NORTH

0 2,000 ft.

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2.7.4 WETLANDS

Wetlands are ecosystems that are periodically inundated by surface or groundwater and that typically support the growth of plant species adapted to saturated soil conditions. Wetlands in southeast Texas generally include swamps, marshes, and stream fringes. Executive Order 11990, *Protection of Wetlands*, directs federal agencies to minimize the destruction, loss, or degradation of wetlands on projects that receive federal funding. In addition, waters of the United States, including wetlands adjacent to such waters, or wetlands with a significant physical, chemical, or biological nexus with waters, are protected under the Clean Water Act of 1972 and require a permit from the U.S. Army Corps of Engineers before they may be filled.

Wetlands must meet three criteria:

- Prevalence of hydrophytic plant species,
- Hydric soils, with reducing chemical potentials, and
- Permanent or periodic inundation or saturation during the growing season.

Potential wetlands at EFD were identified on the airfield by interpretation of color infrared photographs, using the distinctive signature of a wet ground surface to indicate the potential presence of wetlands. This method identified over 20 potential wetlands at EFD, which were then checked by a qualified wetland scientist on February 14, 2014, to determine if wetlands were indeed present. Five wetlands were identified on Airport property by inspection of local microtopography, the observed presence of hydrophyte species, and the observed or inferred presence of periodic saturated conditions. **Exhibit 2-27** shows the locations of the five wetlands, which are all marshes with emergent herbaceous vegetation.

2.7.5 ENDANGERED AND THREATENED SPECIES

Endangered species are plant and animal species that are in imminent danger of extinction, while threatened species are likely to become endangered soon. The U.S. Fish and Wildlife Service (FWS) and the Texas Parks and Wildlife Department (TPWD) keep lists of endangered and threatened species; the Texas list also includes species and habitats of concern. **Table 2-18** lists endangered and threatened species, and species of concern, in Harris County, and indicates whether habitats for these species exist at the Airport.

The Texas Natural Diversity Database, maintained by the TPWD, was consulted to determine if endangered species have been seen at EFD in the past. The endangered Houston toad (*Anaxyrus houstonensis*) was seen at EFD until 1973; the species is now believed to be extirpated from Harris County. In addition, the endangered Texas prairie-dawn (*Hymenoxys texana*) was last observed 0.75-mile northeast of the Airport in 2002. Several plant species of concern have been observed within 2.0 miles of EFD: windmill-sedge (*Chloris texensis*) was seen southwest of EFD in 1984, and giant sharpstem umbrella-sedge (*Cyperus cephalanthus*) was seen northeast of EFD in 2001. None of these species has been seen in recent years at EFD, and habitat for these species is not currently observed on the airfield.

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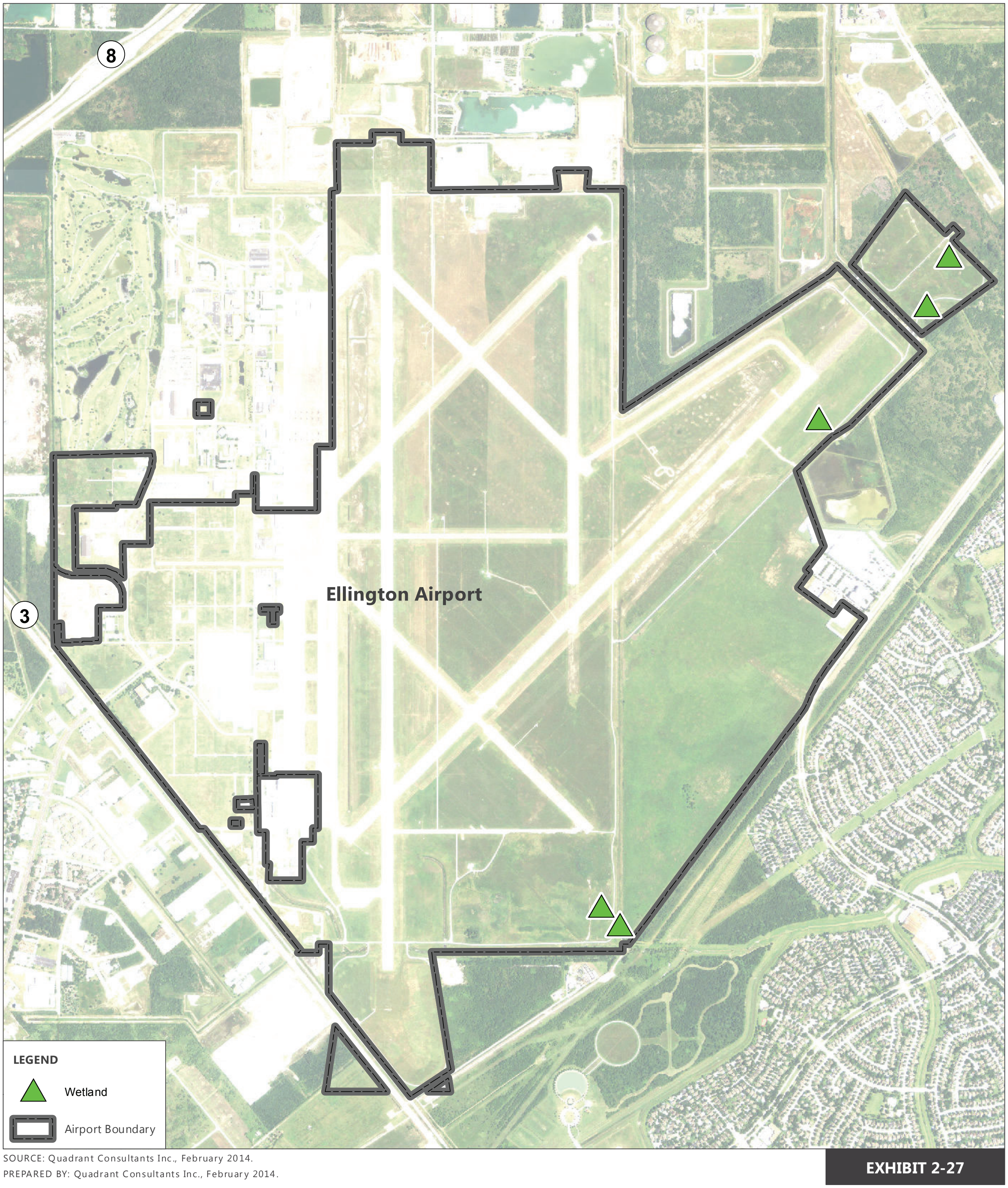

SOURCE: Quadrant Consultants Inc., February 2014.
PREPARED BY: Quadrant Consultants Inc., February 2014.

EXHIBIT 2-27

Wetlands

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Table 2-18 (1 of 3): Endangered and Threatened Species and Species of Concern in Harris County

COMMON NAME	SCIENTIFIC NAME	STATE STATUS	FEDERAL STATUS	HABITAT DESCRIPTION	HABITAT PRESENT?
Amphibians					
Houston toad	*Anaxyrus houstonensis*	E	E†	Sandy soil, breeds in ephemeral pools	No
Birds					
American peregrine falcon	*Falco peregrinus anatum*	T	DM†	Potential migrant, nests in west Texas	No
Arctic peregrine falcon	*Falco peregrinus tundrius*	SOC	DM†	Potential migrant	No
Bald eagle	*Haliaeetus leucocephalus*	T	DM	Near water areas, in tall trees	No
Black rail	*Laterallus jamaicensis*	SOC		Freshwater marshes and grassy swamps	No
Brown pelican	*Pelecanus occidentalis*	E	DM†	Island near coastal areas	No
Henslow's sparrow (wintering)	*Ammodramus henslowii*	SOC	-	Weedy fields, fields with bunch grass, vines, and brambles, needs bare ground	No
Mountain plover	*Charadrius montanus*	SOC	-	Short grass plains and bare dirt (plowed fields)	No
Snowy plover	*Charadrius alexandrinus*	SOC	-	Coastal winter migrant	No
Southeastern snowy plover	*Charadrius alexandrinus tenuirostris*	SOC	-	Winter migrant on Texas coast beaches, bayside mud, or salt flats	No
Red-cockaded woodpecker	*Picoides borealis*	E	E†	Nests in 60+ year pine, forages in 30+ year pine	No
White-faced ibis	*Plegadis chihi*	T	†	Freshwater marshes, but some brackish or salt marshes	No
White-tailed hawk	*Buteo albicaudatus*	T	*	Coastal prairies	No
Whooping crane	*Grus americana*	E	E†	Winters in Aransas National Wildlife Refuge	No
Wood stork	*Mycteria americana*	T	E†	Prairie ponds and flooded pastures	No
Fish					
American eel	*Anguilla rostrata*	SOC	-	Coastal waterways below reservoirs to Gulf	No
Creek chubsucker	*Erimyzon oblongus*	T	*	Variety of small rivers and creeks, prefers headwaters	No
Smalltooth sawfish	*Pristis pectinata*	E	E†	Various water depths	No

Table 2-18 (2 of 3): Endangered and Threatened Species and Species of Concern in Harris County

COMMON NAME	SCIENTIFIC NAME	STATE STATUS	FEDERAL STATUS	HABITAT DESCRIPTION	HABITAT PRESENT?
Mammals					
Louisiana black bear	*Ursus americanus luteolus*	T	T†	Bottomland hardwoods; large, undisturbed forest areas	No
Plains spotted skunk	*Spilogale putorius interrupta*	SOC	†	Wooded, brushy areas and tall-grass prairie	No
Rafinesque's big-eared bat	*Corynorhinus rafinesquii*	T	†	Cavity trees in hardwood forest, concrete culverts, abandoned buildings	No
Red wolf	*Canis rufus*	E	E†	Extirpated, brushy, forested areas, coastal prairies	No
Southeastern myotis bat	*Myotis austroriparius*	SOC	-	Cavity trees in hardwood forest, concrete culverts, abandoned buildings	No
Mollusks					
Little spectacle-case	*Villosa lienosa*	SOC	-	Creeks, rivers, and reservoirs, sandy substrates, slight to moderate currents, along banks in slower currents	No
Louisiana pigtoe	*Pleurobema riddellii*	T	-	Streams and moderate-sized rivers, mud, sand, and gravel	No
Pistol-grip	*Tritogonia verrucosa*	SOC	-	Rock, hard mud, silt, and soft bottoms, often buried deeply	No
Rock pocketbook	*Arcidens confragosus*	SOC	-	Mud, sand, and gravel substrates in standing or slow-flowing water	No
Sandbank pocketbook	*Lampsilis satura*	T	-	Rivers with moderate to swift flows, gravel-sand, and sand	No
Texas pigtoe	*Fusconaia askewi*	T	-	Rivers with mixed mud, sand, and fine gravel in protected areas	No
Wabash pigtoe	*Fusconaia flava*	SOC	-	Creeks to rivers, mud, sand, and gravel, moderate to swift currents	No
Reptiles					
Alligator snapping turtle	*Macrochelys temminckii*	T	*	Deep water of rivers and canals	No
Green sea turtle	*Chelonia mydas*	T	T†	Gulf and bay system	No
Gulf salt marsh snake	*Nerodia clarkii*	SOC	-	Saline flats, coastal bays, and brackish river mouths	No
Kemp's Ridley sea turtle	*Lepidochelys kempii*	E	E†	Gulf and bay system	No

Table 2-18 (3 of 3): Endangered and Threatened Species and Species of Concern in Harris County

COMMON NAME	SCIENTIFIC NAME	STATE STATUS	FEDERAL STATUS	HABITAT DESCRIPTION	HABITAT PRESENT?
Leatherback sea turtle	*Dermochelys coriacea*	E	E†	Gulf and bay system	No
Loggerhead sea turtle	*Caretta caretta*	T	T†	Gulf and bay system	No
Smooth green snake	*Liochlorophis vernalis*	T	*	Gulf coastal prairies, prefers dense vegetation	No
Texas horned lizard	*Phrynosoma cornutum*	T	†	Open, semi-arid regions with bunch grass	No
Timber or canebrake rattlesnake	*Crotalus horridus*	T	*	Swamps and floodplains of hardwood and upland pine	No
Plants					
Coastal gay-feather	*Liatris bracteata*	SOC	-	Coastal prairie grasslands	No
Giant sharpstem umbrella-sedge	*Cyperus cephalanthus*	SOC	-	Deep prairie depressions on saturated, fine sandy loam soils or on heavy black clay	No
Houston daisy	*Rayjacksonia aurea*	SOC	-	Barren, sparsely vegetated saline slicks, pimple mounds, on sandy to sandy loam	No
Texas meadow-rue	*Thalictrum texanum*	SOC	-	Woodland margins on sandy loam, on pimple mounds, clay pan savannahs	No
Texas prairie dawn	*Hymenoxys texana*	E	E	Poorly drained areas in open grasslands; pimple mounds	No
Texas windmill-sedge	*Chloris texensis*	SOC	-	Sandy to sandy loam soils in bare areas	No
Threeflower broomweed	*Thurovia triflora*	SOC	-	Low vegetation, on light colored silt or fine sand over saline clay	No

NOTES:

E = Endangered; T = Threatened; SOC = Species of Concern; DM = Delisted Taxon, Recovered, Being Monitored First 5 Years.

* These species are included on the Texas list of endangered or threatened species, but they are not listed at this time by the U.S. Fish and Wildlife Service.

† These species are listed by the U.S. Fish and Wildlife Service, but they are not listed to occur in Harris County by the Clear Lake (Texas) office of the U.S. Fish and Wildlife Service.

SOURCES: U.S. Fish and Wildlife Service; Texas Parks and Wildlife Department.
PREPARED BY: Quadrant Consultants Inc., 2014.

2.7.6 CULTURAL RESOURCES

Cultural resources include historic (over 50 years old) structures, architecturally important structures, and pre-Columbian archaeological resources. The Texas Historical Commission's *Historic Sites Atlas* shows no site on the National Register of Historic Places, no State Archaeological Landmark, no Official State Historical Marker, and no Recorded Texas Historic Landmark within 1.0 mile of EFD.

2.7.7 DEPARTMENT OF TRANSPORTATION ACT, SECTION 4(F) LANDS

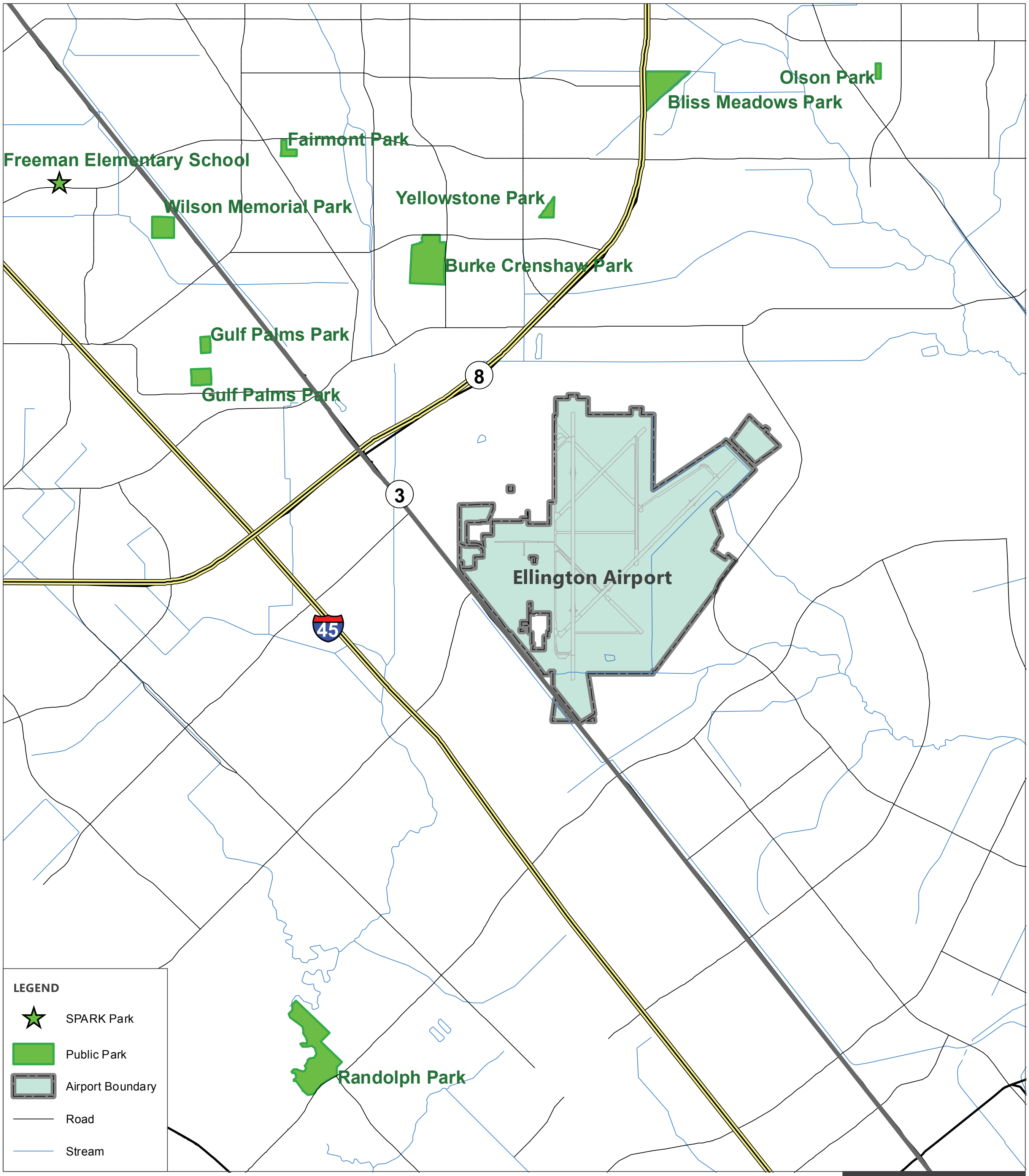
Section 4(f) of the Department of Transportation (DOT) Act of 1966 specifies that transportation projects cannot take land from public parks, historic sites, or wildlife refuges without there first being a determination that no reasonable and prudent alternative exists. A "take" can include physical acquisition of land or sufficient environmental degradation of land (such as from noise, air pollution, or visual intrusion) to make the land unsuitable for its intended use.

Exhibit 2-28 and **Table 2-19** provide the public parks within 3.0 miles of EFD. The table also lists schools within 3.0 miles of EFD with playgrounds that have been designated as SPARK Parks. The SPARK program is a cooperative arrangement between the Houston Independent School District and the City of Houston Department of Parks and Recreation, by which schools open their playgrounds during off-school hours for public use.

Table 2-19: Public Parks and SPARK Parks near Ellington Airport

LAND TYPE	NAME	ADDRESS	DISTANCE FROM EFD (MILES)	DIRECTION FROM EFD
Public Park	Bliss Meadows Park	5900 South Meadow Drive, Pasadena	2	North
Public Park	Burke Crenshaw Park	4950 Burke Road, Pasadena	1	North
Public Park	Gulf Palms Park	11901 Palm Springs Drive, Houston	3	Northwest
Public Park	Randolph Park	5150 FM 2351, Friendswood	3	Southwest
Public Park	Wilson Memorial Park	100 Gilpin Lane, Houston	3	Northwest
Public Park	Fairmont Park	Fairmont Parkway and Allen-Genoa Road, Pasadena	3	Northwest
Public Park	Yellowstone Park	Fairwood Street and Yellowstone Drive, Pasadena	2	North
Public Park	Olson Park	Olson Lane and Janus Road, Pasadena	3	Northeast
SPARK Park	Freeman Elementary School	2323 Theta Street, Houston	2	Northwest

SOURCES: City of Houston, City of Pasadena, Harris County, 2014.
PREPARED BY: Quadrant Consultants Inc., 2014.



SOURCE: City of Houston, City of Pasadena, Harris County, February 2014.
PREPARED BY: Quadrant Consultants Inc., February 2014.

EXHIBIT 2-28

Public Parks and SPARK Parks near Ellington Airport

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2.7.8 SOCIOECONOMIC CONDITIONS/ENVIRONMENTAL JUSTICE

Socioeconomic measures are used to assess the social and economic conditions in a region. Such measures include population and housing statistics, tax revenues, and availability of public services. The U.S. Department of Commerce, Bureau of the Census decennial census provides population characteristics for various geographic entities, including counties, census tracts, block groups, and census blocks. Census tracts subdivide counties, block groups subdivide census tracts, and census blocks subdivide block groups.

Exhibit 2-29 shows the populations of census block groups near EFD from the 2010 Census. The red circles on this exhibit represent the 2010 population of census block groups within census tracts (colored areas); the diameter of each circle is proportional to the population of the census block in which it is placed. The exhibit shows that areas southeast and northwest of EFD have the largest populations, while areas northeast and west of EFD are less populated, and the area to the east is relatively low in population.

Exhibit 2-30 presents the proportions of low-income populations near EFD. Each circle represents 100 percent of the families in a census block group, and the size of the red portion of the circle is the proportion of families whose household incomes are below the poverty limit (as defined by the U.S. Department of Housing and Human Services in 2010). As shown on the exhibit, the proportion of low-income families in block groups around the Airport ranges from near zero to one-third of families. The block groups west and northwest of EFD have higher proportions of low-income families compared with other block groups around EFD.

Exhibit 2-31 shows the proportions of racial minorities (African-American, American Indian, Asian, other, and more than one race) in populations near EFD. The circles inside the census block groups represent the total population of that block group, and the blue portions indicate the proportions of residents who categorize themselves as one or more of the racial populations listed above. This exhibit shows that areas west and northwest of EFD have majorities of racial minorities (more than half of the total population). Areas east and southeast of EFD generally have lower proportions of racial minorities.

Exhibit 2-32 shows the proportions of residents in census block groups near EFD who identified themselves as Hispanic, regardless of race, in the Bureau of the Census *American Community Surveys* from 2007 through 2011. Again, each circle represents the total population of a census block group, and the purple portion represents the Hispanic proportion of the population. This exhibit shows that the highest Hispanic populations reside west and northwest of EFD, some with majority Hispanic populations. Areas south, southeast, and east of EFD have smaller Hispanic populations, generally between 10 and 25 percent.

A comparison of Exhibits 2-31 and 2-32 shows that the population within 3.0 miles of EFD includes substantial proportions of racial and ethnic minorities and low-income families below the poverty level. Some Master Plan Update recommendations (such as property acquisition and runway extensions) could, therefore, affect minority or low-income populations disproportionately, and an environmental justice assessment would be appropriate during the planning process for specific EFD projects.

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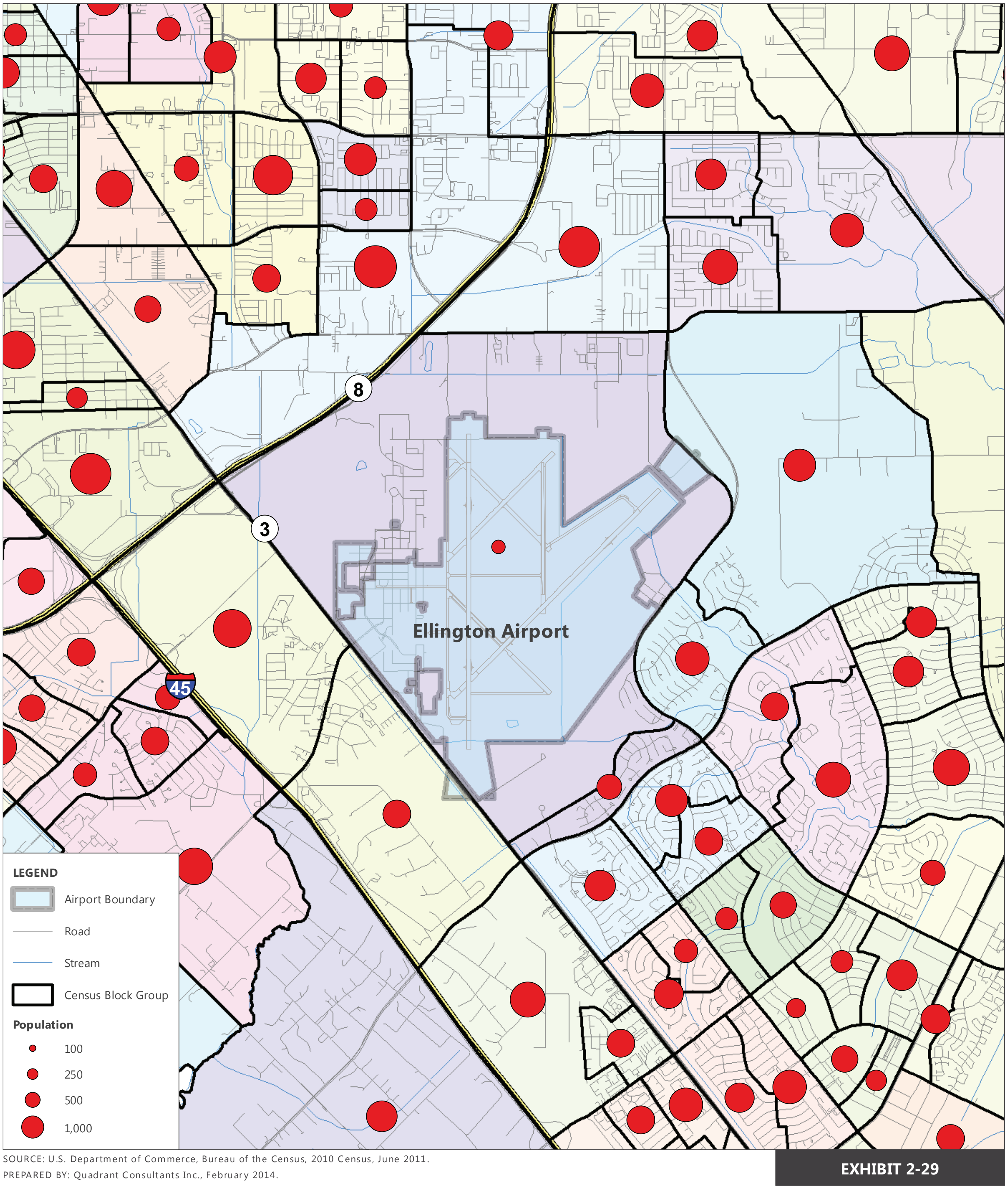

SOURCE: U.S. Department of Commerce, Bureau of the Census, 2010 Census, June 2011.
PREPARED BY: Quadrant Consultants Inc., February 2014.

EXHIBIT 2-29

Population of Census Block Groups near Ellington Airport

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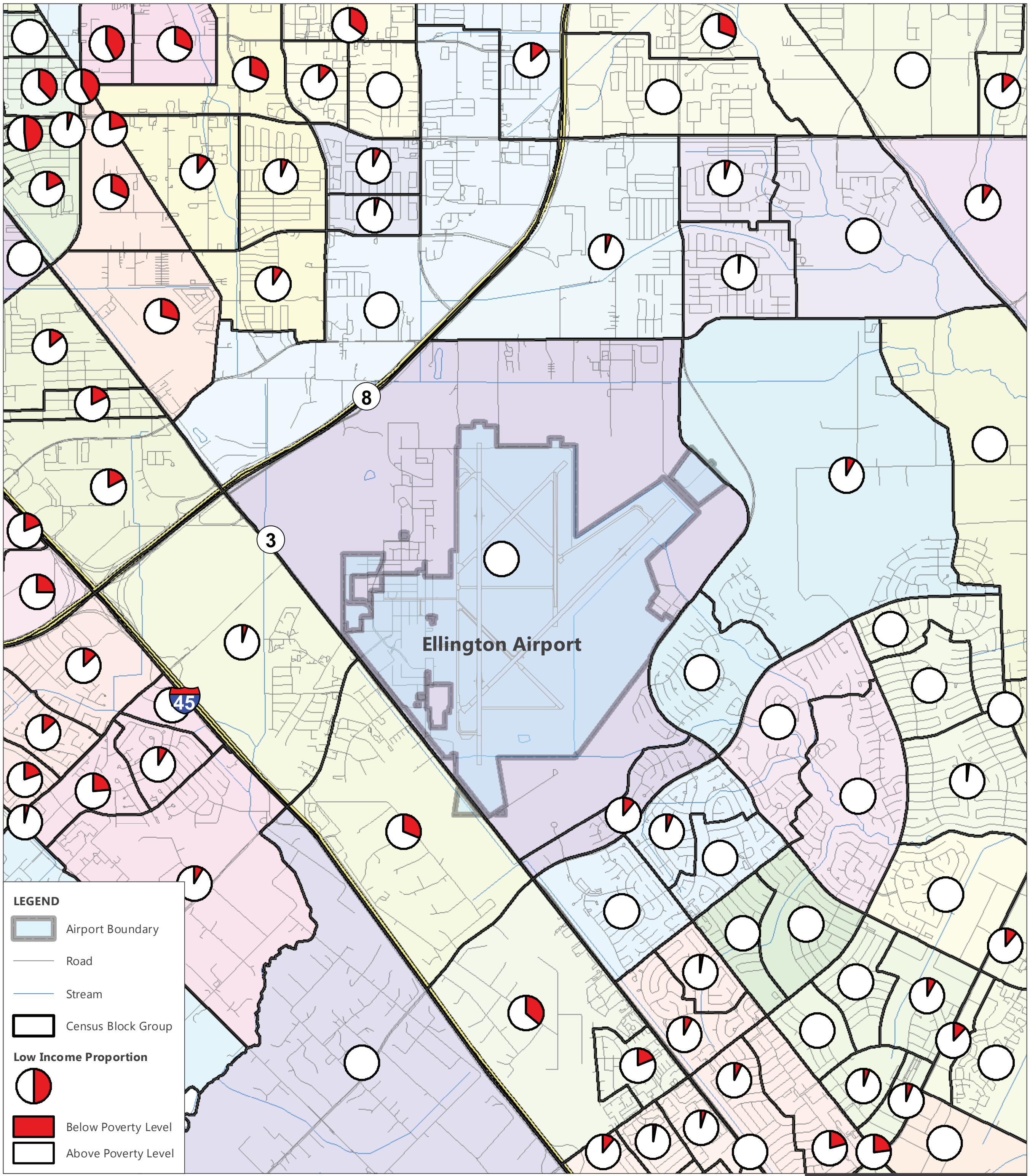

SOURCE: U.S. Department of Commerce, Bureau of the Census, 2007-2011 American Community Survey, June 2012.
PREPARED BY: Quadrant Consultants Inc., February 2014.

EXHIBIT 2-30

Proportions of Low Income Families in Census Block Groups near Ellington Airport

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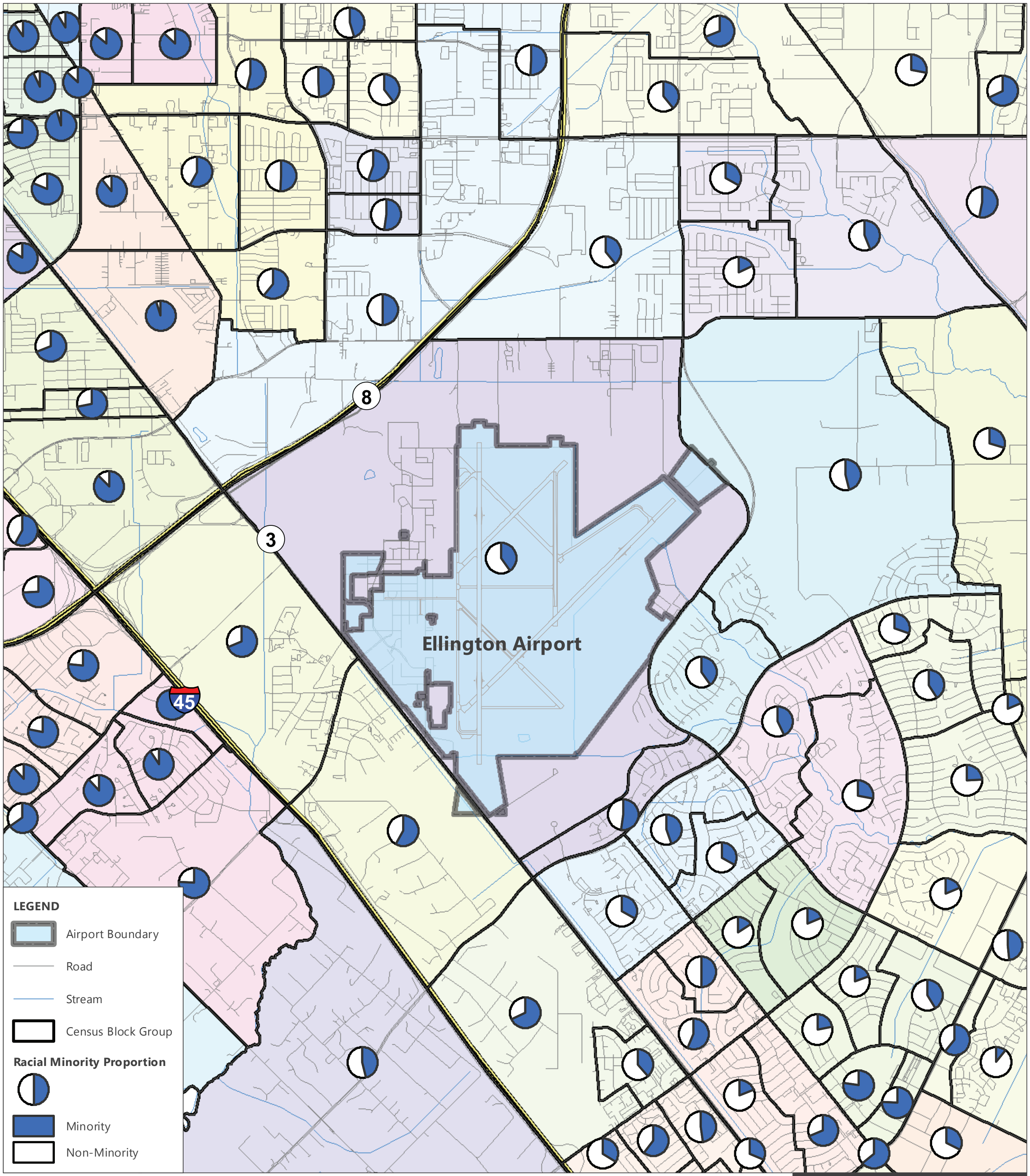

SOURCE: U.S. Department of Commerce, Bureau of the Census, 2007-2011 American Community Survey, June 2012.
PREPARED BY: Quadrant Consultants Inc., February 2014.

EXHIBIT 2-31

Proportions of Racial Minorities in Census Block Groups near Ellington Airport

NORTH 0 5,000 ft.

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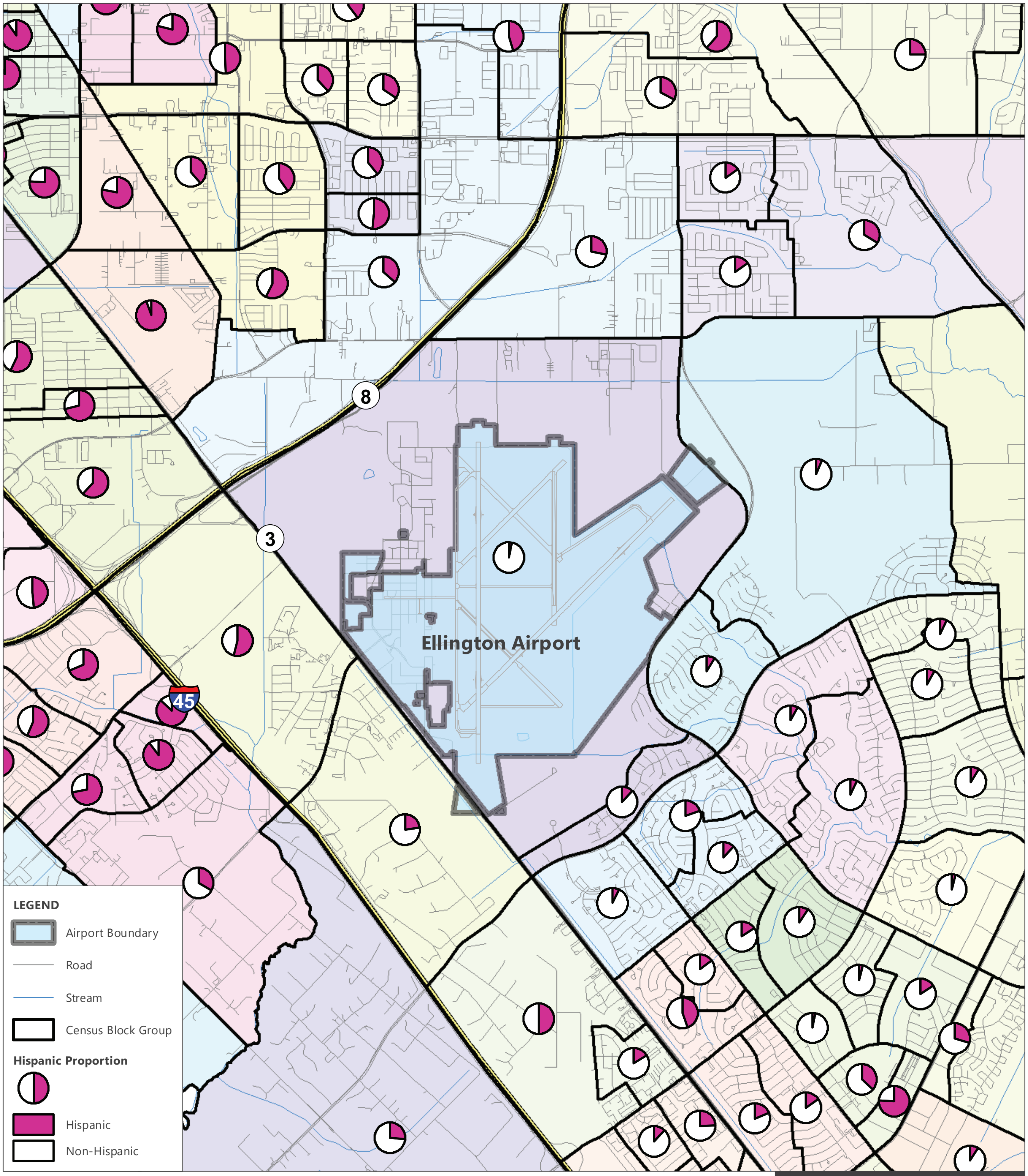

SOURCE: U.S. Department of Commerce, Bureau of the Census, 2007-2011 American Community Survey, June 2012.
PREPARED BY: Quadrant Consultants Inc., February 2014.

EXHIBIT 2-32

Proportions of Hispanic People in Census Block Groups near Ellington Airport

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2.7.9 HAZARDOUS MATERIALS

Databases maintained by the U.S. EPA and Texas Commission on Environmental Quality (TCEQ) to track hazardous materials and sites with hazardous contamination were searched on February 6, 2014, for potential sites within standard radii of the Airport (**Table 2-20**). This search was performed in accordance with Practice E1527-05 of the American Society of Testing and Materials, pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA, also referred to as Superfund) and the Resource Conservation and Recovery Act (RCRA) of 1976. The regulatory databases show 75 mapped sites within standard radii that could be potential sources of contamination at EFD.

2.7.9.1 CERCLIS Sites: No Further Remedial Action Planned

Two sites are listed in the Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS) as "No Further Remedial Action Planned." Such sites were removed from CERCLIS after an initial investigation because no contamination was found, or contamination that was found was quickly removed, or the severity of contamination was found to be insufficient to warrant listing.

- Ellington Air Force Base (EPA ID No. TX4570090007) was initially discovered in May 1982, assessed in April 1988, and archived that same month. The site was reassessed in December 2000. The record provides no details as to the type or source of suspected contamination. As this site was removed from CERCLIS after investigation, it appears to be insufficiently contaminated to be a threat to development at EFD. Site-specific studies may be warranted for individual projects.
- Hughes Landfill (EPA ID No. TXD980514970) was initially listed in CERCLIS in November 1979 and assessed in January 1980. The site was inspected in October 1984 and the site listing was archived in August 1994. This site is 0.5 mile north of the Airport. It is also listed in the Texas Disposal Sites and Landfills database. The site was reported to be a landfill for brush and construction waste materials. Currently, this site is under post-closure care. The Closed Landfill Inventory maintained by the Houston-Galveston Area Council also shows that this site is a landfill site for construction waste and brush. As this site does not handle hazardous waste and is under post-closure care, contamination of the Airport from this site is not likely.

2.7.9.2 RCRA Hazardous Waste Generators

Five RCRA hazardous waste generator sites are within 0.25 mile of the Airport:

- Ellington Field Joint Reserve Base, TxANG, 1057 Ellington Field (EPA ID No. TX1572824067) is a small-quantity generator of hazardous waste. This site is reported to have had two violations. One violation was found on March 14, 1992, and was resolved on June 16, 1992. The other violation was found on May 4, 2001, and was resolved on May 18, 2001. This site does not pose a threat of contamination to the Airport.
- United Parcel Service Ellington, 12012 Blume Avenue (EPA ID No. TXD988089207) was a conditionally exempt small-quantity generator of hazardous waste. The U.S. EPA reports no violations at this site. This site does not pose a threat of contamination to the Airport.

Table 2-20: Potential Hazardous Materials Sites near Ellington Airport

DATABASE SEARCHED	AGENCY	VICINITY SEARCH RADIUS (MILES)	SITES IN SEARCH RADIUS
National Priority List (Superfund) Sites	U.S. EPA	1 mile	0
State-listed Superfund Sites	TCEQ	1 mile	1
Delisted National Priority List Sites	U.S. EPA	0.5 mile	1
CERCLIS Contaminated Sites	U.S. EPA	0.5 mile	0
State-listed Contaminated Sites	TCEQ	0.5 mile	0
CERCLIS Sites, No Further Remedial Action Planned	U.S. EPA	0.5 mile	2
RCRA Waste Generator Corrective Action Sites	U.S. EPA	1 mile	0
State-listed Disposal or Landfill Sites	TCEQ	0.5 mile	3
RCRA Waste Treatment, Storage, and Disposal Sites	U.S. EPA	0.5 mile	0
RCRA Hazardous Waste Generators	U.S. EPA	0.25 mile	5
Other RCRA Sites	U.S. EPA	0.5 mile	8
State-listed Hazardous Waste Generators	TCEQ	0.25 mile	0
State-listed Hazardous Materials Sites	TCEQ	0.25 mile	14
Federal Brownfield Sites	U.S. EPA	0.5 mile	0
State Brownfield Sites	TCEQ	0.5 mile	0
Federal Institutional Control Sites	U.S. EPA	0.5 mile	0
State-listed Institutional Control Sites	TCEQ	0.25 mile	0
Federal Engineering Control Sites	U.S. EPA	0.5 mile	1
State-listed Engineering Control Sites	TCEQ	0.5 mile	0
Voluntary Cleanup Sites	TCEQ	0.5 mile	0
Emergency Response Notification System Sites	U.S. EPA	0.25 mile	11
Leaking Petroleum Storage Tank Sites	TCEQ	0.5 mile	13
Registered Petroleum Storage Tank Sites	TCEQ	0.25 mile	16
Dry Cleaners	TCEQ	0.25 mile	0

NOTES:

CERCLIS = Comprehensive Environmental Response, Compensation, and Liability Information System;

EPA = Environmental Protection Agency;

RCRA = Resource Conservation and Recovery Act;

TCEQ = Texas Commission on Environmental Quality.

SOURCE: Banks Environmental Data *Regulatory Database Report*, February 6, 2014.
PREPARED BY: Quadrant Consultants Inc., 2014.

- Boeing Building 91–05, 13150 Space Center Boulevard (EPA ID No. TXR000043927) is a small-quantity generator of hazardous waste. The U.S. EPA reports no violations at this site. This site does not pose a threat of contamination to the Airport.
- Thin Film Technology Inc., 12430 Galveston Road (EPA ID No. TXR000042820) is a conditionally exempt small-quantity generator of hazardous waste. The U.S. EPA reports no violations at this site. This site does not pose a threat of contamination to the Airport.
- ExxonMobil Upstream Research, 300 Old Choate Road (EPA ID No. TXD000783399) is a small-quantity generator of hazardous waste. The U.S. EPA reports no violations at this site. This site does not pose a threat of contamination to the Airport.

2.7.9.3 Emergency Response Notification System Sites

Eleven Emergency Response Notification System sites are located within 0.25 mile of the Airport:

- TxANG, 147th Fighter Wing (NRC Report 650544). Hydrazine was reportedly spilled onto a concrete surface on July 10, 2003, as a result of F-16 aircraft equipment failure. Absorbents were applied as remedial action. This site does not pose a threat of contamination to the Airport.
- TxANG, 14657 Snider Street (NRC Report 844133). Hydraulic oil reportedly leaked to the storm water drain on August 1, 2007, as a result of equipment failure. Surface water was affected. Clean up remedial action was taken. This site does not pose a threat of contamination to the Airport.
- U.S. Coast Guard Air Station Houston, 1178 Ellington Field (NRC Report 794683). On April 21, 2006, a metal line from a fuel truck broke and released jet fuel to the concrete apron. A spill kit and absorbent pads were used for cleanup, and the cleanup was completed. This site does not pose a threat of contamination to the Airport.
- U.S. Coast Guard Air Station Houston, 1178 Ellington Field (NRC Report 220159). On February 4, 1994, an underground storage tank heating line broke and leaked oil and fuel to the soil subsurface. The affected soil was removed. This site is unlikely to pose a present threat of contamination to the Airport.
- Ellington Airport (NRC Report 911654). On June 30, 2009, a bus bringing prisoners from local prisons to the Airport spilled raw sewage into the storm drains on Airport property. Surface waters were affected. Although this is the only record of such pollution, the bus operator indicated that such spills are common. Raw sewage is a biohazard, but it is not regulated as a hazardous material under CERCLA. It is likely that the sewage was flushed from the Airport's storm sewer system into surface waters, and it is not likely that the spill poses any further threat of contamination to the Airport.
- South Coast Construction, 13150 Space Center Boulevard (NRC Report 965015), was reported to have released 75 to 100 gallons of diluted oil-based paint into the storm drain on January 18, 2011, as a result of operator error. Surface water was affected and was cleaned up by the responsible party. This site is down-gradient and about 0.02 mile east of the Airport. The affected storm water with diluted oil probably flowed north to a detention pond, which drained southeast through a ditch crossing Space Center Boulevard and eventually flowed to Horsepen Bayou, all off Airport property. Therefore, this site does not pose a threat of contamination to the Airport.

- Grumman Houston Corporation, 12130 Galveston Road (NRC Report 32706), was reported to have spilled waste-stripping solution on a concrete surface on July 23, 1990, as a result of equipment failure. Sorbents were used in the leak area and the spill was cleaned. This site does not pose a threat of contamination to the Airport.
- ExxonMobil, 301 Old Choate Road (NRC Report 638055), was reported to have spilled salt water and oil into a ditch on February 28, 2003, as a result of equipment failure. Surface water was affected. The area was isolated and cleaned up. This site does not pose a threat of contamination to the Airport.
- ExxonMobil, 301 Old Choate Road (NRC Report 568910). On June 9, 2001, oil flowed from a pit at a truck washing station to a stream as a result of heavy rains raising the level in the pit and causing sheen. Surface water was affected. The released oil was cleaned up with a suction cleaner. This site does not pose a threat of contamination to the Airport.
- ExxonMobil, 350 Old Choate Road (NRC Report 85561). Crude oil spilled into Turkey Creek on August 26, 1991, as a result of equipment failure. Water was affected. Remedial action was taken. The valve was shut off and the spill was contained by oil trap. This site does not pose a threat of contamination to the Airport.
- ExxonMobil, 350 Old Choate Road (NRC Report 90210). On September 29, 1991, a corroded pipeline spilled crude oil to Turkey Creek. Surface water was affected. A boom was used to contain the spill. This site does not pose a threat of contamination to the Airport.

2.7.9.4 Registered Petroleum Storage Tanks Sites

There are 16 sites with registered underground storage tanks containing petroleum products within 0.25 mile of Airport property. These storage tanks are either in use without any reported violation, or were removed from the ground. Therefore, these sites do not pose a threat of contamination to the Airport.

2.7.9.5 Leaking Underground Petroleum Storage Tanks

Thirteen leaking underground petroleum storage tanks are listed in the database search:

- TxANG, 1057 Ellington Field (TCEQ No. 107912). This site had 17 underground tanks. Eleven of the tanks were removed, and six tanks remain in use. Tanks were found to be leaking on January 20, 1994. Soil was affected, but the contamination did not affect any receptor. This site was completely remediated and TCEQ has closed the case. This site does not pose a threat of contamination to the Airport.
- TxANG, 147th Reconnaissance Wing, Ellington Field (TCEQ No. 118260). On November 18, 2009, this site was found to have a leaking tank. Groundwater was not affected, and there is no apparent threat or impact to any receptor. Final concurrence has been issued for this site and TCEQ has closed the case. This site does not pose a threat of contamination to the Airport.
- U.S. Coast Guard Air Station Houston, 1178 Ellington Field (TCEQ No. 107940). On February 4, 1994, this site was found to have a leaking underground oil-water separator. Groundwater was affected, but the contamination did not affect any receptor. The site was completely remediated and TCEQ has closed the case. This site does not pose a threat of contamination to the Airport.

- Landmark Aviation, 12704 McLoughlin Street (TCEQ No. 116650). On January 21, 2005, this site was found to have a leaking tank. Groundwater was not affected, and there are no apparent threats or impacts to any receptors. Final concurrence has been issued for this site and TCEQ has closed the case. Therefore, this site does not pose a threat of contamination to the Airport.
- Petroleum Oils Lubricants Storage, Ellington Field, TxANG 147th Group (TCEQ No. 099849). This site had 17 tanks, 11 were removed and 6 remain in use. This site was found to have a leaking tank on January 4, 1991. Groundwater was affected. This site was completely remediated and TCEQ has closed the case. This site does not pose a threat of contamination to the Airport.
- Ellington Air Force Base, Kirk Avenue (TCEQ No. 107056). This site had one underground diesel tank that was found to be leaking on August 3, 1993. Groundwater was not affected, and the contamination did not affect any receptor. The tank was removed from ground, final concurrence has been issued for this site, and TCEQ has closed the case. This site does not pose a threat of contamination to the Airport.
- Ellington Field, 510 Ellington Field (TCEQ No. 108463). This site had 29 tanks, 23 were removed and 6 remain in use. This site was found to have a leaking tank on July 12, 1994. Groundwater was not affected, and the contamination did not affect any receptor. The site was completely remediated and TCEQ has closed the case. This site does not pose a threat of contamination to the Airport.
- Ellington Field, 510 Ellington Field and 12501 Goodwin (TCEQ No. 108466). On July 12, 1994, this site was found to have a leaking tank. Groundwater was not affected, and the contamination did not affect any receptor. The site was completely remediated and TCEQ has closed the case. This site does not pose a threat of contamination to the Airport.
- Ellington Field, 510 Boone Street at Perrie Street (TCEQ No. 093163). On June 5, 1989, this site was found to have a leaking tank. Groundwater was not affected, and the contamination did not affect any receptor. The site was completely remediated and TCEQ has closed the case. This site does not pose a threat of contamination to the Airport.
- Former Humble Oil 6 7711, 11902 Old Galveston Road at Dixie Farm Road (TCEQ No. 117285). On March 12, 2007, this site was found to have a leaking tank. Groundwater was affected, but the contamination did not affect any receptor. The tank was removed, the site was completely remediated, and TCEQ has closed the case. This site does not pose a threat of contamination to the Airport.
- Grumman Houston Building 2, 12130 Old Galveston Road (TCEQ No. 116979). On August 7, 2006, two underground tanks at this site were found to be leaking. Groundwater was affected, but the contamination did not affect any receptor. The tanks were removed, the site was completely remediated, and TCEQ has closed the case. This site does not pose a threat of contamination to the Airport.
- Martin Transfer & Storage, 333 Tristar Drive (TCEQ No. 107865). On February 18, 1994, two underground storage tanks at this site were found to be leaking. Soil was affected, but the contamination did not affect any receptor. The tanks were removed, the site was completely remediated, and TCEQ has closed the case. This site does not pose a threat of contamination to the Airport.

- Schlumberger Offshore Services, 369 Tristar Drive (TCEQ No. 093207). On June 6, 1989, two underground storage tanks at this site were found to be leaking. Soil was contaminated and required a full site assessment. All tanks were removed from ground. The site was completely remediated and TCEQ has closed the case. Therefore, it is unlikely that this site would pose a threat of contamination to the Airport.

2.7.9.6 State-Listed Superfund Sites

One State Equivalent National Priority List site is within 1 mile of the Airport: Harris Landfill, Farley Street, southeast Houston (TCEQ No. RN105167050). This site has been inactive since April 18, 1988. Cleanup was completed and no further action is required. This site does not pose a threat of contamination to the Airport.

2.7.9.7 State-Listed Disposal or Landfill Sites

Three waste disposal sites or landfills are listed within 0.5 mile of the Airport in the database search:

- Hughes Sand Pits, Inc., 2122 Genoa Red Bluff Road (TCEQ No. RN101999878). This site is a landfill for brush and construction demolition materials, located 0.5 mile north of the Airport. It appears to be the same site as listed above under CERCLIS Sites: No Further Remedial Action Planned. The permit for this site was issued on September 22, 1975. Currently, this landfill is closed and is under post-closure care. This landfill did not accept hazardous materials and it does not pose a threat of contamination to the Airport.
- Hughes Sand Pits Landfill, 2200 feet south of Genoa Red Bluff Road (TCEQ No. CN600582779) appears to be a planned extension of the above landfill, 0.25 mile north of the Airport. The extension was not constructed and the permit was withdrawn. This site does not pose a threat of contamination to the Airport.
- Delbert T. Walker Landfill, southeast intersection of Genoa Red Bluff Road and Grayson Lane (TCEQ No. CN601538606) was planned as a landfill for brush and construction demolition materials. This landfill was not constructed and the permit was withdrawn. This site does not pose a threat of contamination to the Airport.

2.7.9.8 Other RCRA Sites

Eight sites are listed as “other RCRA sites” because they are not classifiable as “treatment, storage, disposal of hazardous material,” “hazardous waste generator,” or “corrective action.”

- Continental Express, 11401 Blume Avenue (EPA No. TXD988071817) is confirmed by the TCEQ to be free of hazardous contamination. The site has no reported violations and does not pose a threat of contamination to the Airport.
- U.S. Coast Guard Air Station, 1178 Ellington Field, Building 388 (EPA No. TX6690324607) is confirmed by the TCEQ to be free of hazardous contamination. The site has no reported violations and does not pose a threat of contamination to the Airport.
- Air BP, Ellington Field, Building 493, Landmark Aviation (EPA No. TXD987993110) is confirmed by the TCEQ to be free of hazardous contamination. The site has no reported violations and does not pose a threat of contamination to the Airport.

- McDonnell Douglas Aerospace, 13000 Space Center Boulevard (EPA No. TXD987992336) is confirmed by the TCEQ to be free of hazardous contamination. The site has no reported violations and does not pose a threat of contamination to the Airport.
- Pall Corporation, 12130 Galveston Road (EPA No. TXD072180565) is confirmed by the TCEQ to be free of hazardous contamination. One violation was reported on June 12, 1986, which was resolved on August 14, 1986. The site does not pose a threat of contamination to the Airport.
- Auto Center of Clear Lake, 12722 Galveston Road, Suite J (EPA No. TX0000104539) is confirmed by the TCEQ to be free of hazardous contamination. The site has no reported violations and does not pose a threat of contamination to the Airport.
- Ellington Field, 363 Ellington Field (EPA No. TXD981057946) is confirmed by the TCEQ to be free of hazardous contamination. This site has no reported violations and does not pose a threat of contamination to the Airport.
- ExxonMobil Corporation, 301 Old Choate Road (EPA No. TXD988022182) is confirmed by the TCEQ to be free of hazardous contamination. This site is reported to have no violations and does not pose a threat of contamination to the Airport.

2.7.9.9 Federal Engineer Control Site

One Federal Engineer Control Site is located within 0.5 mile of the Airport: a site 1,000 feet south of Genoa Red Bluff Road (EPA No. TXD980745582) has affected soil and groundwater. Soil was excavated and groundwater was monitored under federal engineer controls. Site assessment was completed in 1985. This site does not appear to pose a threat of contamination to the Airport.

2.7.9.10 State-Listed Hazardous Materials Sites

Fourteen Texas hazardous waste sites are located within 0.25 mile of the Airport. Nine of these sites are inactive, one is merged, and the remaining four are currently active. None of these sites appears to be a potential source of contamination to the Airport.

2.7.9.11 Oil and Gas Wells

The Texas Railroad Commission database of oil and gas wells lists 38 wells within 0.5 mile of the Airport, part of the Friendswood Oil and Gas Field owned by ExxonMobil. The oil field was developed in the 1950s and 1960s. Thirty-two wells are currently plugged or abandoned, five are south of the Airport, and one is 0.5 mile east of the Airport. All six open wells are down-gradient of the Airport and, therefore, would not pose a threat of contamination to the Airport. In addition, no pit for oil or drilling fluids was observed adjacent to the Airport. Therefore, these oil and gas wells are not likely to be sources of contamination to the Airport.

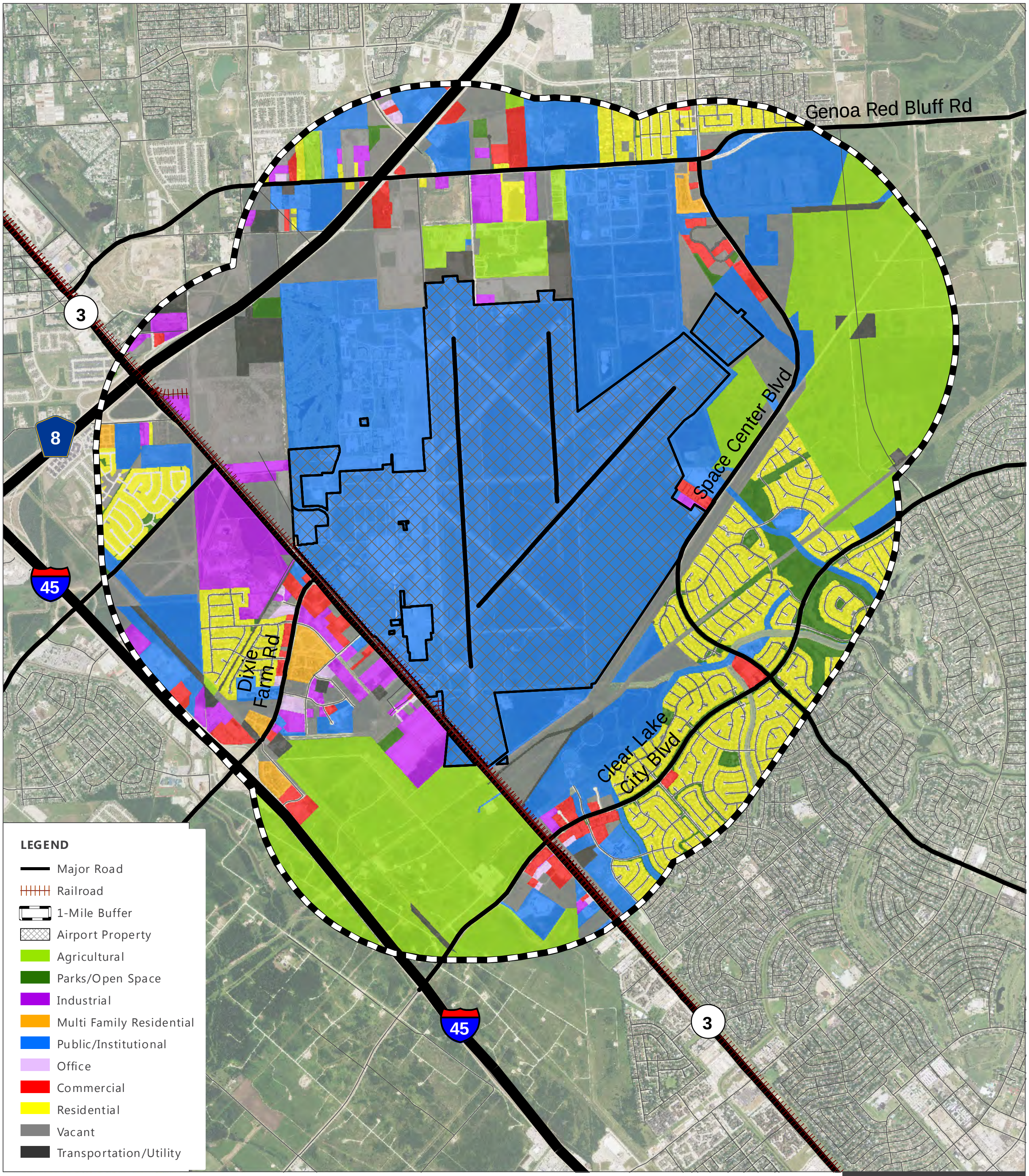
2.8 Land Use Compatibility

The development of land uses that are not compatible with airports or aircraft noise is a major concern across the country. In addition to aircraft noise, other issues, such as safety and other environmental impacts on land use around airports, need to be considered when addressing the overall issue of land use compatibility. Although several federal grant-in-aid programs include noise standards or guidelines as part of their funding eligibility and performance criteria, the primary responsibility for integrating airport considerations into the local land use planning process rests with local governments. The objectives of compatible land use planning are to encourage land uses that are generally considered to be incompatible with airports (such as residences, schools, and churches) to locate away from airports and to encourage land uses that are more compatible (such as industrial and commercial uses) to locate around airports. The FAA actively supports programs to minimize aircraft noise impacts in airport environs.

To implement effective land use planning and control measures around airports, it is necessary to identify specific planning boundaries. These boundaries define the airport environs for land use planning purposes. It is essential that airport owners/operators, elected officials, land use planners, and developers understand the components of an effective compatible airport land use plan. A land use plan incorporates federal and state airport design criteria, flight safety requirements, and land use provisions unique to the community. HAS recommends that safety zones, standard traffic patterns, overflight areas, noise contours, and 14 CFR Part 77 height restriction criteria be considered as "building blocks" by land use planners when developing zoning ordinances, airport overlay districts, and comprehensive land use plans for their communities.

Exhibit 2-33 illustrates the existing land uses in the Airport vicinity. **Table 2-21** lists the land use classifications within a 3-mile buffer around the Airport boundary. It should be noted that the primary land use around Ellington Airport is residential (88.0 percent), followed by vacant properties (4.2 percent) and commercial development (3.7 percent). The vacant/undetermined parcels are a cost efficient alternative for procurement and provide HAS an opportunity to control the development in terms of types of permissible land use, height restrictions, and the ability to not develop the parcel to remain compatible with future Airport expansion plans.

In addition to the effects of noise on land use compatibility, the FAA also assesses the compatibility of land uses in the vicinity of an airport to ensure that those uses do not adversely affect safe aircraft operations. The Houston City Council passed Chapter 9 of the Code of Ordinances, Houston, Texas, "Airport Hazard Area Regulations Ordinance" on December 16, 2009, and it became effective on March 1, 2010. This ordinance made it unlawful to create or maintain any electronic emission, visual effect, or other object or activity in an airport hazard area that adversely affects the operation of aircraft. The ordinance also made it unlawful to plant or permit to grow any object of natural growth whose typical height at maturity will penetrate any airport hazard notification surface (see **Table 2-22**).



SOURCE: Houston-Galveston Area Council, Harris County Appraisal District 2012, Houston Airport System 2013.
PREPARED BY: UrbanCore Collaborative, Inc. and Knudson, LP, February 2014.

EXHIBIT 2-33

Existing Land Use
in the Airport Vicinity

NORTH

0 4,000 ft.

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Table 2-21: Land Use Classifications

LAND USE TYPE	PERCENTAGE OF TOTAL	NUMBER OF PARCELS	TOTAL (SQUARE FEET)	TOTAL (ACRES)
Missing data	0.8%	368	--	32
Agricultural	0.3%	171	1,600	5,362
Residential	88.0%	39,718	81,080,503	11,209
Multifamily	0.4%	205	18,205,766	980
Industrial	1.1%	498	9,370,303	2,388
Office	0.4%	199	3,704,476	320
Commercial	3.7%	1,654	12,292,094	5,409
Public/Institutional	0.5%	214	3,038,858	4,089
No Data/Public Right-of-Way	0.1%	25	--	44
Vacant/Undetermined	4.2%	1,889	15,632	18,075
Transportation/Utilities	0.9%	376	67,436	988

NOTE: TOTALS MAY NOT ADD TO 100% DUE TO ROUNDING.

SOURCE: Harris County Appraisal District, May 2012.
PREPARED BY: UrbanCore Collaborative, Inc., August 2012.

Table 2-22: Applicable Statutes and Implementing Regulations

APPLICABLE STATUTES AND IMPLEMENTING REGULATIONS	SUMMARY DESCRIPTION	OVERSIGHT AGENCY
49 United States Code (USC) Section 47106(a)(1) (Airport Improvement – Project grant application approval conditioned on satisfying project requirements)	Under this section, the Secretary of Transportation (the Secretary) may approve an application for a project grant only if the project is consistent with the plans (existing when FAA approves the project) of public agencies authorized by the state to plan for development of the area surrounding the airport.	FAA
49 USC Section 47107(a)(10) (Airport Improvement – Project grant application approval conditioned on assurances on airport operations)	For airport actions, the Compatible Land Use chapter of the environmental document must include documentation to support the required airport sponsor's assurance under this section. That assurance must state that appropriate action, including adopting zoning laws, has been or will be taken to the extent reasonable. Such actions are needed to restrict the use of land adjacent to or in the immediate vicinity of the airport to activities and purposes compatible with normal airport operations, including the landing and takeoff of aircraft. The assurance must be related to existing and planned land uses.	FAA
49 USC Sections 47501 to 47510 (Noise Abatement) 14 CFR Part 150	These sections require the Secretary to: • establish a single system showing a highly reliable relationship between projected noise and surveyed reactions of individuals to noise; • establish a single system to determine the reaction of individuals (at or near airports) to noise resulting from airport operations; and • identify land uses that are normally compatible with various exposures of individuals to noise levels. Regulations at 14 Code of Federal Regulations (CFR) Part 150 provide this information.	FAA
49 USC Section 44718, Subsection (d) (Limitation on Landfill Construction)	Birds attracted to municipal solid waste landfill facilities (MSWLF) near airports pose aviation hazards. MSWLFs built after Congress enacted Public Law 106-181 (April 5, 2000) cannot be located within 6 miles of a public airport: • receiving Airport Improvement Program (AIP) grants; • chiefly serving general aviation aircraft; and • chiefly having regularly scheduled flights of aircraft with 60 seats or less. Note: The State of Alaska is exempt from this requirement.	FAA
40 CFR Section 258.10 (Criteria for Municipal Solid Waste Landfills; Airport Safety)	The Environmental Protection Agency recognizes that MSWLFs often attract large numbers of birds because these facilities provide food and cover. As a result, birds using MSWLFs could cause potential threats to aircraft safety. This regulation requires the following minimum separations between the airport and MSWLF: • 5,000 feet for airports serving piston-powered aircraft; or • 10,000 feet for airports serving turbine-powered aircraft. In addition, the owner/operator of a new MSWLF within a 5-statute mile radius of any airport runway serving either aircraft type has certain duties. The owner/operator must: • notify the airport and FAA of the proposal; and • show and have proof in its operating manual that the MSWLF's design and use will not pose aviation hazards.	FAA
Interagency Memorandum of Agreement (MOA) of July 2003 addressing wildlife hazards and airports	FAA, the U.S. Air Force (USAF), U.S Army Corps of Engineers (ACE), U.S. EPA, U.S. Fish and Wildlife Service (FWS), and the Department of Agriculture Wildlife Services (WS) signed this MOA. The MOA provides guidelines to these agencies on how they will cooperatively address wildlife habitats near public use airports.	FAA, USAF, ACE, EPA, FWS, and WS

SOURCE: Federal Aviation Administration, *Airport Desk Reference*, Chapter 5, "Compatible Land Use," October 2007.
PREPARED BY: Ricondo & Associates, Inc., December 2013.

Exhibit 2-34 illustrates the noise-sensitive land-uses in the vicinity of the Airport. **Table 2-23** lists the number of noise-sensitive land uses, such as community centers, hospitals, libraries/universities, schools, and parks, exposed to various levels of aircraft noise. The primary land-uses around Ellington Airport are residential and commercial. Within the area exposed to 75-decibels (dBA), there are no noise-sensitive land uses. In the area exposed to 70 dBA to 75 dBA, there is one park; in the area exposed to 65 dBA to 70 dBA, there is a hospital, a library, and two parks. Four schools and five parks are exposed to 60 dBA to 65 dBA. Outside the area exposed to 60 dBA and within a 3-mile buffer of the Airport are three community centers, four hospitals, seven libraries, 25 schools, and 20 public parks.

Table 2-23: Noise-Sensitive Land Uses

NOISE EXPOSURE AREA	COMMUNITY CENTERS	HOSPITALS	LIBRARY	SCHOOLS	PARK
Outside 60 dBA – within 3 Mile Buffer	3	4	7	25	20
Between 60 dBA and 65 dBA	0	0	0	4	5
Between 65 dBA and 70 dBA	0	1	1	0	2
Between 70 dBA and 75 dBA	0	0	0	0	1
Within 75 dBA	0	0	0	0	0

NOTE: DBA = A-WEIGHTED DECIBELS

SOURCES: Harris County Appraisal District, Houston-Galveston Area Council, August 2012.
PREPARED BY: UrbanCore Collaborative, Inc., August 2012.

2.9 Utility Infrastructure

This section documents the existing utility infrastructure serving the Airport. The existing utility infrastructure status for potable water, sanitary and storm sewer, electrical power, natural gas, and telecommunications systems are discussed.

All information provided in this section was obtained through online research, review of available as-built plans, interviews, and field visits.

2.9.1 POTABLE WATER SYSTEM

The Ellington Airport property is located within two separate water district boundaries. The majority of the Airport property, located north of Runway 4-22, lies within the City of Houston's water utility jurisdiction (Southeast Water Purification Plant). The remainder of the Airport property, located south of Runway 4-22, is contained within the Clear Lake City Water Authority service boundary. A map of the existing potable water system infrastructure and the two district boundaries is provided on **Exhibit 2-35**.

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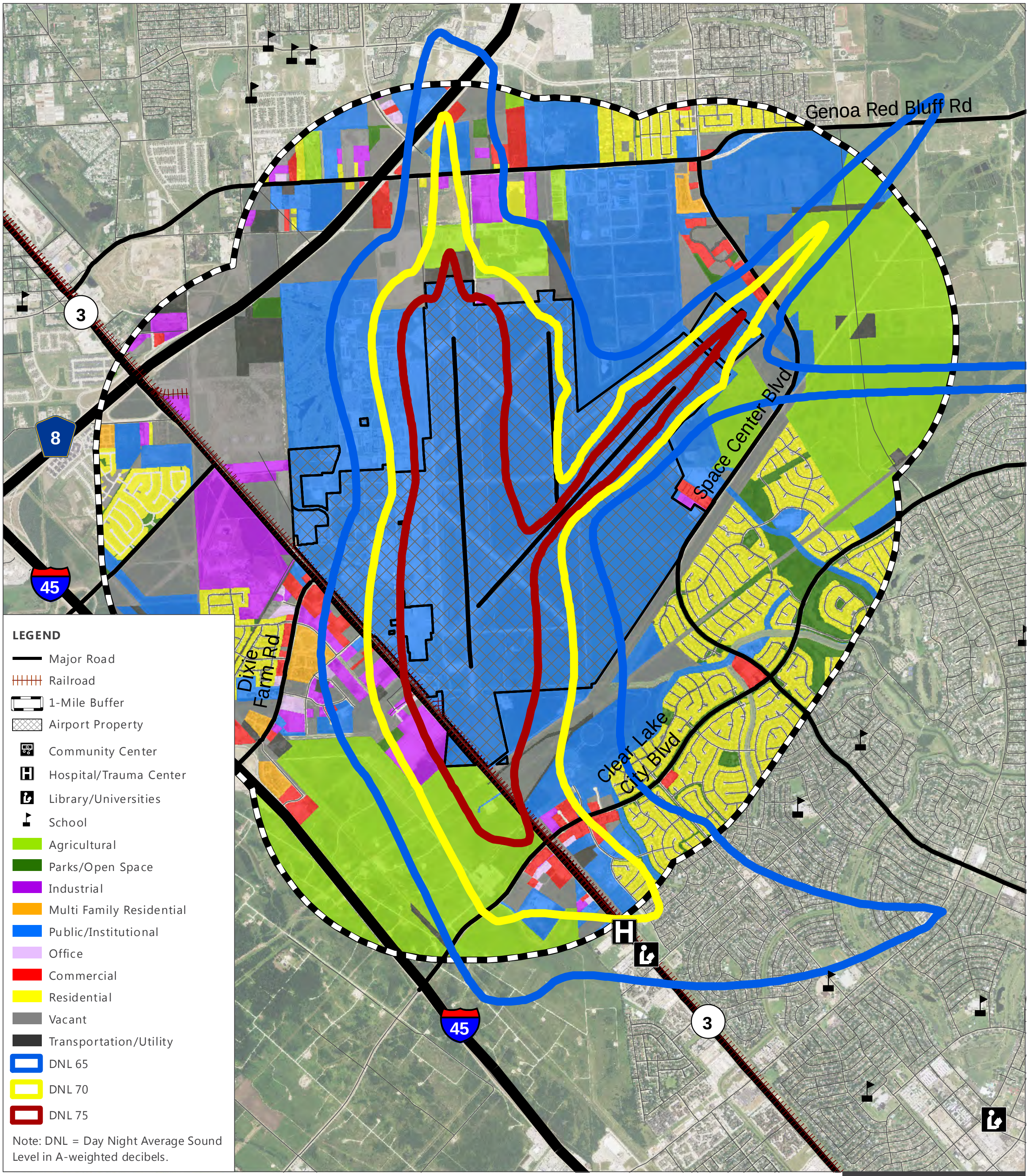

Note: DNL = Day Night Average Sound Level in A-weighted decibels.

SOURCES: Houston-Galveston Area Council, Harris County Appraisal District 2012, Houston Airport System 2013, Noise Contours, Federal Aviation Administration, 2008.
PREPARED BY: UrbanCore Collaborative, Inc. and Knudson, LP, February 2014.

EXHIBIT 2-34

NORTH

0 4,000 ft.

Noise-Sensitive Land Uses

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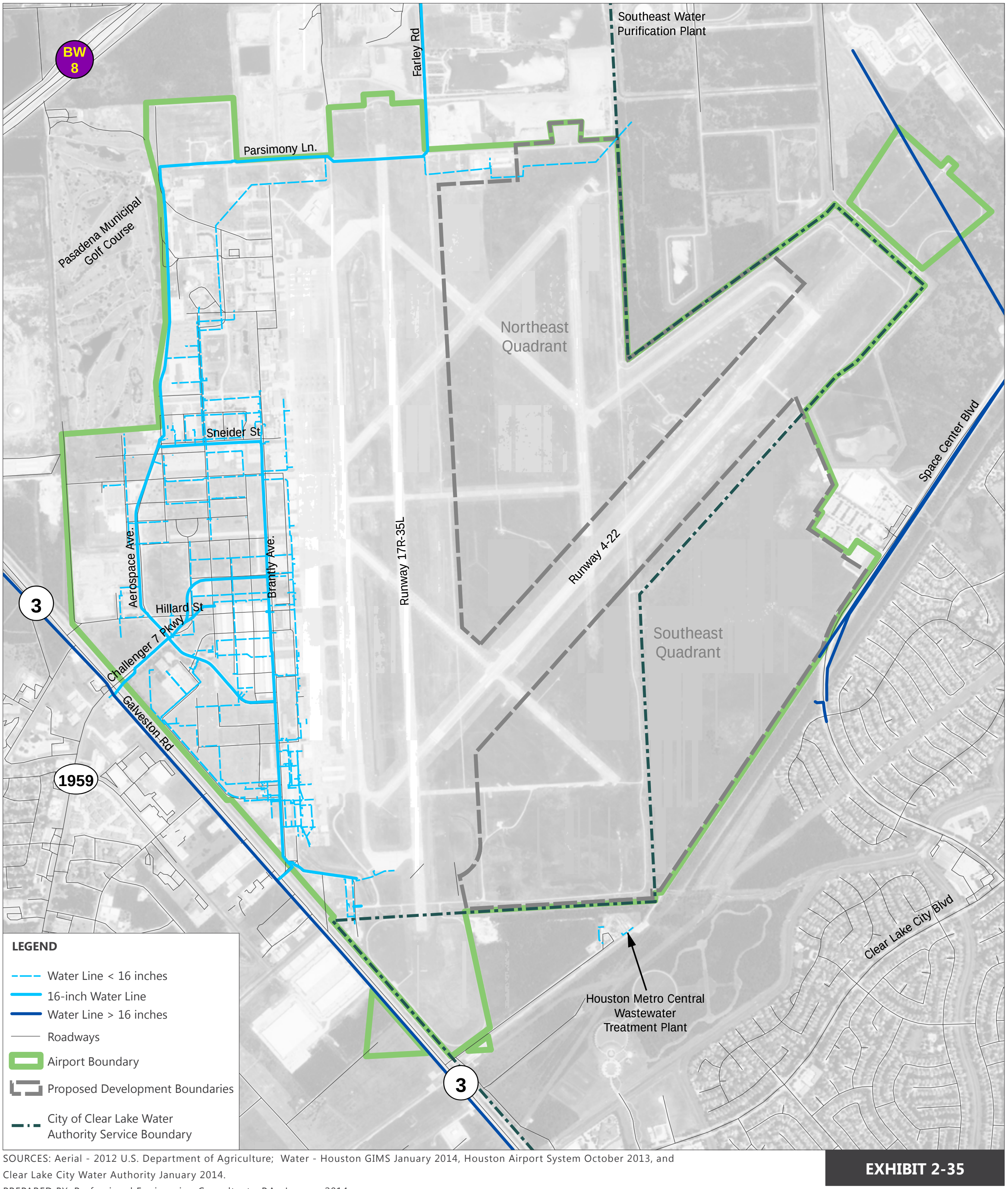

SOURCES: Aerial - 2012 U.S. Department of Agriculture; Water - Houston GIMS January 2014, Houston Airport System October 2013, and Clear Lake City Water Authority January 2014.

PREPARED BY: Professional Engineering Consultants, P.A., January 2014.

EXHIBIT 2-35

NORTH

0 2,000 ft.

Potable Water System Infrastructure

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City of Houston Water Distribution

Water service to Ellington Airport, as currently developed, is provided by the City of Houston's water system. The Airport's potable water system is served by an onsite looped 16-inch ductile iron main line connected to a 42-inch transmission mainline located in State Highway 3, and a 96-inch transmission line located in State Highway 8. The water distribution system at the Airport is fed from the internal 16-inch loop and served by smaller 6-inch and 8-inch lines located along the campus' internal grid streets.

City of Houston Transmission Mains

The 42-inch transmission line in State Highway 3 (see Exhibit 2-35) under the jurisdiction of the City of Houston, is capable of delivering 18,000 gallons of water per minute at a velocity of 4.2 feet per second. According to the City of Houston Public Works Department, the 42-inch main is in extremely poor condition and is projected to be replaced as a Capital Improvement Program (CIP) project within 10 years.

The 42-inch transmission main replacement project is in the early stages of planning and design. Several routing possibilities are under consideration by the City of Houston, including rerouting to the east of the Airport property. Should an easterly route be selected, a smaller water main would be installed within the State Highway 3 right-of-way. It is important to note that the City of Houston will give consideration to the Ellington Airport Master Plan Update when deciding final size and location for the new water main.

The 96-inch transmission main is the primary water supply line exiting Houston's Southeast Water Purification Plant (located northeast of the Airport, see Exhibit 2-35), thus providing water supply for the plant's entire service area. This transmission line has an average pressure of 90 pounds per square inch and is capable of delivering 90,000 gallons per minute at a velocity of 4 feet per second.

City of Houston Water Supply

The Southeast Water Purification Plant (see **Exhibit 2-36**) was built in 1989 and upgraded in 2011. The plant is owned and operated by the City of Houston. In addition to serving Ellington Airport, the plant serves a large section of the City of Houston, City of Clear Lake, City of Pasadena, City of Galveston Bay, and several other small communities in the area. The plant, as currently configured, is capable of producing 200 million gallons of water per day. The City of Houston currently has a peak production of 131 million gallons per day.

Clear Lake Water Authority Transmission Mains

Water service to the portion of Airport property located within the City of Clear Lake Water Authority Boundary is available from an existing 24-inch ductile iron water main located in Space Center Boulevard. The 24-inch water main is capable of delivering 6,000 gallons of water per minute at a velocity of 4.8 feet per second. The condition of the 24-inch main in Space Center Boulevard is unknown, but suspected to be in fair condition.

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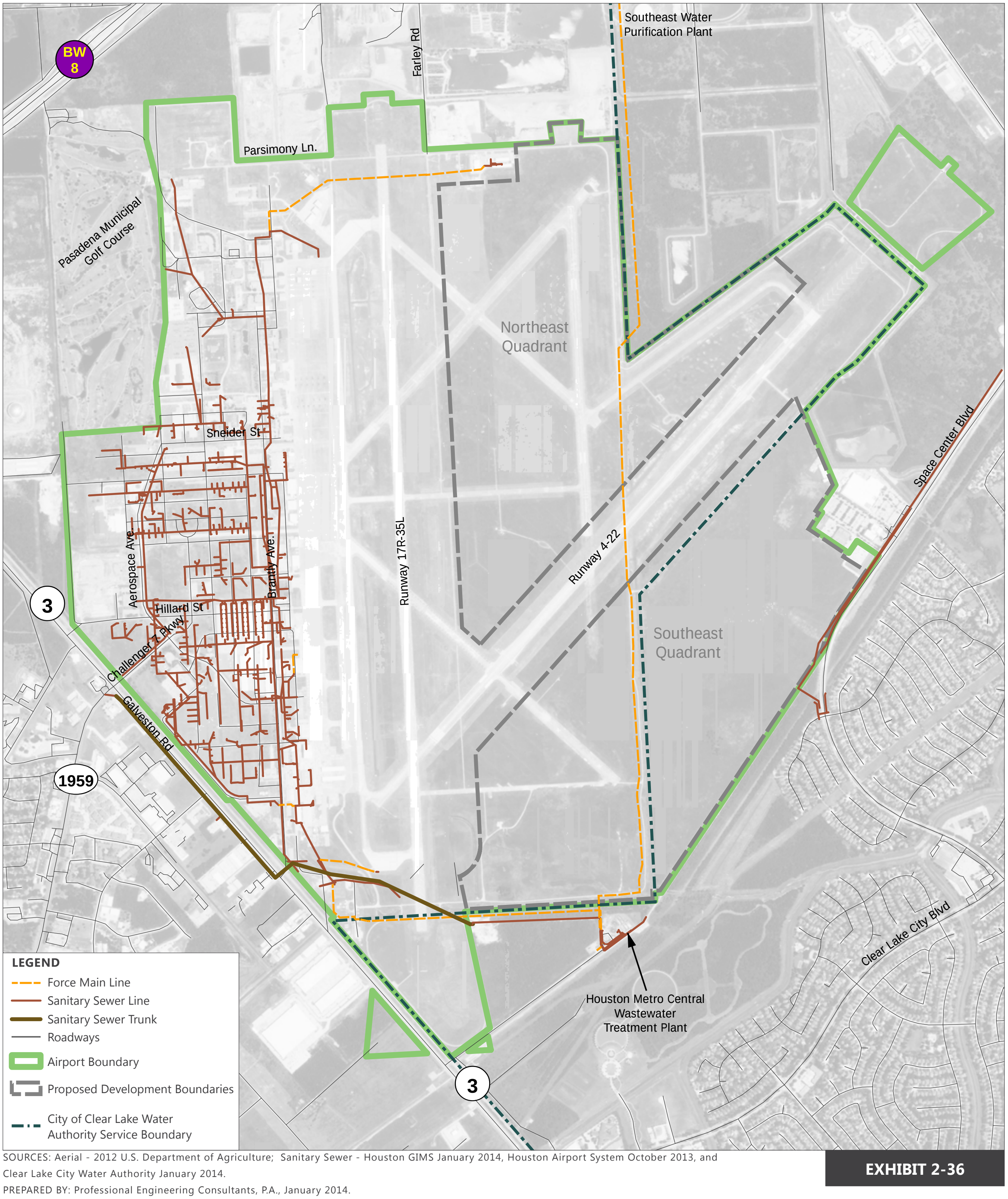

SOURCES: Aerial - 2012 U.S. Department of Agriculture; Sanitary Sewer - Houston GIMS January 2014, Houston Airport System October 2013, and Clear Lake City Water Authority January 2014.

PREPARED BY: Professional Engineering Consultants, P.A., January 2014.

EXHIBIT 2-36

NORTH 0 2,000 ft.

Sanitary Sewer Infrastructure

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Clear Lake Water Authority Water System

The City of Clear Lake Water Authority receives water through the City of Houston, from the Southeast Water Purification Plant, and has rights to 23 million gallons per day. A 24-inch water main connection to the 96-inch transmission line, located northeast of the Airport, is the primary source of potable water for the City of Clear Lake. The 24-inch supply line traverses south through Airport property, beneath the eastern end of the flight path for Runway 4-22, to the City of Clear Lake's pumping station and underground storage facility. The 24-inch supply line is in poor condition, experiencing continual leaks and line breaks. Any development on the eastern end of Airport property should be coordinated with the Clear Lake Water Authority, such that improvements to the supply line can be made in conjunction with Airport improvements as appropriate, and provide for minimal/coordinated disruption to Airport activities.

2.9.2 SEWER SYSTEM

2.9.2.1 Sanitary Sewer

The Airport is also located within two separate sewer district boundaries. The majority of the Airport property, located north of Runway 4-22, lies within the City of Houston's sewer utility jurisdiction. The remainder of the Airport property, located south of Runway 4-22, lies within the City of Clear Lake service boundary. A map of the existing sanitary sewer system infrastructure and the two district boundaries is provided on Exhibit 2-36**.**

The City of Houston provides all sanitary sewer service to the developed areas of the Airport north of Runway 4-22. The existing sanitary sewer infrastructure serving the Airport is located on the landside of the Airport and consists of gravity sanitary mains ranging in diameter from 6 inches to 20 inches. This network of sewer lines, along with a larger offsite sanitary sewer drainage basin, ultimately converges into a 78-inch interceptor line located at the southernmost end of Airport property. The 78-inch interceptor line discharges to a large lift station and pumps to the Houston Metro Central Wastewater Treatment Plant (see **Exhibit 2-37**), located adjacent to the southern boundary of Ellington Airport.

Sanitary sewer service for Ellington Airport's Airfield Services Complex, located near the northern end of Runway 17R-35L, is provided by a private lift station and 4-inch force main. The force main discharges to the west and connects to a manhole located on the landside of the Airport. The Airport is currently experiencing problems with this forced sewer system's pumps and 4-inch discharge line. Any development in the area should address these problems.

The Houston Metro Central Wastewater Treatment Plant has a capacity of 5 million gallons per day. Improvements to the treatment plant are needed. The City of Houston is in the early stages of planning/exploring improvement versus relocation of the plant. The City of Houston has indicated that it will take into consideration development plans for Ellington Airport when deciding how best to proceed.

In addition to the gravity sanitary sewer systems located west of the Airport, an existing 6-inch force main, located east of Runway 17R-35L, traverses south across Airport property from the aforementioned Southeast Water Purification Plant. This force main is for the sole purpose of serving the Water Purification Plant and is unavailable for sewer service to Airport property. The City of Houston has expressed an interest in relocating this main and is researching opportunities and alternate discharge locations.

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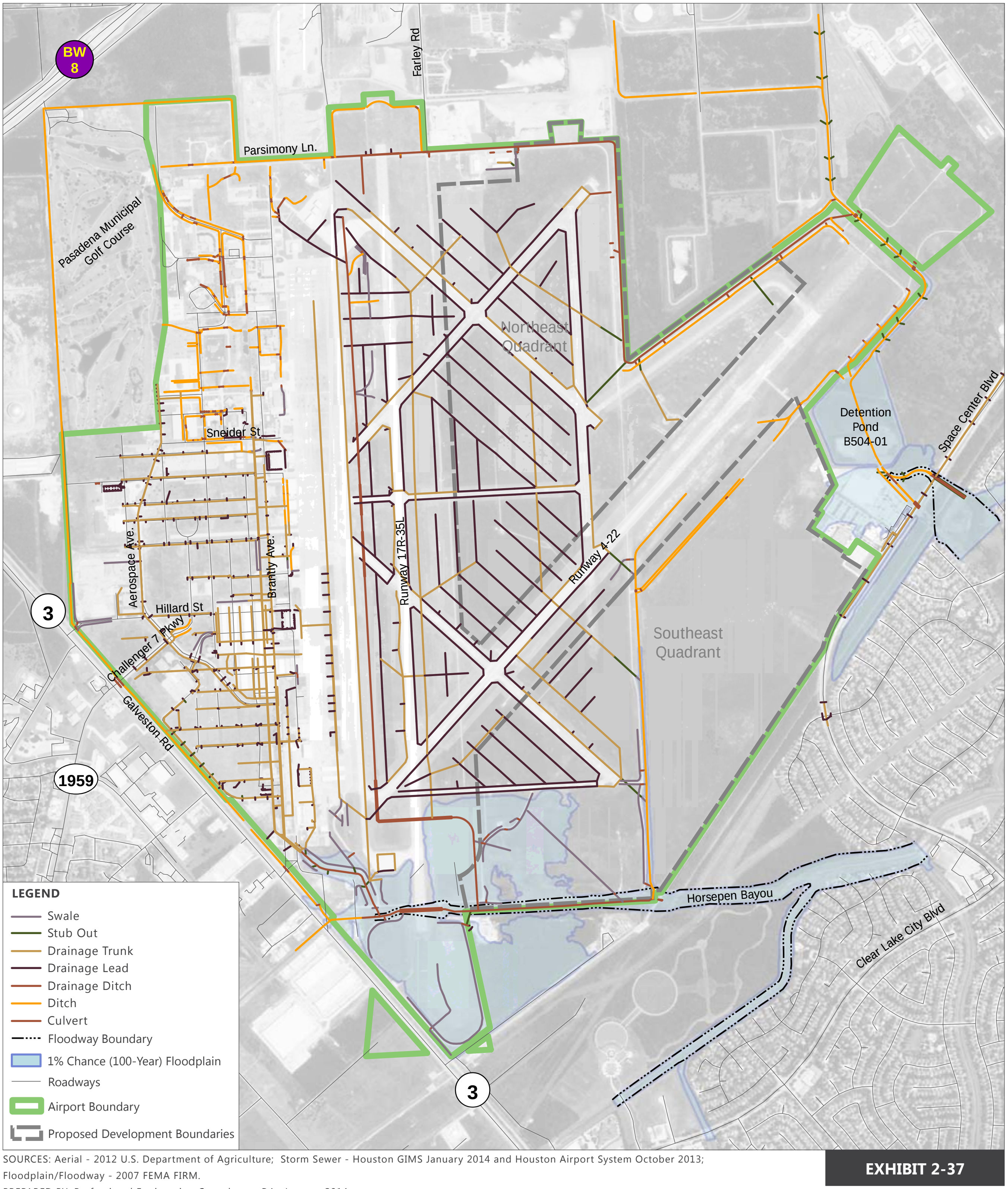

SOURCES: Aerial - 2012 U.S. Department of Agriculture; Storm Sewer - Houston GIMS January 2014 and Houston Airport System October 2013; Floodplain/Floodway - 2007 FEMA FIRM.

PREPARED BY: Professional Engineering Consultants, P.A., January 2014.

EXHIBIT 2-37

Storm Sewer Infrastructure

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Airport property located south of Runway 4-22 is served by a 24-inch gravity sewer main, owned by the Clear Lake Water Authority, located in Space Center Boulevard. Full pipe flow of a 24-inch sewer main at minimum grade of 0.08 percent is 2,800 gallons per minute. The condition of the 24-inch sanitary sewer line is suspected to be fair with no known issues. The City of Clear Lake Water Authority Waste Water Treatment Plant has a capacity to treat 10 million gallons per day.

2.9.2.2 Storm Sewer System

Ellington Airport occupies approximately 2,300 acres of land and drains southeasterly. The Airport is located entirely within the Armand Bayou watershed, governed by the Harris County Flood Control District (HCFCD). An overview of the Armand Bayou watershed, including the channels through which stormwater is directed, is provided in **Exhibit 2-38**.

Ellington Airport property is subject to storm water management requirements of the City of Houston, the City of Clear Lake, and the Harris County Flood Control District, based on City service boundary lines and connection to Horsepen Bayou, respectively. The City of Houston currently serves as the Floodplain Administrator, while the HCFCD serves as the governing body, similar to FEMA.

According to available records, the base floodplain elevation overtops the channel banks (Ditch M) at the south end of Ellington Airport and slightly encroaches upon the airfield in the southern area of Runway 17R-35L. Drainage is effectively split between the western and eastern portions of the occupied land. The western portion of the Airport, referred to as the landside, consists of 580 acres and drainage is collected and drained through storm sewer systems. The eastern portion of the Airport, referred to as the airside, consists of the remaining 1,720 acres and is drained by a combination of storm sewer and channel flow (see Exhibit 2-37 for existing drainage lines at Ellington Airport).

Landside Drainage System

The existing drainage facilities on the landside at EFD contain the following storm sewer systems:

- A 10-foot x 8-foot concrete box storm sewer along Brantly Avenue discharges into Ditch M south of the Airport. Ditch M flows eastward into the Horsepen Bayou.
- A double 5-foot x 4-foot concrete box storm sewer aligned parallel to the above-mentioned system also drains into Ditch M.
- An 8-foot x 7-foot concrete box storm sewer running along Boone Avenue increases to 8 feet x 8 feet in the middle of the run and again increases to 10 feet x 8 feet south of Scholl Street.

All of the above-mentioned drainage systems form the basis of the trunk line, which outfalls into Horsepen Bayou.

Airfield Drainage System

The drainage system on the airfield consists of seven storm sewer systems that discharge into open ditches surrounding the Airport. The storm sewer system contains pipes with diameters ranging from 8 inches to 54 inches in diameter. The ditches either drain southward or eastward into Horsepen Bayou.

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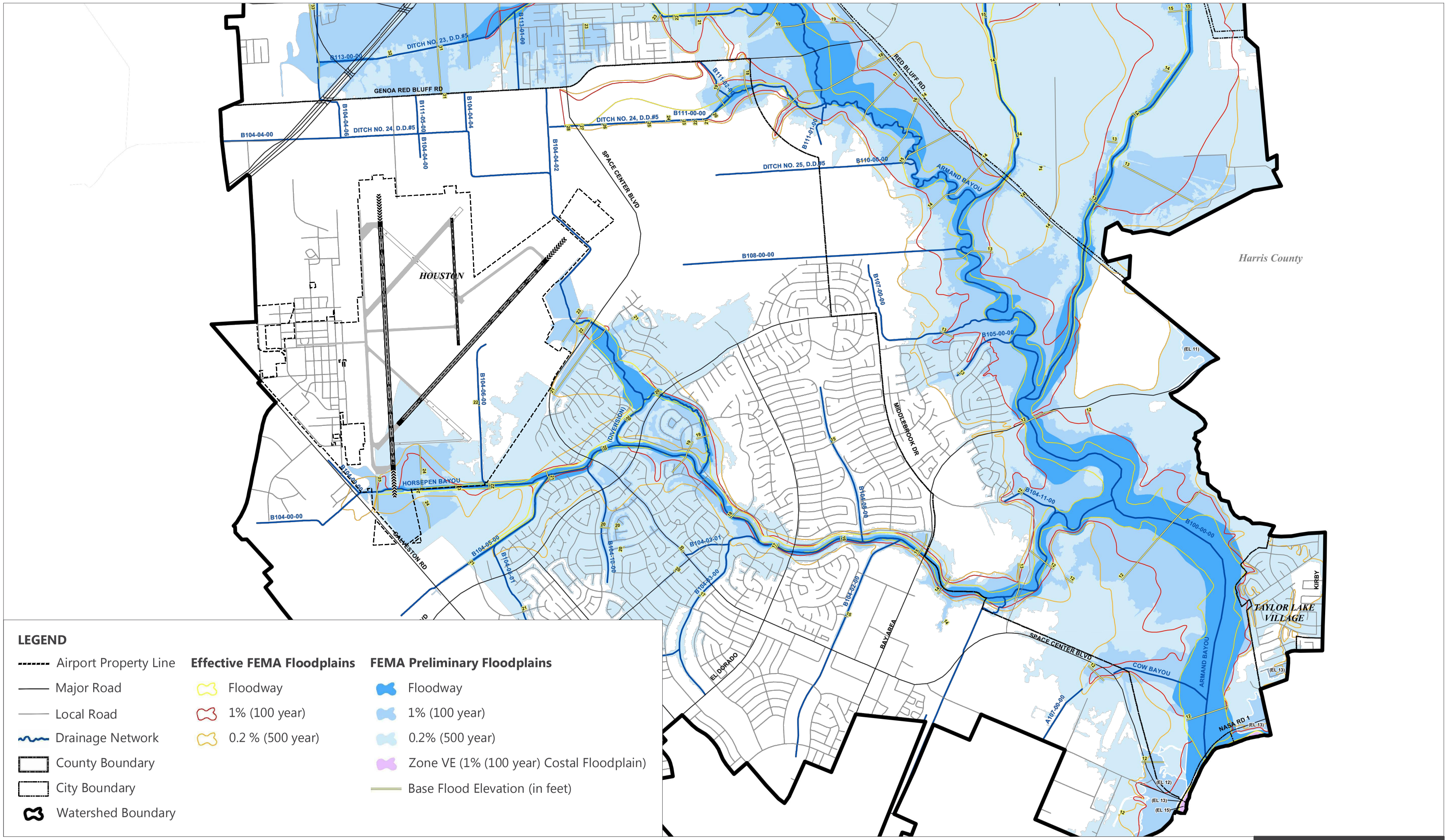

EXHIBIT 2-38

SOURCES: Ricondo & Associates, Inc., Ellington Airport, Draft Airport Layout Plan, April 2015; TSARP Comparison Map Armand Bayou Wathershed, October, 2004; Ricondo & Associates, Inc., April 2015.
PREPARED BY: Ricondo & Associates, Inc., April 2015.

NORTH
0 Not to Scale

Armand Bayou Watershed

Drawing: Z:\Houston\1-EFD\EFD Master Plan 2012\02_Inventory\CAD\Exhibit Armand Bayou Watershed.dwg Layout: 2-38 - Armand Bayou Watershed (Horizontal Legend) Plotted: Sep 25, 2015, 10:34AM

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Existing Regional Detention Pond B504-01

An existing regional detention pond, referred to as B504-01, is located on the east side of the Airport (see Exhibit 2-37). This detention pond was constructed to mitigate the peak runoff rates from portions of the adjacent airfield.

Existing Drainage Issues

A drainage assessment conducted by HAS in 2012 and the 2008 *Drainage Master Plan*[17] included evaluations of the detention storage requirements for future site development, with consideration toward controlling the peak discharge rate. The City of Houston requires the overall post-development peak discharge rate to be less than the existing peak discharge rate. In addition to this peak rate reduction, the HCFCD set allowable discharge rates to ensure no adverse impacts upstream or downstream of the proposed discharge. Volumetric storage of post-development runoff is a requirement of the City of Clear Lake and requires 1 acre-foot of detention storage for every 1 acre of development.

Occasional back-ups in Armand Bayou, downstream of Horsepen Bayou, cause Horsepen Bayou to flood, Also, the proposed Airport improvements (based on the 2004 Airport Master Plan) would significantly change the existing drainage at the Airport and affect the allowable discharge rates. The 2008 *Drainage Master Plan* describes the major drainage improvements required with site development. Based on this report, an assumed 60 percent post-development percent impervious was used to calculate the increase in peak runoff rates and resulted in the recommendation for channel improvements, additional box culverts, and construction of a 207-acre-foot storage volume detention pond, as shown on **Exhibit 2-39**.

The actual post-development percent impervious will likely be much higher than 60 percent, which will result in the need for a larger detention pond (refer to the 2008 *Drainage Master Plan* for more information). It should be noted that an updated hydraulic and hydrological study will be required by the Harris County Flood Control District to ensure that no adverse impacts will result to the receiving bayou. To further mitigate potential flooding issues, future spaceport tenants and facilities will be required to have on-site detention.

2.9.3 ELECTRICAL POWER SYSTEM

Existing electrical lines are shown on **Exhibit 2-40**. The Center Point Energy Planning Department did not provide sufficient load capacity and usage data for Ellington Airport to determine the available electrical supply capacity. Center Point Energy did indicate that the two existing 12 kilovolt (kV) medium voltage circuits (EL04 and EL06) supply the east side of Ellington Airport from the Center Point Energy-owned and operated Ellington Substation. These circuits do not have sufficient electrical capacity to accommodate significant future development at the Airport. More detailed and definitive data on available capacity can be determined by Center Point Energy when future facility load requirements are known.

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[17] A&S Engineers, Inc., *Ellington Field Drainage Master Plan*, February 22, 2008.

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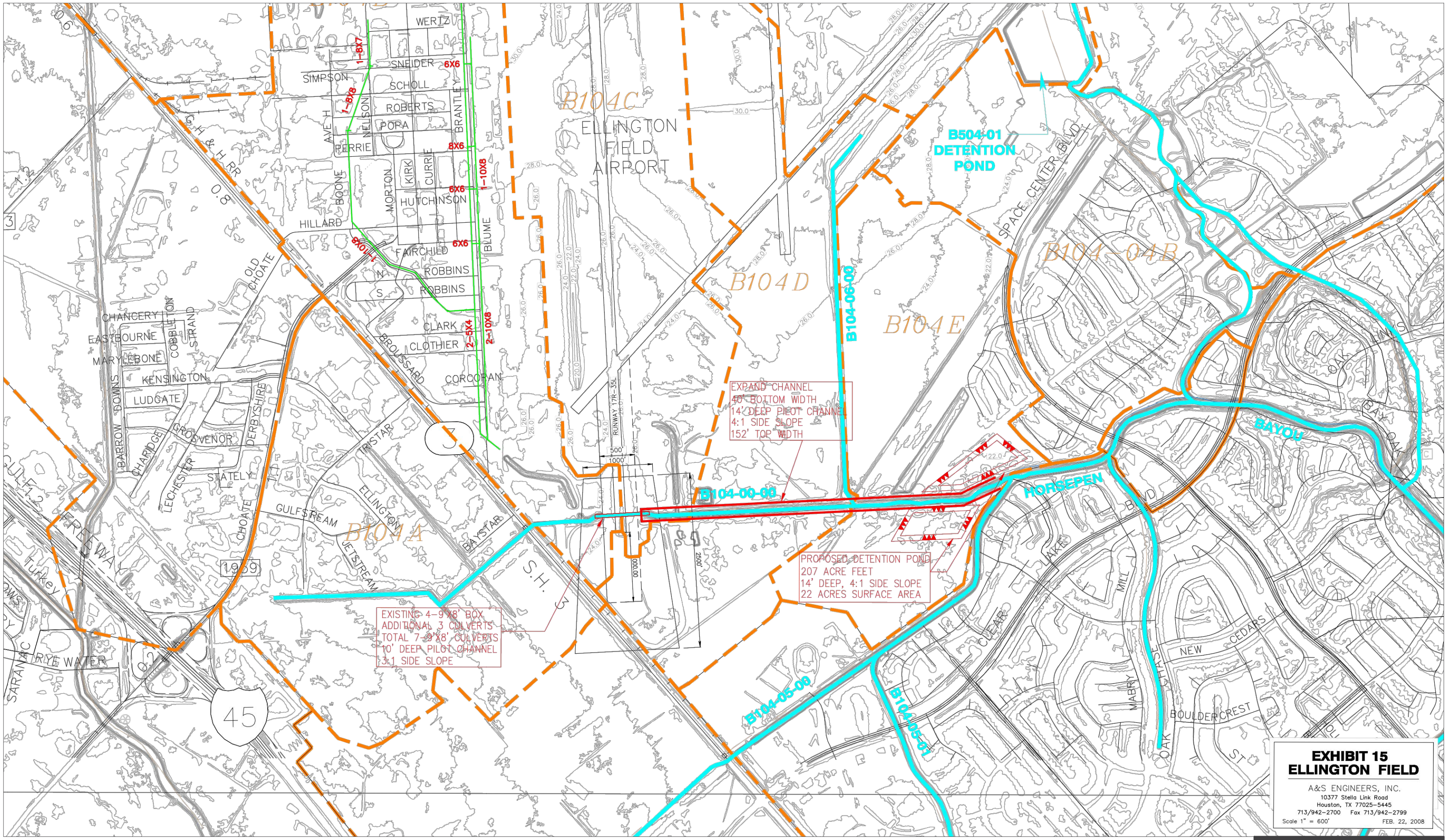

SOURCE: A&S Engineers, Inc., February, 2008.
PREPARED BY: Ricondo & Associates, Inc., April 2015.

EXHIBIT 2-39

NORTH

0 Not to Scale

Proposed Drainage Improvements

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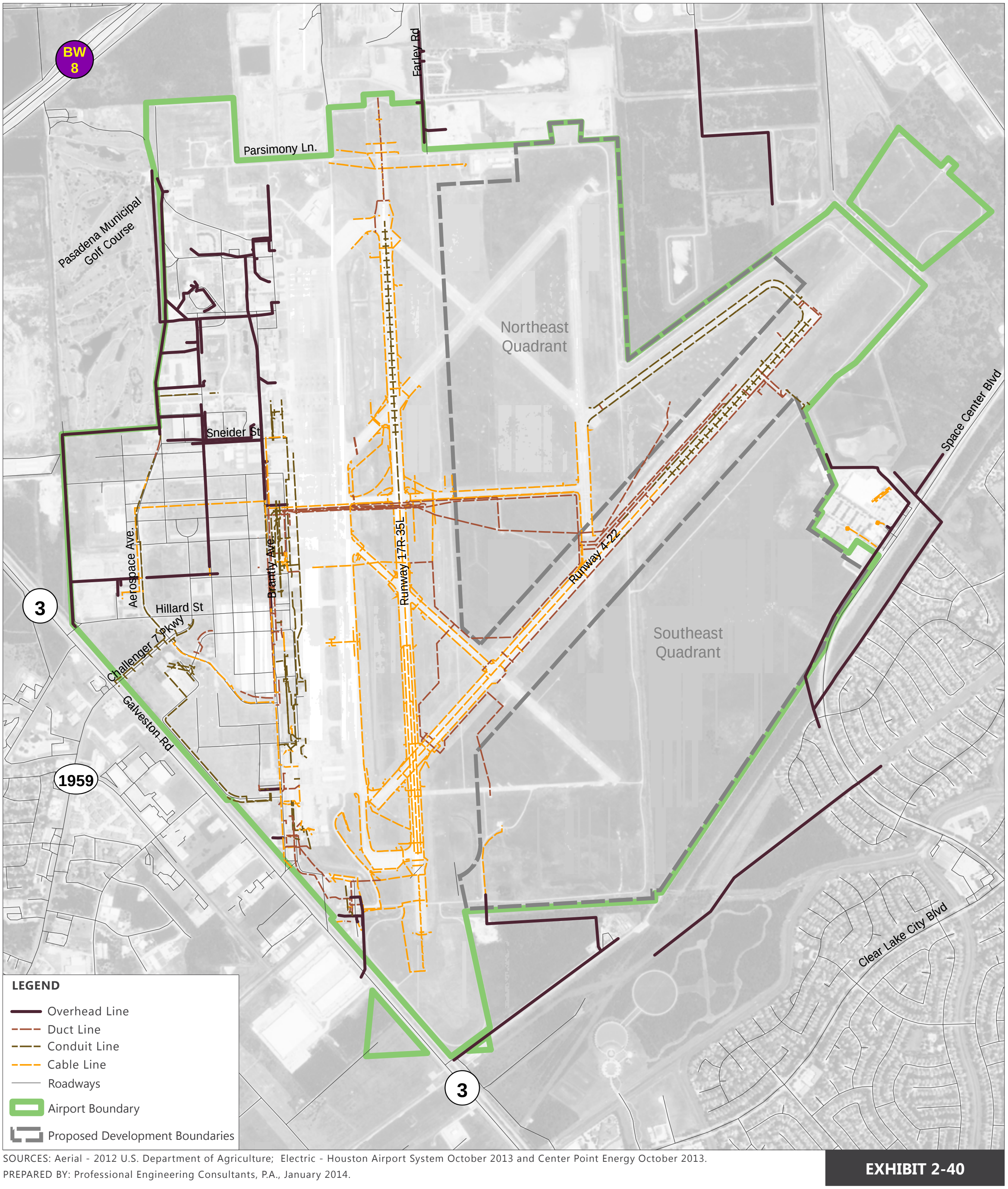

SOURCES: Aerial - 2012 U.S. Department of Agriculture; Electric - Houston Airport System October 2013 and Center Point Energy October 2013.
PREPARED BY: Professional Engineering Consultants, P.A., January 2014.

EXHIBIT 2-40

NORTH 0 2,000 ft.

Electrical Infrastructure

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In general, landside facilities at Ellington Airport are served by pole mounted 12 kV overhead power distribution lines. The existing electrical system on the airfield is a combination of direct bury cable and cables in conduit that serve the airfield lighting and navigational facilities. Center Point Energy also stated that it is investigating loop feeding the two circuits in the future to provide redundant power to the area.

The following facilities are served from the existing two 12 kV medium voltage electrical services stated above:

- NASA Training Facility:
    - Three 3,000 kVA pad-mounted transformers (277/480-volt secondary) – Main Building
    - One pole-mounted transformer – Out Building
- Boeing Facility: one pad-mounted transformer
- Houston Product Support Center Facility: one pad-mounted transformer (277/480-volt secondary)
- Ellington Airfield Antenna Facility: one pad-mounted transformer (277/480-volt secondary)

2.9.4 NATURAL GAS SYSTEM

Existing natural gas lines are shown on **Exhibit 2-41**. The campus main gas line begins at Hillard Street and extends through the campus serving the City of Houston Airport property and tenants. There are no known issues with the existing campus gas infrastructure. During discussions with Center Point Energy, it was stated that the existing infrastructure has available capacity to serve future development at the Airport. More definitive capacity availability should be discussed as actual development demands are known.

2.9.5 TELECOMMUNICATIONS SYSTEM

Telecommunications service to the area is provided by AT&T and Phonoscope through underground duct-bank systems. Phonoscope provides many services in the area, including Ethernet point-to-point, Voice over Internet Protocol (VOIP), video teleconferencing, Internet bandwidth, and dark fiber runs (fiber is installed by Phonoscope, but energized by the customer). The Phonoscope service is provided via aerial transmission lines of multiple 12-strand multimode (OM3) outside plant (OSP) rated optical fiber cabling. Phonoscope uses these transmission lines to provide multiple 10-gigabyte circuits to clients in the Ellington Airport service area.

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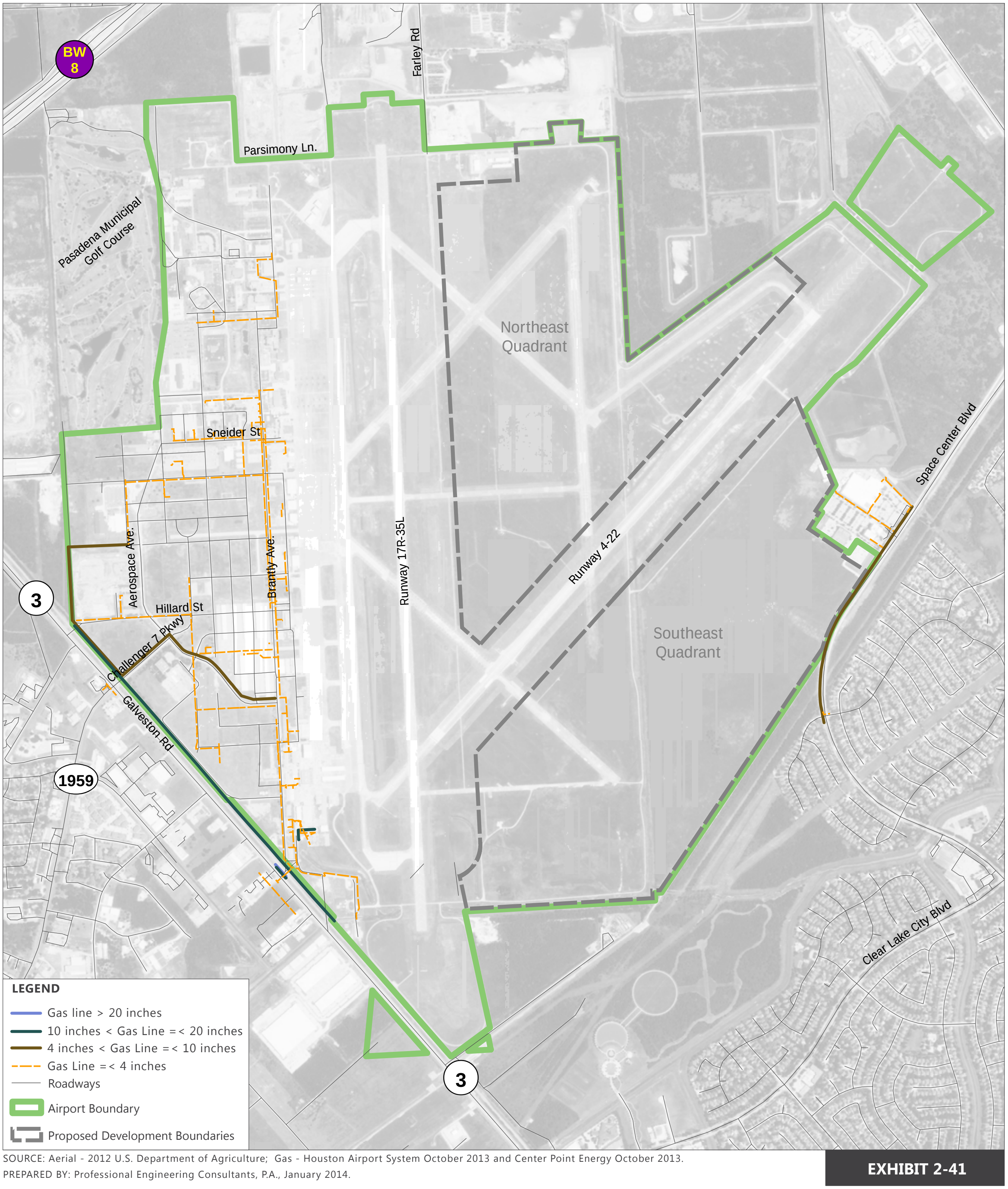

SOURCE: Aerial - 2012 U.S. Department of Agriculture; Gas - Houston Airport System October 2013 and Center Point Energy October 2013.
PREPARED BY: Professional Engineering Consultants, P.A., January 2014.

EXHIBIT 2-41

Gas Infrastructure

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3. Aviation Activity Forecasts

This section presents a discussion of historical aviation activity at the Airport and summarizes forecasts of aviation activity through 2030. The forecasts were developed for general aviation and military aircraft operations and based aircraft. The forecasts provide the basis for determining future facility requirements at EFD and for conducting the environmental, financial, and other analyses necessary for preparation of this Master Plan Update.

The forecasts were developed in 2013, using 2012 as a base year, the latest calendar year for which full-year data were available at the time. The forecasts are based on the data available and assumptions made during 2012 - 2013.

The aviation activity forecasts presented in this section are based on assumptions about aviation activity in the Houston region and other factors that may affect future aviation activity at the Airport, including:

- National aviation industry trends and factors affecting those trends, including events related to the economy, fuel costs, etc., over the past 10 years.
- Policy goals and objectives of the Houston Airport System
- Ellington Airport's role in the Houston Airport System
- Historical activity and trends in air service at the Airport, including comparisons of historical U.S. market shares
- Local socioeconomic and demographic trends compared with State of Texas and national trends
- Availability of services at other Houston area general aviation airports

Because future conditions are, by definition, unknown, actual activity at the Airport will vary from the forecasts because of unforeseen events and changes in support services at the Airport or at competing airports. Developing forecasts carries the further uncertainty of how pilots, aircraft owners, and service providers respond to changes in operating costs and demand. Therefore, the forecast scenarios presented in this section represent a range of possible, not necessarily actual, future activity.

In addition to the Baseline forecasts, two alternative forecast scenarios were developed to account for potential changes in service patterns that could emerge during the planning period for the Master Plan Update (through 2030). These forecast scenarios are intended to be used to guide Airport facility development decisions. The remainder of this section is organized as follows:

- Historical Activity and Trends
- Factors Affecting Aviation Activity at the Airport
- Forecast Development Methodology Overview and Process
- Forecast Scenarios

Activity at the Airport is generated by several tenants, aircraft based at the Airport, and itinerant aircraft operations, such as:

- Flight schools
- HAS aircraft T-hangars
- NASA
- Landmark Aviation (formerly Southwest Airport Services) FBO
- Texas Air National Guard
- Texas Army National Guard
- U.S. Coast Guard

3.1 Historical Activity and Trends

The Airport is classified as a general aviation reliever airport by the FAA. As shown in **Table 3-1**, the Airport accommodated approximately 106,000 aircraft operations in 2012, including approximately 61,700 general aviation operations, 8,800 air taxi (primarily charter aircraft) operations, 27,200 military, and 8,300 NASA operations.

The EFD ATCT compiles activity counts, but does not record aircraft operations by aircraft type or runway use beyond the primary categories of general aviation, air taxi, and military. Whether an operation is local or itinerant and operating under VFR or IFR is also noted. These counts are published by HAS and were used in developing the forecasts. The FAA *Terminal Area Forecast* (TAF) counts and HAS published operations counts do not agree in any year from 2007 through 2012.

Table 3-1: Historical EFD Aircraft Operations: 2007 - 2012

YEAR	AIR CARRIER	AIR TAXI	GENERAL AVIATION	NASA	MILITARY	TOTAL	ANNUAL GROWTH RATE
2007	48	4,450	108,875	9,825	34,531	157,729	--
2008	7	7,150	92,250	9,403	36,168	144,978	-8.1%
2009	--	9,748	88,739	10,432	28,215	137,134	-5.4%
2010	--	8,592	79,078	13,418	22,823	123,911	-9.6%
2011	--	8,160	76,968	11,177	23,734	120,039	-3.1%
2012	--	8,827	61,683	8,335	27,197	106,042	-11.7%
Compound Annual Growth Rate							
2007 – 2012	-100.0%	14.7%	-10.7%	-3.2%	-4.7%	-7.6%	

NOTE: NASA data for 2009 are not available; the figure for 2009 was approximated based on the 2007 - 2012 average.

SOURCE: Houston Airport System, *Statistical Report* http://www.fly2houston.com/TrafficStats, accessed October 2013.
PREPARED BY: Ricondo & Associates, Inc., October 2013.

3.1.1 AIRPORT AVIATION ACTIVITY

Between 2007 and 2012, the number of annual aircraft operations at EFD decreased at a compound annual growth rate (CAGR) of 7.6 percent, primarily as a result of a decrease in general aviation aircraft operations. In comparison, the number of GA aircraft operations at EFD was relatively steady between 2007 and 2012, but GA operations at HOU decreased at a 10 percent CAGR. **Tables 3-2** and **3-3** show historical total aircraft operations and total GA aircraft operations, respectively, at the three HAS airports from 2007 through 2012. Ellington Airport's share of HAS general aviation aircraft operations decreased from 53.6 percent in 2007 to 47.5 percent in 2012.

Air taxi, general aviation and NASA, and military aircraft operations at the Airport are shown in **Tables 3-4**, **3-5**, and **3-6**, respectively; the latter two tables show local and itinerant operations. Air taxi operations include all operations by aircraft with payloads heavier than 18,000 pounds or with more than 60 seats that are flown for hire, not including scheduled commercial passenger flights; operations in this category increased by a CAGR of 14.7 percent between 2007 and 2012. General aviation aircraft operations decreased at a 10.7 percent CAGR between 2007 and 2012. In 2012, 65 percent of general aviation aircraft operations at the Airport were itinerant. The itinerant to local ratio was stable between 2007 and 2012. General aviation and NASA aircraft operations accounted for 66 percent of total aircraft operations at the Airport in 2012. In comparison, military aircraft operations increased in 2010 through 2012, accounting for 25.6 percent of the Airport total in 2012.

Table 3-2: Historical Total Aircraft Operations at HAS Airports: 2007 - 2012

	EFD		HOU		IAH		
YEAR	**AIRCRAFT OPERATIONS**	**SHARE OF HAS TOTAL**	**AIRCRAFT OPERATIONS**	**SHARE OF HAS TOTAL**	**AIRCRAFT OPERATIONS**	**SHARE OF HAS TOTAL**	**HAS TOTAL**
2007	157,729	15.8%	234,777	23.5%	606,595	60.7%	999,101
2008	144,978	15.4%	221,929	23.5%	576,662	61.1%	943,569
2009	137,402	15.5%	209,459	23.7%	538,168	60.8%	885,029
2010	123,911	14.3%	209,614	24.2%	531,347	61.5%	864,872
2011	120,039	13.9%	216,638	25.0%	528,722	61.1%	865,399
2012	106,042	12.9%	204,788	24.9%	510,242	62.1%	821,072
Compound Annual Growth Rate							
2007 - 2012	-7.6%		-2.7%		-3.4%		-3.8%

NOTE: Ellington Airport total including NASA aircraft operations.

SOURCE: Houston Airport System, *Statistical Report* http://www.fly2houston.com/TrafficStats, accessed October 2013.
PREPARED BY: Ricondo & Associates, Inc., October 2013

Table 3-3: Historical General Aviation Aircraft Operations at HAS Airports: 2007 - 2012

	EFD		HOU		IAH		
YEAR	**AIRCRAFT OPERATIONS**	**SHARE OF HAS TOTAL**	**AIRCRAFT OPERATIONS**	**SHARE OF HAS TOTAL**	**AIRCRAFT OPERATIONS**	**SHARE OF HAS TOTAL**	**HAS TOTAL**
2007	108,875	53.6%	80,145	39.4%	14,271	7.0%	203,291
2008	92,250	49.7%	81,273	43.8%	11,959	6.5%	185,482
2009	88,739	51.9%	71,908	42.1%	10,208	6.0%	170,855
2010	79,078	49.9%	68,003	43.0%	11,267	7.1%	158,348
2011	76,968	50.5%	63,617	41.7%	11,867	7.8%	152,452
2012	61,683	47.5%	55,963	43.1%	12,159	9.4%	129,805
Compound Annual Growth Rate							
2007 - 2012	-10.7%		-6.9%		-3.2%		-8.6%

NOTE: Ellington Airport total including NASA aircraft operations.

SOURCE: Houston Airport System, *Statistical Report* http://www.fly2houston.com/TrafficStats, accessed October 2013.
PREPARED BY: Ricondo & Associates, Inc., October 2013

Table 3-4: Historical Air Taxi Operations at Ellington Airport: 2007 - 2012

YEAR	AIR TAXI	SHARE OF EFD TOTAL	EFD TOTAL
2007	4,450	2.8%	157,729
2008	7,150	4.9%	144,978
2009	9,748	7.1%	137,134
2010	8,592	6.9%	123,911
2011	8,160	6.8%	120,039
2012	8,827	8.3%	106,042
Compound Annual Growth Rate			
2007 – 2012	14.7%		-7.6%

SOURCE: Houston Airport System, *Statistical Report* http://www.fly2houston.com/TrafficStats, accessed October 2013.
PREPARED BY: Ricondo & Associates, Inc., October 2013

Table 3-5: Historical General Aviation and NASA Aircraft Operations at Ellington Airport: 2007 - 2012

YEAR	ITINERANT	ITINERANT SHARE	LOCAL	LOCAL SHARE	GA SUBTOTAL	NASA	TOTAL	SHARE OF EFD TOTAL	EFD TOTAL
2007	68,692	63.1%	40,183	36.9%	108,875	9,825	118,700	75.3%	157,729
2008	59,963	65.0%	32,287	35.0%	92,250	9,403	101,653	70.1%	144,978
2009	57,682	65.0%	31,057	35.0%	88,739	10,700	99,439	72.5%	137,134
2010	51,400	65.0%	27,678	35.0%	79,078	13,418	92,496	74.6%	123,911
2011	50,029	65.0%	26,939	35.0%	76,968	11,177	88,145	73.4%	120,039
2012	40,094	65.0%	21,589	35.0%	61,683	8,335	70,018	66.0%	106,042
Compound Annual Growth Rate									
2007 - 2012	-10.2%		-11.7%		-10.7%		-10.0%		-7.6%

SOURCES: Houston Airport System, *Statistical Report* http://www.fly2houston.com/TrafficStats, accessed October 2013; Federal Aviation Administration, *Terminal Area Forecast*, December 2012.
PREPARED BY: Ricondo & Associates, Inc., October 2013

Table 3-6: Historical Military Aircraft Operations at Ellington Airport: 2007 - 2012

YEAR	ITINERANT	ITINERANT SHARE	LOCAL	LOCAL SHARE	TOTAL	SHARE OF EFD TOTAL	EFD TOTAL
2007	21,582	62.5%	12,949	37.5%	34,531	21.9%	157,729
2008	24,561	67.9%	11,607	32.1%	36,168	24.9%	144,978
2009	18,836	66.8%	9,379	33.2%	28,215	20.6%	137,134
2010	13,934	61.1%	8,889	38.9%	22,823	18.4%	123,911
2011	14,490	61.1%	9,244	38.9%	23,734	19.8%	120,039
2012	16,604	61.1%	10,593	38.9%	27,197	25.6%	106,042
Compound Annual Growth Rate							
2007 - 2012	-5.1%		-3.9%		-4.7%		-7.6%

SOURCE: Federal Aviation Administration, *Terminal Area Forecast*, December 2012.
PREPARED BY: Ricondo & Associates, Inc., October 2013

The Airport has not served scheduled commercial passenger airlines (with the exception of diversions or other unscheduled airline operations) since 2004, when Continental Express provided scheduled regional aircraft service between EFD and IAH (between 2000 and 2004). The Airport also does not serve scheduled express package delivery operators.

Table 3-7 presents historical based aircraft at the Airport between 2007 and 2012. In 2012, 214 aircraft were based at the Airport. Between 2007 and 2012, the total decreased 3.9 percent, led by significant decreases in jet and ‘other’ based aircraft.

Table 3-8 presents air cargo activity at HAS airports between 2008 and 2012. While overall air cargo activity at the Airport increased, EFD’s share of the total for HAS airports represented only 1/100 of 1 percent.

Table 3-7: Historical Based Aircraft at Ellington Airport by Category: 2007 - 2012

YEAR	SINGLE ENGINE	MULTI-ENGINE	JET	HELICOPTER	OTHER	TOTAL
2007	124	31	62	5	39	261
2008	101	25	56	3	42	227
2009	141	29	60	3	24	257
2010	90	24	56	3	-	173
2011	143	25	42	8	1	219
2012	140	25	40	8	1	214
Compound Annual Growth Rate						
2007 - 2012	2.5%	-4.2%	-8.4%	9.9%	-51.9%	-3.9%

NOTE: 2011 and 2012 results do not include military or NASA based aircraft.

SOURCES: Federal Aviation Administration, *Terminal Area Forecast*, https://aspm.faa.gov/main/taf.asp, accessed October 16, 2013 (2006 through 2010 only); Houston Airport System, Revised FAA Form 5010-1 for 2011 and 2012.

PREPARED BY: Ricondo & Associates, Inc., October 2013

Table 3-8: Historical Air Cargo (Excluding Air Mail) at HAS Airports (in pounds)

YEAR	EFD	HOU	IAH	HAS TOTAL	EFD SHARE OF HAS TOTAL
2008	454	16,347,109	820,115,155	836,462,718	0.00005%
2009	874	25,401,401	740,773,386	766,175,661	0.00011%
2010	2,609	24,740,021	857,641,906	882,384,536	0.00030%
2011	1,944	23,126,254	910,971,845	934,100,043	0.00021%
2012	924	26,415,517	897,762,902	924,179,343	0.00010%

SOURCE: Houston Airport System, *Statistical Report* http://www.fly2houston.com/TrafficStats, accessed October 2013;

PREPARED BY: Ricondo & Associates, Inc., October 2013.

3.1.2 AIRPORT GENERAL AVIATION GROWTH COMPARED WITH U.S. GROWTH

Table 3-9 shows GA aircraft operations and based aircraft at EFD compared with those in the State of Texas and the United States, along with compound annual growth rates and the shares of Texas and U.S. activity accounted for by the Airport. General aviation operations at the Airport decreased at a higher rate than in the State and in the nation. Between 2007 and 2012, the number of based aircraft at the Airport decreased at a higher rate than in the nation. Compared to based aircraft in the State, the number of based aircraft at the Airport decreased at a higher rate between 2009 and 2012.

Table 3-9: Historical General Aviation Aircraft Operations and Based Aircraft

	ANNUAL GENERAL AVIATION AIRCRAFT OPERATIONS				
YEAR	**EFD**	**TEXAS**	**UNITED STATES**	**EFD/TEXAS**	**EFD/UNITED STATES**
2007	108,875	5,298,397	80,312,797	2.1%	0.14%
2008	92,250	5,171,559	78,134,743	1.8%	0.12%
2009	88,739	4,813,455	73,811,433	1.8%	0.12%
2010	79,078	4,713,116	71,456,331	1.7%	0.11%
2011	76,968	4,647,810	70,844,120	1.7%	0.11%
2012	61,683	4,719,790	70,514,484	1.3%	0.09%
Compound Annual Growth Rate					
2007 - 2012	-10.7%	-2.3%	-2.6%		
2009 - 2012	-11.4%	-0.7%	-1.5%		
		BASED AIRCRAFT			
2007	261	14,611	200,064	1.8%	0.13%
2008	227	11,516	176,040	2.0%	0.13%
2009	257	12,340	177,875	2.1%	0.14%
2010	173	11,535	165,860	1.5%	0.10%
2011	219	11,653	167,608	1.9%	0.13%
2012	214	11,794	169,240	1.8%	0.13%
Compound Annual Growth Rate					
2007 - 2012	-3.9%	-4.2%	-3.3%		
2009 - 2012	-5.9%	-1.5%	-1.6%		

SOURCES: Houston Airport System, *Statistical Report* http://www.fly2houston.com/TrafficStats, accessed October 2013; Houston Airport System, Revised FAA Form 5010-1 for 2011 and 2012. Federal Aviation Administration, *Terminal Area Forecast*, December 2012.

PREPARED BY: Ricondo & Associates, Inc., October 2013

3.1.3 AIRPORT AIR TRADE AREA CHARACTERISTICS

Over the same period (2007–2012), socioeconomic activity in the Houston-Woodlands-Sugar Land Metropolitan Statistical Area (MSA), including Harris, Fort Bend, Montgomery, Brazoria, Galveston, Liberty, Waller, Chambers, and Austin counties, has been both positive and negative. Population increased at a CAGR of 2.3 percent, while per capita personal income decreased at a CAGR of 0.6 percent. Gross regional product (GRP) in the Houston MSA decreased at a CAGR of 0.2 percent; however, it compared favorably with the national gross domestic product (GDP), which decreased at a CAGR of 0.5 percent (See **Table 3-10**). These results indicate that EFD, and the Houston area in general, should generally be equal to or higher than national and regional aviation activity growth.

Table 3-10: Airport Air Trade Area Socioeconomic Characteristics

	GROSS REGIONAL PRODUCT (IN MILLIONS OF 2005 DOLLARS)	TOTAL PERSONAL INCOME PER CAPITA (IN 2005 DOLLARS)	TOTAL PERSONAL INCOME PER CAPITA (IN 2012 DOLLARS)	TOTAL PERSONAL INCOME (IN MILLIONS OF 2005 DOLLARS)	TOTAL POPULATION (IN THOUSANDS)	TOTAL EMPLOYMENT (IN THOUSANDS OF JOBS)
2007	$314,462	$42,533	$44,872	$236,766	5,567	3,368
2008	$322,791	$44,740	$48,741	$255,118	5,702	3,471
2009	$296,053	$39,278	$42,815	$229,865	5,852	3,449
2010	$295,251	$39,609	$44,001	$236,723	5,976	3,449
2011	$302,600	$40,880	$46,518	$248,820	6,087	3,535
2012	$311,891	$41,285	$47,831	$257,058	6,226	3,644
Compound Annual Growth Rate						
2007 - 2012	-0.2%	-0.6%	1.3%	1.7%	2.3%	1.6%

SOURCE: Woods & Poole Economics, Inc., accessed September 2013.
PREPARED BY: Ricondo & Associates, Inc., October 2013.

It is expected that, in the long term, the Airport will maintain its role as a general aviation reliever airport. Given the strength of its economic base and leading socioeconomic indicators, the Houston MSA is expected to be able to support long-term growth in aviation activity.

3.2 Factors Affecting Aviation Activity at the Airport

A number of factors affect aviation activity. On a national basis, aviation activity is closely tied to the economy. Each area of the industry (commercial passenger airline, general aviation, and air cargo) is affected by the strength or weakness of the economy. Correspondingly, airports are affected by changes in the economy – although the effects vary depending on the type and size of airport and the type of activity accommodated at the airport. Changes in the industry itself – including the introduction of new aircraft, airline and aviation business practices, and federal aviation policy – also affect aviation activity. Several local factors will affect the future of the Airport, including the goals and policies of the Houston Airport System (including defined roles of the airports within the system) and socioeconomic and demographic trends in the region, which will affect demand for airline travel in the region. The following subsections describe some of the aviation industry factors and local factors that influence aviation activity at the Airport.

3.2.1 AVIATION INDUSTRY FACTORS

Significant national and international events in 2001 through 2012 have affected aviation activity. Of the several factors that continue to affect the industry and add uncertainty to the forecasting, the following four are among the most significant.

3.2.1.1 Cost of Aviation Fuel

The volatile price of fuel is one of the most significant forces affecting the aviation industry today. The average price of jet fuel was $0.81 per gallon in 2000 compared to a peak of $3.84 per gallon in 2008. In March 2014, the average price of jet fuel was $3.02 per gallon. If jet fuel prices approach or surpass their mid-2008 peak (July's average price was $3.84), aviation activity nationwide may be negatively impacted.

3.2.1.2 Economic Conditions

In addition to aviation cost factors, the overall state of the economy affects the propensity to travel and, therefore, activity. Because economic conditions are typically cyclical over time (over longer periods, average changes are more regular and predictable), trends can be extracted from the balance of strong and weak economic years. However, when combined with the uneven growth in the industry and at the Airport in recent years (EFD annual growth rates for aircraft operations have varied from annual decreases of 3.1 percent to 11.7 percent between 2007 and 2012), changing economic conditions can affect the reliability of forecasts of aviation activity by further reducing the correlation between economic conditions and Airport activity.

3.2.1.3 Airport Security

The requirements and uncertainties related to airport security and the processes and procedures of the Department of Homeland Security (DHS) can affect the decision to, and the mode choice for, travel. With enactment of the Aviation and Transportation Security Act (ATSA) in November 2001, the Transportation Security Administration (TSA) was created, followed by the Homeland Security Act (which created the DHS) in November 2002. The ATSA mandates certain passenger, cargo, and baggage screening requirements, security awareness programs for airport personnel, and deployment of explosives detection systems. These security requirements have increased the time required in the terminal to reach aircraft gates, as well as bag check decisions. Wait time expectations at a particular airport may affect the travel mode choice made by passengers. These mode choices as they relate to EFD include aircraft charter and for hire operations and corporate and private aircraft ownership and operations.

3.2.1.4 Threat of Terrorism

As has been the case since September 11, 2001, terrorism incidents directed against either domestic or world aviation, or against other targets that directly affect either domestic or world aviation, remain a risk to achieving activity forecasts. Tighter security measures have restored much of the public's confidence in the integrity of U.S. and world aviation security systems. Any terrorist incident aimed at aviation during the planning period for the Master Plan Update, however, could immediately and significantly affect demand for aviation services in any or all of the aviation operations categories.

3.2.1.5 Summary

The cost of aviation fuel, unpredictable economic conditions, increased airport security measures, and threats of terrorism can and might affect the assumptions and results of the EFD Master Plan Update forecasts. Given how these circumstances can also affect forecast variables, the EFD planning forecasts indicate possible, rather than predicted, results.

3.2.2 GENERAL AVIATION OPERATIONS AND BASED AIRCRAFT, OTHER AIR TAXI OPERATIONS, AND MILITARY OPERATIONS

The FAA notes in its 2013 *Aerospace Forecasts* that general aviation operations in the United States at airports with FAA or contract ATCTs increased 0.6 percent in 2012, with a forecast decrease of 0.2 percent in 2013. These data parallel a decline in general aviation aircraft fleet size. The changes are taking place primarily in the single-engine and multi-engine (non-jet) part of the GA aircraft fleet, where aircraft purchase and maintenance, insurance, and fuel costs drive down discretionary flying. These trends are not expected to change in the near future.

The FAA forecasts a slight decrease in general aviation aircraft operations 2013 followed by 0.4 percent average annual increases in operations through 2030.

In its *Aerospace Forecasts 2013-2040*, The FAA notes:

> After growing rapidly for most of the past decade, and then slowing over the past few years, the most recent shipment activity indicates a cautiously optimistic outlook that the hard impact of the recession on the business jet market is coming to an end. The forecast calls for robust growth in the long-term outlook, driven by higher corporate profits and the growth of worldwide gross domestic product, though at rates lower than those predicted last year. Additionally, continued concerns about safety, security, and flight delays keep business aviation attractive relative to commercial air travel.

3.2.3 AIR CARGO

Based on the latest FAA *Aerospace Forecasts*, total domestic and international air cargo revenue-ton-miles increased at a CAGR of 1.6 percent between 2000 and 2012, led by a 3.9 percent CAGR in international cargo. Domestic freight/express revenue-ton-miles decreased at a CAGR of 1.6 percent during this period.

As relatively low volumes of cargo and mail are shipped by air through the Airport (cargo volumes at EFD are 0.0030 percent of the volumes at IAH and 0.0001 percent of the volumes at HOU), changes in the air cargo industry, particularly as a result of new security requirements, are not anticipated to have a large effect on the cargo carriers serving the Airport.

The initiation of regular air cargo service would have a significant effect on cargo volume at the Airport. Weekday (500 annual operations) service by one specialty cargo carrier carrying 1,000 pounds of cargo per flight would generate 500,000 annual pounds for each daily flight. Weekday (500 annual operations) service by one large express (or integrator) cargo carrier carrying 30,000 pounds per flight would generate 7.5 million annual pounds for each daily flight. Upon confirmation of such new service, HAS should initiate a planning review of cargo area requirements and related airfield requirements.

3.2.4 POLICY ISSUES: THE ROLE OF THE AIRPORT IN THE HOUSTON AIRPORT SYSTEM

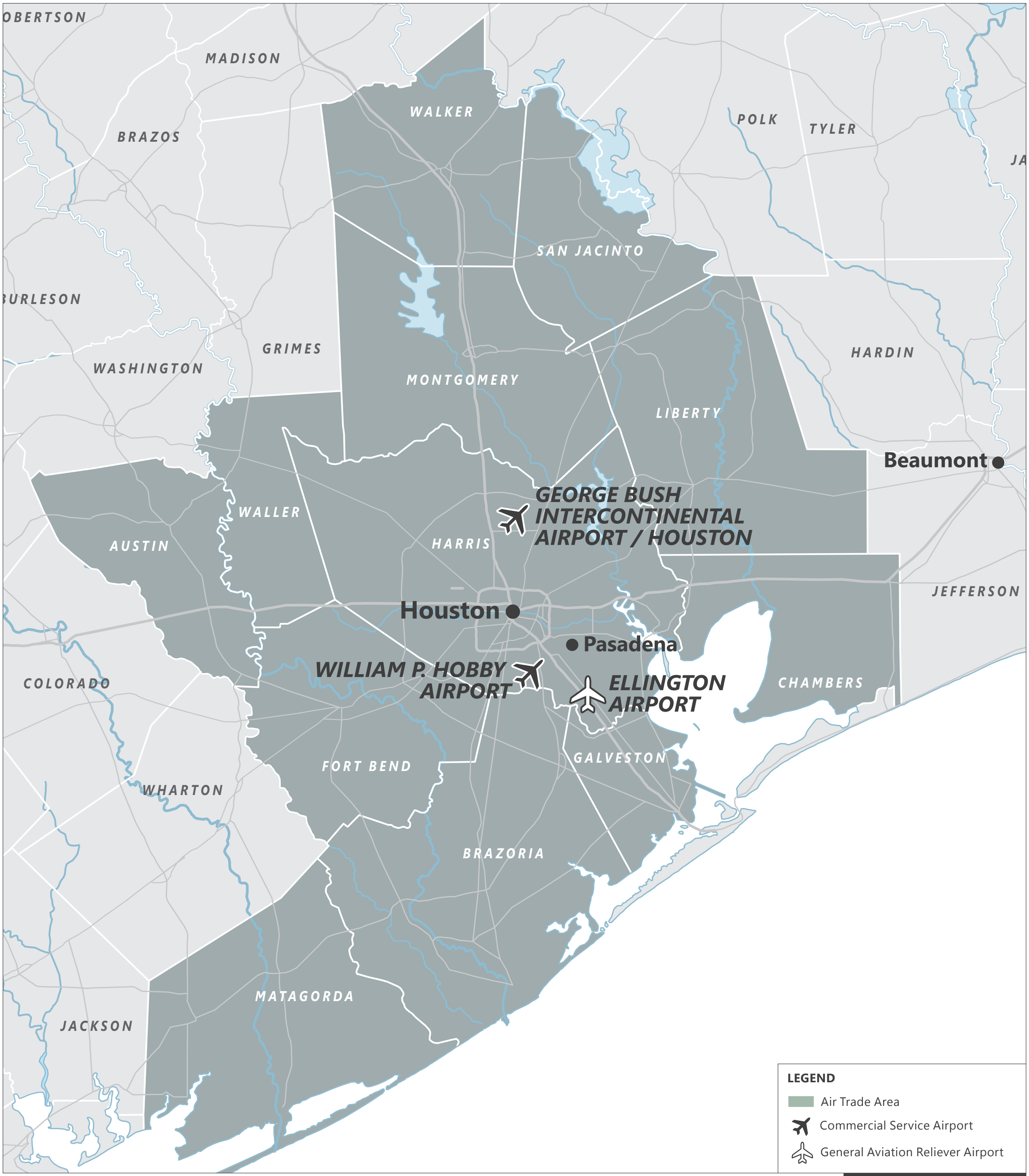
The role of the Airport within the Houston Airport System is driven by HAS's mandate to expand EFD's role as a Spaceport, aircraft manufacturing, or any number of non-traditional aeronautical functions.

Any recommended development for EFD in this Master Plan Update is intended to provide the facilities and services necessary to accommodate unconstrained aviation activity at the Airport through 2030. Airport facilities are to be adequate to accommodate and encourage increases in aircraft operations

3.2.5 SOCIOECONOMIC AND DEMOGRAPHIC TRENDS

Airport activity is sensitive to changes in local and national economic conditions. Barring other circumstances that may influence aviation activity, the strength of the local economy – measured by growth in population, per capita income, per capita retail sales, employment, and other economic indicators – typically correlates to the level of aviation activity at an airport. An airport located in a region with a strong economy will typically experience positive growth in aviation activity. The following subsections describe the socioeconomic and demographic trends in the Houston MSA, which serve as the basis for the aviation activity forecasts developed for the Master Plan Update.

Data are included for the Houston MSA, which consists of Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, Montgomery, Waller, and Austin Counties. The City of Houston lies in three counties: Harris, Fort Bend, and Montgomery. The Houston MSA is illustrated on **Exhibit 3-1**. The Houston MSA represents the Air Trade Area for the Airport.



SOURCE: Map Resources, 2007 (vector map graphics); Ricondo & Associates, Inc, November 2012.
PREPARED BY: Ricondo & Associates, Inc., November 2012.

EXHIBIT 3-1

Consolidated Metropolitan Statistical Area

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3.2.5.1 Population

The population of the Houston MSA grew at higher rates than the populations of the State of Texas and the nation, as shown in **Table 3-11**. From a base of approximately 5.6 million people in 2007, the area is projected to experience 2.3 percent average annual growth through 2012 to 6.2 million people. During the same period, the population of Texas grew an average of 1.9 percent annually and the population of the nation grew an average of 0.9 percent annually.

Table 3-11 also summarizes the projected Houston MSA growth in population through 2030 based on Woods & Poole Economics, Inc. data. The population of the Houston MSA is projected to grow at a CAGR of 2.0 percent, while the population of Texas is projected to grow at a CAGR of 1.7 percent and the population of the United States is projected to grow at a CAGR of 1.0 percent.

Table 3-11: Houston MSA Population (thousands)

YEAR	HOUSTON AREA CMSA	TEXAS	UNITED STATES
Historical			
2007	5,567	23,832	301,231
2008	5,702	24,309	304,094
2009	5,852	24,802	306,772
2010	5,976	25,253	309,330
2011	6,087	25,675	311,592
Projected			
2012	6,226	26,175	314,659
2013	6,368	26,679	317,791
2014	6,510	27,189	320,977
2015	6,652	27,700	324,187
2016	6,795	28,212	327,418
2017	6,939	28,727	330,673
2018	7,083	29,243	333,953
2019	7,227	29,762	337,251
2020	7,372	30,280	340,554
2025	8,097	32,884	357,194
2030	8,821	35,480	373,751
Compound Annual Growth Rate			
2007-2012	2.3%	1.9%	0.9%
2012-2030	2.0%	1.7%	1.0%

SOURCE: Woods & Poole Economics, Inc., accessed September 2013.
PREPARED BY: Ricondo & Associates, Inc., October 2013.

3.2.5.2 Employment and Income

The size and growth of the labor force are indications of the strength of a region's economic base. Between 2007 and 2012, employment is projected to increase significantly in the Houston MSA, from approximately 3.4 million to more than 3.6 million, or a CAGR of 1.6 percent, as shown in **Table 3-12**. Employment is projected to increase at a CAGR of 2.0 percent through 2030, slightly higher than employment in Texas (1.8 percent) and the United States (1.3 percent).

Table 3-12: Houston MSA Employment and Per Capita Personal Income

	EMPLOYMENT (THOUSANDS)			TOTAL PER CAPITA PERSONAL INCOME (IN 2005 DOLLARS)		
YEAR	HOUSTON AREA MSA	TEXAS	UNITED STATES	HOUSTON AREA MSA	TEXAS	UNITED STATES
Historical						
2007	3,368	14,024	179,900	$42,533	$35,164	$37,447
2008	3,471	14,388	179,645	$44,740	$36,363	$37,586
2009	3,449	14,229	174,209	$39,278	$33,485	$35,637
2010	3,449	14,286	173,767	$39,609	$33,980	$35,951
2011	3,535	14,537	175,363	$40,880	$34,845	$36,663
Projected						
2012	3,644	14,806	177,066	$41,285	$34,950	$36,741
2013	3,716	15,077	179,451	$41,860	$35,198	$36,907
2014	3,789	15,352	181,869	$42,078	$35,449	$37,209
2015	3,864	15,633	184,320	$42,392	$35,780	$37,601
2016	3,940	15,918	186,804	$42,779	$36,170	$38,057
2017	4,017	16,209	189,321	$43,220	$36,604	$38,559
2018	4,096	16,504	191,872	$43,704	$37,072	$39,094
2019	4,177	16,805	194,457	$44,225	$37,570	$39,657
2020	4,259	17,111	197,077	$44,783	$38,097	$40,245
2025	4,694	18,726	210,717	$48,057	$41,117	$43,520
2030	5,171	20,490	225,301	$52,141	$44,789	$47,347
Compounded Annual Growth Rate						
2007-2012	1.6%	1.1%	-0.3%	-0.6%	-0.1%	-0.4%
2012-2030	2.0%	1.8%	1.3%	1.3%	1.4%	1.4%

SOURCE: Woods & Poole Economics, Inc., accessed September 2013.
PREPARED BY: Ricondo & Associates, Inc., October 2013.

Per capita personal income in the Houston MSA decreased at a CAGR of 0.6 percent between 2007 and 2012. Woods & Poole Economics, Inc., projects that this rate will increase through the planning period at a CAGR of 1.3 percent, slightly lower than the 1.4 percent CAGR projected for Texas and the United States.

3.2.5.3 Houston MSA Gross Regional Product

As shown in **Table 3-13**, between 2007 and 2012, the Houston GRP decreased at a CAGR of 0.2 percent, while the Texas GDP decreased at a CAGR of 0.1 percent and the U.S. GDP decreased at a CAGR of 0.5 percent. Projected increases through 2030 are a 2.9 percent CAGR for the Houston MSA and the State of Texas and a 2.3 percent CAGR for the United States.

Table 3-13: Gross Regional/Domestic Product (in millions of 2005 dollars)

YEAR	HOUSTON AREA MSA	TEXAS	UNITED STATES
Historical			
2007	$314,462	$1,087,597	$13,209,790
2008	$322,791	$1,110,000	$13,028,025
2009	$296,053	$1,036,234	$12,691,919
2010	$295,251	$1,042,006	$12,666,042
2011	$302,600	$1,061,556	$12,787,312
Projected			
2012	$311,891	$1,082,392	$12,911,575
2013	$321,260	$1,138,125	$13,295,453
2014	$330,513	$1,169,858	$13,596,133
2015	$340,028	$1,202,472	$13,903,665
2016	$349,814	$1,235,995	$14,218,210
2017	$359,878	$1,270,449	$14,539,930
2018	$370,228	$1,305,856	$14,868,994
2019	$380,871	$1,342,253	$15,205,574
2020	$391,816	$1,379,660	$15,549,836
2025	$451,376	$1,582,908	$17,392,975
2030	$519,862	$1,816,109	$19,457,308
Compound Annual Growth Rate			
2007-2012	-0.2%	-0.1%	-0.5%
2012-2030	2.9%	2.9%	2.3%

SOURCE: Woods & Poole Economics, Inc., accessed September 2013.
PREPARED BY: Ricondo & Associates, Inc., October 2013.

3.3 Forecast Development Methodology Overview and Process

Several methodologies were reviewed to develop forecasts of aircraft operations at the Airport, as well as the projected fleet mix. These methodologies are described below.

3.3.1 MARKET SHARE ANALYSIS

The Airport's historical activity was compared with activity in the United States as a whole to determine the Airport's share of the U.S. market in each of the aviation activity categories. As appropriate, these historical shares were used to identify trends at the Airport through the planning period. The FAA's activity forecasts contained in *Aerospace Forecasts, Fiscal Years 2013-2033* were used as a basis for the market share analysis.

3.3.2 SOCIOECONOMIC REGRESSION ANALYSIS

Regression analyses are used to compare historical relationships between a dependent variable (e.g., general aviation operations) and one or more independent variables (socioeconomic factors, such as population, employment, per capita personal income) to forecast future growth in aviation activity.

3.3.3 TREND ANALYSIS

Trend analyses are used to determine the relative increase or decrease in aviation activity over time. Forecasts derived from a trend analysis suggest that external factors will affect future aviation activity in a manner similar to that experienced in the past. External factors may include the relative strength of the economy, effects of climate, and quality of life.

3.3.4 OTHER CONSIDERATIONS

In addition to the methodologies described above, the resulting forecasts were compared with other available forecasts addressing the particular aviation activity element being analyzed. These include the FAA TAF and the Texas Department of Transportation's regional aviation forecasts.

3.3.5 FORECAST DEVELOPMENT PROCESS

Typical forecast development involves relating trends in regional socioeconomic data with airport activity. However, over the past decade, activity results have been erratic compared to regional population and income, resulting in a relatively low fit between the data using regression analysis.

Therefore, the EFD forecasts were developed using assumptions about daily flight activity changes for general aviation, air taxi, and military operations at the Airport. Results were then compared with other forecast sources, such as historical trends, the FAA TAF and *Aerospace Forecasts*, and Texas DOT regional results.

The very low levels of air cargo activity at the Airport make trend analysis for air cargo forecasts difficult. As discussed in Section 3.2.3 if new cargo service is initiated, the expected annual cargo volumes should be evaluated and related forecasts prepared based on comparisons with national statistics and trend or regression analysis.

3.3.6 SPECIFIC ASSUMPTIONS AND RESULTS: BASELINE SCENARIO

Using the approach outlined in Section 3.3.5, the Baseline forecasts were developed for general aviation and other air taxi components of flight activity at the Airport. Forecasts for military and NASA aircraft operations are related to policy and operational decisions of their respective organizations and are not predictable using typical forecasting methodologies. These results were fixed at 2012 levels throughout the planning period.

3.3.6.1 General Aviation Aircraft Operations

EFD general aviation aircraft operations have been slowly declining as a percent of overall Texas and national general aviation operations, as reported in the 2012 FAA TAF and shown in **Table 3-14**. However, the activity at EFD may be constrained by the lack of hangar facilities and the loss of a flight school (Aerosim Flight Academy). Operations for the first 8 months of 2013, as reported by HAS, show a less marked decrease from 2012 data compared with previous year decreases. The Houston area's overall socioeconomic characteristics are strong with respect to those of the State and the nation, indicating that the Airport should be able to keep pace with growth in the State and nation. The FAA 2012 TAF forecasts a 0.7 percent annual increase in general aviation operations in Texas through 2030. This growth rate was selected for general aviation operations growth at EFD. Results are shown in **Table 3-15**, with annual operations forecast to number 69,313 in 2030. Operations by NASA (primarily T-38 training and cross-country sorties) are shown at 8,335 annually through 2030, and are included with the general aviation results.

Table 3-14: General Aviation Aircraft Operations Forecast Development

	ANNUAL GENERAL AVIATION OPERATIONS				
YEAR	EFD	TEXAS	UNITED STATES	EFD/TEXAS	EFD/UNITED STATES
Historical					
2007	108,875	5,298,397	80,312,797	2.1%	0.14%
2008	92,250	5,171,559	78,134,743	1.8%	0.12%
2009	88,739	4,813,455	73,811,433	1.8%	0.12%
2010	79,078	4,713,116	71,456,331	1.7%	0.11%
2011	76,968	4,647,810	70,844,120	1.7%	0.11%
2012	61,683	4,719,790	70,514,484	1.3%	0.09%
Forecast					
2013		4,748,212	70,801,188		
2014		4,777,085	71,092,547		
2015		4,806,414	71,384,736		
2020		4,960,279	72,889,580		
2030		5,307,883	76,253,080		
Compounded Annual Growth Rate					
2007 - 2012	-10.7%	-2.3%	-2.6%		
2009 - 2012	-11.4%	-0.7%	-1.5%		
2012 - 2030		0.7%	0.4%		

SOURCES Houston Airport System, *Statistical Report* http://www.fly2houston.com/TrafficStats, accessed October 2013; Federal Aviation Administration, *Terminal Area Forecast,* December 2012.

PREPARED BY: Ricondo & Associates, Inc., October 2013.

Table 3-15: General Aviation Aircraft Operations Forecasts (including NASA) - Baseline

YEAR	ITINERANT	ITINERANT SHARE	LOCAL	LOCAL SHARE	GENERAL AVIATION TOTAL	NASA	TOTAL
Historical							
2007	68,692	63.1%	40,183	36.9%	108,875	9,825	118,700
2008	59,963	65.0%	32,287	35.0%	92,250	9,403	101,653
2009	57,682	65.0%	31,057	35.0%	88,739	10,700	99,439
2010	51,400	65.0%	27,678	35.0%	79,078	13,418	92,496
2011	50,029	65.0%	26,939	35.0%	76,968	11,177	88,145
2012	40,094	65.0%	21,589	35.0%	61,683	8,335	70,018
Forecast							
2013	40,510	65.2%	21,574	34.8%	62,084	8,335	70,419
2014	40,929	65.5%	21,558	34.5%	62,487	8,335	70,822
2015	41,352	65.7%	21,541	34.3%	62,894	8,335	71,229
2016	41,779	66.0%	21,523	34.0%	63,302	8,335	71,637
2017	42,210	66.2%	21,504	33.8%	63,714	8,335	72,049
2018	42,645	66.5%	21,483	33.5%	64,128	8,335	72,463
2019	43,083	66.7%	21,461	33.3%	64,545	8,335	72,880
2020	43,526	67.0%	21,439	33.0%	64,964	8,335	73,299
2021	43,972	67.2%	21,414	32.8%	65,387	8,335	73,722
2022	44,423	67.5%	21,389	32.5%	65,812	8,335	74,147
2023	44,877	67.7%	21,363	32.3%	66,240	8,335	74,575
2024	45,335	68.0%	21,335	32.0%	66,670	8,335	75,005
2025	45,798	68.2%	21,306	31.8%	67,103	8,335	75,438
2026	46,264	68.5%	21,275	31.5%	67,540	8,335	75,875
2027	46,735	68.7%	21,244	31.3%	67,979	8,335	76,314
2028	47,210	69.0%	21,211	31.0%	68,420	8,335	76,755
2029	47,689	69.2%	21,176	30.8%	68,865	8,335	77,200
2030	48,172	69.5%	21,141	30.5%	69,313	8,335	77,648
Compound Annual Growth Rate							
2007 - 2012	-10.2%		-11.7%		-10.7%	-3.2%	-10.0%
2012 - 2013	1.0%		-0.1%		0.6%	0.0%	0.6%
2012 - 2015	1.0%		-0.1%		0.6%	0.0%	0.6%
2015 - 2020	1.0%		-0.1%		0.6%	0.0%	0.6%
2020 - 2030	1.0%		-0.1%		0.6%	0.0%	0.6%
2012 - 2030	1.0%		-0.1%		0.6%	0.0%	0.6%

NOTE: Total may not add due to rounding.

SOURCES: Houston Airport System, *Statistical Report* http://www.fly2houston.com/TrafficStats, accessed October 2013 (Historical); Ricondo & Associates, Inc. (Forecast), October 2013.
PREPARED BY: Ricondo & Associates, Inc., October 2013.

3.3.6.2 Other Air Taxi Operations

Other air taxi activity at EFD increased significantly from 2007 through 2012, but has slowed over the past 3 years. Growth rates were considerably higher than growth rates in Texas and the nation with respect to air taxi activity, as reported in the 2012 FAA TAF, and as shown in **Table 3-16**. Other air taxi operations for the first 8 months of 2013, as reported by HAS, increased over 2012 numbers compared with previous years data. The FAA 2012 TAF forecasts a 2.0 percent annual increase in other air taxi operations in the State of Texas through 2030. This forecast growth rate was selected for other air taxi growth at EFD through the planning period. Results are shown in **Table 3-17**, with annual air taxi operations forecast to number 12,607 in 2030.

Table 3-16: Other Air Taxi Operations Forecast Development – Baseline

	ANNUAL OTHER AIR TAXI OPERATIONS				
YEAR	EFD	TEXAS	UNITED STATES	EFD/TEXAS	EFD/UNITED STATES
Historical					
2007	4,450	931,320	14,578,997	0.48%	0.03%
2008	7,150	869,367	13,820,662	0.82%	0.05%
2009	9,748	731,549	12,279,615	1.33%	0.08%
2010	8,592	758,483	12,130,641	1.13%	0.07%
2011	8,160	728,846	11,966,708	1.12%	0.07%
2012	8,827	740,909	11,899,620	1.19%	0.07%
Forecast					
2013		758,108	12,037,989		
2014		777,755	12,245,165		
2015		795,972	12,447,464		
2020		874,326	13,293,078		
2030		1,058,462	15,154,545		
Compound Annual Growth Rate					
2007 - 2012	14.7%	-4.5%	-4.0%		
2009 - 2012	-3.3%	0.4%	-1.0%		
2012 – 2030		2.0%	1.4%		

SOURCES: Houston Airport System, *Statistical Report* http://www.fly2houston.com/TrafficStats, accessed October 2013; Federal Aviation Administration, *Terminal Area Forecast*, December 2012.

PREPARED BY: Ricondo & Associates, Inc., October 2013.

Table 3-17: Other Air Taxi Forecasts - Baseline

YEAR	TOTAL
Historical	
2007	4,450
2008	7,150
2009	9,748
2010	8,592
2011	8,160
2012	8,827
Forecast	
2013	9,004
2014	9,184
2015	9,367
2016	9,555
2017	9,746
2018	9,941
2019	10,139
2020	10,342
2021	10,549
2022	10,760
2023	10,975
2024	11,195
2025	11,419
2026	11,647
2027	11,880
2028	12,118
2029	12,360
2030	12,607
Compound Annual Growth Rate	
2007 - 2012	14.7%
2012 - 2013	2.0%
2012 - 2015	2.0%
2015 - 2020	2.0%
2020 - 2030	2.0%
2012 - 2030	2.0%

SOURCES: Houston Airport System, *Statistical Report* http://www.fly2houston.com/TrafficStats, accessed October 2013 (Historical); Ricondo & Associates, Inc. (Forecast), October 2013.

PREPARED BY: Ricondo & Associates, Inc., October 2013.

3.3.6.3 Operations Forecast Summary

Aircraft operations forecasts by category are presented in **Table 3-18** and **Exhibit 3-2.** Baseline Scenario forecast CAGR results for aircraft operations at EFD for 2012 through 2030 are as follows:

General Aviation	0.6 percent (61,683 in 2012 – 69,313 in 2030)
NASA	0.0 percent (8,335 in 2012 – 8,335 in 2030)
Other Air Taxi	2.0 percent (8,827 in 2012 – 12,607 in 2030)
Military	0.0 percent (27,197 in 2012 – 27,200 in 2030)
Total	0.6 percent (106,042 in 2012 – 117,455 in 2030)

3.3.6.4 Comparison with Other Forecasts

EFD Master Plan Update Baseline Scenario CAGR (2012 – 2030)	0.57 percent
2012 FAA TAF CAGR (2012 – 2030)	0.23 percent
Market Share 2013 FAA Aerospace Forecasts (2012-2030)	0.23 percent
Texas DOT 2010 Forecast for HOU CAGR (2008 – 2030)	1.02 percent

The forecast results are compared to the FAA TAF and the FAA Aerospace Forecasts, as shown graphically on **Exhibit 3-3**.

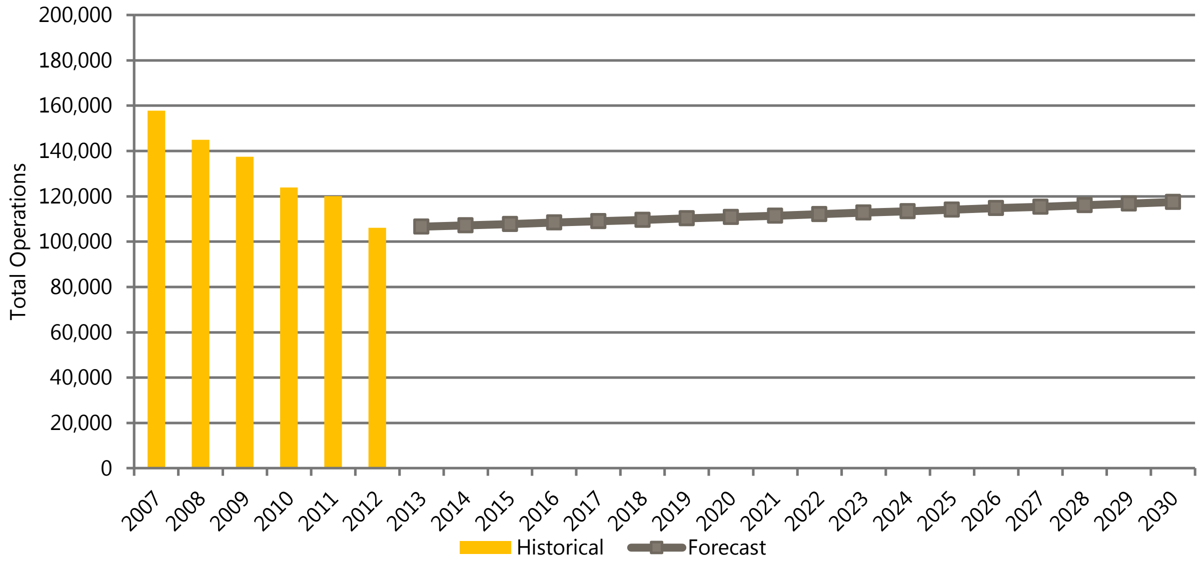
Table 3-18: Historical and Forecast Aircraft Operations - Baseline

YEAR	AIR CARRIER	AIR TAXI	GENERAL AVIATION + NASA	MILITARY	AIRPORT TOTAL
Historical					
2007	48	4,450	118,700	34,531	157,729
2008	7	7,150	101,653	36,168	144,978
2009		9,748	99,439	28,215	137,402
2010		8,592	92,496	22,823	123,911
2011		8,160	88,145	23,734	120,039
2012		8,827	70,018	27,197	106,042
Forecast					
2013		9,004	70,419	27,200	106,623
2014		9,184	70,822	27,200	107,206
2015		9,367	71,229	27,200	107,796
2016		9,555	71,637	27,200	108,392
2017		9,746	72,049	27,200	108,995
2018		9,941	72,463	27,200	109,604
2019		10,139	72,880	27,200	110,219
2020		10,342	73,299	27,200	110,841
2021		10,549	73,722	27,200	111,471
2022		10,760	74,147	27,200	112,107
2023		10,975	74,575	27,200	112,750
2024		11,195	75,005	27,200	113,400
2025		11,419	75,438	27,200	114,057
2026		11,647	75,875	27,200	114,722
2027		11,880	76,314	27,200	115,394
2028		12,118	76,755	27,200	116,073
2029		12,360	77,200	27,200	116,760
2030		12,607	77,648	27,200	117,455
Compound Annual Growth Rate					
2007 - 2012	-100.0%	14.7%	-10.0%	-4.7%	-7.6%
2012 - 2013	-	2.0%	0.6%	0.0%	0.5%
2012 - 2015	-	2.0%	0.6%	0.0%	0.5%
2015 - 2020	-	2.0%	0.6%	0.0%	0.6%
2020 - 2030	-	2.0%	0.6%	0.0%	0.6%
2012 - 2030	-	2.0%	0.6%	0.0%	0.6%

SOURCES: Houston Airport System, *Statistical Report* http://www.fly2houston.com/TrafficStats, accessed October 2013 (Historical); Ricondo & Associates, Inc. (Forecast), October 2013.

PREPARED BY: Ricondo & Associates, Inc., October 2013.

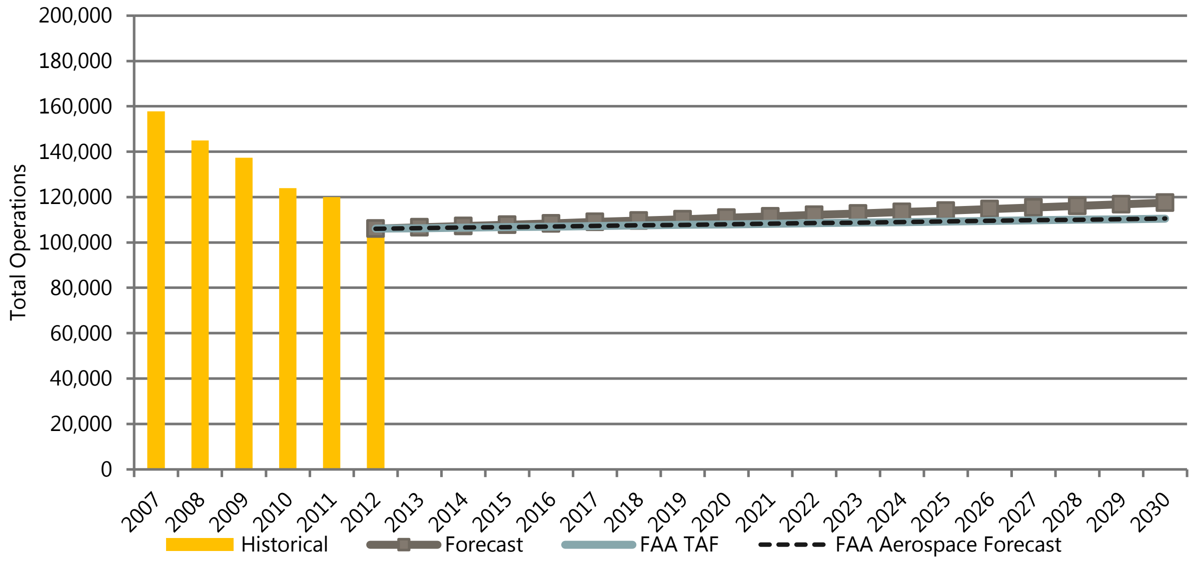
Exhibit 3-2: Historical and Forecast Total Aircraft Operations - Baseline



SOURCES: Houston Airport System, *Statistical Report* http://www.fly2houston.com/TrafficStats, accessed October 2013 (Historical); Ricondo & Associates, Inc. (Forecast), October 2013.

PREPARED BY: Ricondo & Associates, Inc., October 2013.

Exhibit 3-3: Historical and Forecast Total Aircraft Operations—FAA Comparison



SOURCES: Houston Airport System, *Statistical Report* http://www.fly2houston.com/TrafficStats, accessed October 2013 (Historical); Federal Aviation Administration, *Terminal Area Forecast*, December 2012 (Forecast), Federal Aviation Administration, *Aerospace Forecasts FY 2013-2033* (Forecast), Ricondo & Associates, Inc. (Forecast), October 2013.

PREPARED BY: Ricondo & Associates, Inc., October 2013.

3.3.6.5 Based Aircraft

The decline in the number of based aircraft at EFD from 2007 through 2012 is similar to the declines throughout Texas and the United States. EFD's share of based aircraft in Texas and in the United States has remained relatively constant, as shown in **Table 3-19**. The FAA 2012 *Terminal Area Forecast* shows a 1.09 percent average annual increase from 2012 to 2030 in the number of based aircraft in Texas and a 0.86 percent average annual increase in the number of nationwide based aircraft. Because of the relative strength of the Houston and Texas economies compared to the United States economy, the FAA TAF annual percentage increase for Texas was selected for the EFD based aircraft forecasts. Results are shown in **Table 3-20**. The number of based aircraft at EFD is forecast to increase from 214 in 2012 to 260 in 2030.

Table 3-19: Based Aircraft Forecast Development - Baseline

	BASED AIRCRAFT				
YEAR	EFD	TEXAS	UNITED STATES	EFD/TEXAS	EFD/UNITED STATES
Historical					
2007	261	14,611	200,064	1.79%	0.13%
2008	227	11,516	176,040	1.97%	0.13%
2009	257	12,340	177,875	2.08%	0.14%
2010	173	11,535	165,860	1.50%	0.10%
2011	219	11,653	167,608	1.88%	0.13%
2012	214	11,794	169,240	1.81%	0.13%
Forecast					
2013		11,911	170,633		
2014		12,043	172,042		
2015		12,180	173,444		
2020		12,831	181,035		
2030		14,325	197,357		
Compound Annual Growth Rate					
2007 - 2012	-3.9%	-4.2%	-3.3%		
2009 - 2012	-5.9%	-1.5%	-1.6%		
2012 – 2030		1.1%	0.9%		

SOURCES:Houston Airport System, *Statistical Report* http://www.fly2houston.com/TrafficStats, accessed October 2013; Houston Airport System Revised FAA Form 5010-1 for 2011 and 2012 (Historical); Federal Aviation Administration, *Terminal Area Forecast* (Forecast), December 2012.

PREPARED BY: Ricondo & Associates, Inc., October 2013.

Table 3-20: Based Aircraft Forecasts for Ellington Airport - Baseline

YEAR	SINGLE ENGINE	MULTI-ENGINE	JET	HELICOPTER	OTHER	TOTAL
Historical						
2007	124	31	62	5	39	261
2008	101	25	56	3	42	227
2009	141	29	60	3	24	257
2010	90	24	56	3	-	173
2011	143	25	42	8	1	219
2012	140	25	40	8	1	214
Forecast						
2013	141	25	41	9	-	216
2014	142	25	43	9	-	219
2015	142	25	44	9	-	220
2016	143	25	46	9	-	223
2017	144	25	48	9	-	226
2018	145	25	49	9	-	228
2019	146	25	51	9	-	231
2020	147	25	53	9	-	234
2021	148	25	54	10	-	237
2022	149	25	56	10	-	240
2023	150	25	58	10	-	243
2024	151	25	59	10	-	245
2025	151	25	61	10	-	247
2026	152	25	62	10	-	249
2027	153	25	64	10	-	252
2028	154	25	66	10	-	255
2029	155	25	67	10	-	257
2030	156	25	69	10	-	260
Compound Annual Growth Rate						
2007 - 2012	2.5%	-4.2%	-8.4%	9.9%	-51.9%	-3.9%
2012 - 2013	0.7%	0.0%	2.5%	12.5%	-	0.9%
2012 - 2030	0.6%	0.0%	3.1%	1.2%	-	1.1%

SOURCES:Houston Airport System, *Statistical Report* http://www.fly2houston.com/TrafficStats, accessed October 2013; Houston Airport System Revised FAA Form 5010-1 for 2011 and 2012 (Historical); Federal Aviation Administration, *Terminal Area Forecast* (Forecast), December 2012.

PREPARED BY: Ricondo & Associates, Inc., October 2013.

In the nation, the numbers of single-engine and multi-engine based aircraft have been slowly decreasing whereas the number of single-engine aircraft at EFD has increased an average of 2.5 percent per year from 2007 through 2012, as also shown in Table 3-20. In recent years, the number of jet aircraft based at EFD has decreased while the national number has increased. The decrease at EFD includes some changes within the NASA and military counts. The FAA *Aerospace Forecasts 2012 – 2032* forecasts the number of piston aircraft to decrease at an average annual rate of 0.3 percent, while the number of jet aircraft is forecast to increase an average of 2.9 percent annually. Based on historical results and the trends, the number of single-engine aircraft based at EFD is forecast to increase at a CAGR of 0.6 percent, while the number of multi-engine aircraft based at EFD is forecast to remain at current levels through the planning period. The number of based jet aircraft is forecast to increase at a CAGR of 3.1 percent through 2030. Total based aircraft at the Airport are forecast to number 260 in 2030.

3.3.6.6 Spacecraft-Related Operations

The Houston Airport System is currently analyzing the requirements for spaceflight operations at EFD. (See *Ellington Spaceport: Economics and Business Study*, prepared by XSC, August 2012.) These operations would initially be limited to suborbital flights and lighter-weight launch vehicles. The markets that could be served by spacecraft able to fly out of EFD are those that show the greatest prospects for growth in the coming decade, including commercial suborbital human spaceflights and the growing interest in low-cost spacecraft capable of carrying small satellites.

The forecasts of potential spaceflight operations prepared for HAS show various scenarios for EFD, with as many as 60 suborbital and 9 orbital launches per year (robust scenario). Assuming two operations per vehicle capable of self-launch and three operations per piggyback vehicles, this translates to 138 to 207 annual operations. This level of activity is very small (averaging two to four operations per week) compared with other flight operations at EFD, and would not produce a significant change in the annual operations results for the Airport; therefore, they are not shown in the forecast tables.

These spacecraft and associated operations would have specialized facility and airfield requirements, as will be discussed later in this document.

3.3.6.7 Air Cargo

As noted in Section 3.2.3, air cargo carried to or from the Airport or cargo aircraft operations represent a very small percentage of overall activity at the Airport and within the HAS. Typical growth rates for either weight carried or aircraft operations, such as reported in the FAA *Aerospace Forecasts*, would not increase activity at EFD significantly by 2030.

Threshold events, such as the return of scheduled air cargo operations or the location and operation of a cargo center at the Airport would generate demand. Depending on the scale of these potential operations, analysis would be required to determine the capacity of the airfield to accommodate both the number and size of aircraft associated with increased cargo demand.

3.3.7 PEAK PERIOD AIRCRAFT OPERATIONS

The derivation of peak month and peak month average day (PMAD) activity at an airport is based on the historical ratio of peak month activity to annual activity, and for PMAD the peak month activity divided by the number of days in the month for. At EFD, the peak month for operations in 2012 was October. Development of PMAD and peak hour activity for the forecast years is shown in **Table 3-21**. PMAD operations are forecast to increase from 359 in 2012 to 398 in 2030. Peak hour operations are based on ATCT counts for 2012 and indicate that the peak 6-hour period for the day is noon to 6:00 p.m. Assuming that approximately one third of operations during this period occur in the peak hour, 51 peak hour operations occurred in 2012, increasing to 56 peak hour operations in 2030.

Table 3-21: Peak Hour Aircraft Operations Forecasts - Baseline

		ACTUAL	**FORECAST**		
		2012	**2015**	**2020**	**2030**
Annual Operations		106,042	107,796	110,842	117,455
Peak Month Operations Ratio (October 2012)		0.105	0.105	0.105	0.105
Peak Month Operations		11,134	11,319	11,638	12,333
Peak Month Average Day (Peak Month / 31)		359	365	375	398
6 Hour Peak Period Ratio (noon – 6:00 p.m.)		0.427	0.427	0.427	0.427
Peak Period Operations (noon – 6:00 p.m.)		153	156	160	170
Peak Hour Operations (assuming 33% of Peak Period Operations)		51	51	53	56
PEAK HOUR BY OPERATIONS TYPE	**PERCENT OF TOTAL DAILY OPERATIONS**				
IFR	16.4%	8	8	9	9
VFR Itinerant	12.3%	6	6	7	7
VFR Local	59.2%	30	30	31	33
NASA Local	8.0%	4	4	4	4
Other	4.2%	2	2	2	2
PEAK HOUR BY AIRCRAFT TYPE	**PERCENT OF TOTAL DAILY OPERATIONS**				
Single Engine	60.0%	30	31	32	34
Multi-engine	13.0%	7	7	7	7
Jet/NASA	23.0%	12	12	12	13
Military	4.0%	2	2	2	2

NOTE: Totals may not add due to rounding.

ASSUMPTIONS:

1/ Assuming 2012 base year results as recorded by EFD ATCT personnel

2/ Internal ratios do not change over the planning period.

3/ Peak hour aircraft type ratios are based on FAA Form 5010 (2011) based aircraft ratios.

4/ Peak hour operations by approach type are based on 2012 ATCT records

SOURCES: Houston Airport System, *Statistical Report* http://www.fly2houston.com/TrafficStats, accessed October 2013; Houston Airport System Revised FAA Form 5010-1 for 2011 and 2012 (Historical); Ricondo & Associates, Inc. (Forecast), October 2013.

PREPARED BY: Ricondo & Associates, Inc., October 2013.

It should be noted that fleet mix information was not available for this analysis. Assuming that operations are proportional to based aircraft counts at the Airport, 60 percent of the peak hour operations would be by single engine land aircraft, 13 percent would be by multi-engine land aircraft, 23 percent would be by jet (including NASA) aircraft, and 4 percent would be by other aircraft. These percentages would vary throughout the day, e.g., the number of jet operations might be higher during early morning and late afternoon/evening hours and the number of single-engine land aircraft operations for pilot training might be higher on weekends.

3.4 Forecast Scenarios

To test the sensitivity of the Baseline forecasts to changes in conditions that might affect aviation activity at the Airport, a Low Growth Scenario and a High Growth Scenario were developed, as described below.

3.4.1 LOW GROWTH SCENARIO

The Baseline forecasts include forecasts for general aviation operations increasing an average of 0.65 percent per year whereas the most recent five years have declined at an average of 10 percent per year declines. Other air taxi operations increased substantially between 2007 and 2012; however, these operations were relatively flat during the latter 3 years of that period. The Low Growth Scenario holds growth flat through 2030 for both general aviation and other air taxi operations, with NASA and military operations fixed at their lowest annual level in the 2007 – 2012 period (8,335 for NASA operations and 22,823 for military operations). The Low Growth Scenario reduces forecast operations to approximately 101,000 in 2030, compared with 117,455 in the Baseline Scenario—a 14 percent reduction. The Low Growth Scenario reduces the number of based aircraft to 214 from 261—an 18 percent reduction. Results of the Low Growth Scenario are shown in **Tables 3-22** and **3-23**.

Table 3-22: Historical and Forecast Total Operations – Low Growth Scenario

YEAR	AIR CARRIER	AIR TAXI	GENERAL AVIATION + NASA	MILITARY	AIRPORT TOTAL
Historical					
2007	48	4,450	118,700	34,531	157,729
2008	7	7,150	101,653	36,168	144,978
2009		9,748	99,439	28,215	137,402
2010		8,592	92,496	22,823	123,911
2011		8,160	88,145	23,734	120,039
2012		8,827	70,018	27,197	106,042
Forecast					
2013		8,160	70,018	22,823	101,001
2014		8,160	70,018	22,823	101,001
2015		8,160	70,018	22,823	101,001
2016		8,160	70,018	22,823	101,001
2017		8,160	70,018	22,823	101,001
2018		8,160	70,018	22,823	101,001
2019		8,160	70,018	22,823	101,001
2020		8,160	70,018	22,823	101,001
2021		8,160	70,018	22,823	101,001
2022		8,160	70,018	22,823	101,001
2023		8,160	70,018	22,823	101,001
2024		8,160	70,018	22,823	101,001
2025		8,160	70,018	22,823	101,001
2026		8,160	70,018	22,823	101,001
2027		8,160	70,018	22,823	101,001
2028		8,160	70,018	22,823	101,001
2029		8,160	70,018	22,823	101,001
2030		8,160	70,018	22,823	101,001
Compound Annual Growth Rate					
2007 - 2012	-100.0%	14.7%	-10.0%	-4.7%	-7.6%
2012 - 2013	-	-7.6%	0.0%	-16.1%	-4.8%
2012 - 2015	-	-2.6%	0.0%	-5.7%	-1.6%
2015 - 2020	-	0.0%	0.0%	0.0%	0.0%
2020 - 2030	-	0.0%	0.0%	0.0%	0.0%
2012 - 2030	-	-0.4%	0.0%	-1.0%	-0.3%

SOURCES:Houston Airport System, *Statistical Report* http://www.fly2houston.com/TrafficStats, accessed October 2013 (Historical); Ricondo & Associates, Inc. (Forecast), October 2013.

PREPARED BY: Ricondo & Associates, Inc., October 2013.

Table 3-23: Historical and Forecast Based Aircraft – Low Growth Scenario

YEAR	SINGLE ENGINE	MULTI-ENGINE	JET	HELICOPTER	OTHER	TOTAL
Historical						
2007	124	31	62	5	39	261
2008	101	25	56	3	42	227
2009	141	29	60	3	24	257
2010	90	24	56	3	-	173
2011	143	25	42	8	1	219
2012	140	25	40	8	1	214
Forecast						
2013	140	25	40	8	1	214
2014	140	25	40	8	1	214
2015	140	25	40	8	1	214
2016	140	25	40	8	1	214
2017	140	25	40	8	1	214
2018	140	25	40	8	1	214
2019	140	25	40	8	1	214
2020	140	25	40	8	1	214
2021	140	25	40	8	1	214
2022	140	25	40	8	1	214
2023	140	25	40	8	1	214
2024	140	25	40	8	1	214
2025	140	25	40	8	1	214
2026	140	25	40	8	1	214
2027	140	25	40	8	1	214
2028	140	25	40	8	1	214
2029	140	25	40	8	1	214
2030	140	25	40	8	1	214
Compound Annual Growth Rate						
2007 - 2012	2.5%	-4.2%	-8.4%	9.9%	-51.9%	-3.9%
2012 - 2013	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2012 - 2030	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

SOURCES:Houston Airport System, *Statistical Report* http://www.fly2houston.com/TrafficStats, accessed October 2013; Houston Airport System Revised FAA Form 5010-1 for 2011 and 2012 (Historical); Federal Aviation Administration, *Terminal Area Forecast* (Forecast), December 2012.

PREPARED BY: Ricondo & Associates, Inc., October 2013.

3.4.2 HIGH GROWTH SCENARIO

The High Growth Scenario is based on EFD's share of the FAA's *Terminal Area Forecast* results for the State of Texas. Between 2007 and 2012, EFD's share of Texas operations peaked in 2009. For general aviation and other air taxi operations, this share was applied to the 2030 FAA TAF for the State. The CAGR required to reach this level was then calculated based on 2012 operations. For general aviation operations (including NASA), this resulted in a high growth forecast of 106,189 in 2030, or a CAGR of 2.3 percent between 2012 and 2030. This calculation produces a high growth forecast for air taxi operations of 14,104 in 2030, with a CAGR from 2012 of 2.6 percent. Military operations are again held constant in the High Growth Scenario through the planning period. Therefore, the High Growth Scenario forecast for total EFD operations is 147,463 in 2030 with a CAGR from 2012 of 1.8 percent. For the High Growth Scenario based aircraft forecast, the average of the Baseline Scenario growth rate for single-engine aircraft (0.6 percent) and the historical growth rate from 2007 to 2012 (a CAGR of 2.5 percent) was used, resulting in a 1.5 percent CAGR from 2012 to 2030. For multi-engine based aircraft, a CAGR of 0.5 percent was selected. The Baseline Scenario CAGR for based jet aircraft of 3.1 percent was maintained in the High Growth Scenario with no change for helicopters, resulting in 289 based aircraft in 2030 under the High Growth Scenario and a CAGR for 2012 through 2030 of 1.7 percent. Results for the High Growth Scenario are shown in **Tables 3-24** and **3-25**.

3.4.3 BASELINE, LOW GROWTH, AND HIGH GROWTH FORECAST SCENARIO COMPARISON

A comparison of the Baseline, Low Growth, and High Growth Scenarios is shown on **Exhibits 3-4** and **3-5**. Total EFD operations are forecast to number 117,455 in 2030 in the Baseline Scenario compared with 101,001 in the Low Growth Scenario and 147,463 in the High Growth Scenario. The CAGRs from 2012 to 2030 are 0.6 percent (Baseline), -0.3 percent (Low Growth) and 1.8 percent (High Growth).

For based aircraft, the Baseline Scenario forecast of 261 in 2030 compares with 214 in the Low Growth Scenario and 289 in the High Growth Scenario. The based aircraft CAGRs from 2012 to 2030 are 1.1 percent (Baseline), 0.0 percent (Low Growth) and 1.7 percent (High Growth).

Table 3-24: Historical and Forecast Total Aircraft Operations – High Growth Scenario

YEAR	AIR CARRIER	AIR TAXI	GENERAL AVIATION + NASA	MILITARY	AIRPORT TOTAL
Historical					
2007	48	4,450	118,700	34,531	157,729
2008	7	7,150	101,653	36,168	144,978
2009	-	9,748	99,439	28,215	137,402
2010	-	8,592	92,496	22,823	123,911
2011	-	8,160	88,145	23,734	120,039
2012	-	8,827	70,018	27,197	106,042
Forecast			-		
2013		9,060	71,620	27,200	107,880
2014		9,299	73,263	27,200	109,762
2015		9,544	74,949	27,200	111,693
2016		9,796	76,679	27,200	113,675
2017		10,054	78,454	27,200	115,708
2018		10,319	80,275	27,200	117,794
2019		10,592	82,143	27,200	119,935
2020		10,871	84,060	27,200	122,131
2021		11,158	86,026	27,200	124,384
2022		11,452	88,044	27,200	126,696
2023		11,754	90,114	27,200	129,068
2024		12,064	92,237	27,200	131,501
2025		12,383	94,416	27,200	133,999
2026		12,709	96,652	27,200	136,561
2027		13,044	98,945	27,200	139,189
2028		13,389	101,298	27,200	141,887
2029		13,742	103,712	27,200	144,654
2030		14,104	106,189	27,200	147,493
Compound Annual Growth Rate					
2007 - 2012	-100.0%	14.7%	-10.0%	-4.7%	-7.6%
2012 - 2013	-	2.6%	2.3%	0.0%	1.7%
2012 - 2015	-	2.6%	2.3%	0.0%	1.7%
2015 - 2020	-	2.6%	2.3%	0.0%	1.8%
2020 - 2030	-	2.6%	2.4%	0.0%	1.9%
2012 - 2030	-	2.6%	2.3%	0.0%	1.8%

SOURCES:Houston Airport System, *Statistical Report* http://www.fly2houston.com/TrafficStats, accessed October 2013 (Historical); Ricondo & Associates, Inc. (Forecast), October 2013.

PREPARED BY: Ricondo & Associates, Inc., October 2013.

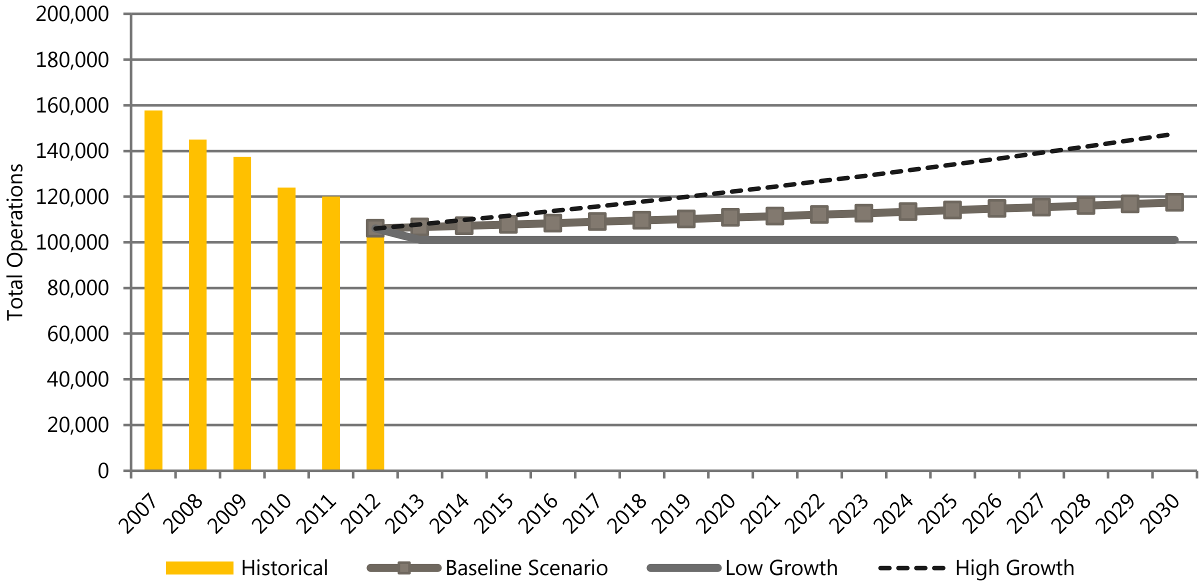
Table 3-25: Historical and Forecast Based Aircraft – High Growth Scenario

YEAR	SINGLE ENGINE	MULTI-ENGINE	JET	HELICOPTER	OTHER	TOTAL
Historical						
2007	124	31	62	5	39	261
2008	101	25	56	3	42	227
2009	141	29	60	3	24	257
2010	90	24	56	3	-	173
2011	143	25	42	8	1	219
2012	140	25	40	8	1	214
Forecast						
2013	142	25	41	9	-	217
2014	144	25	43	9	-	221
2015	146	25	44	9	-	224
2016	149	26	46	9	-	230
2017	151	26	48	9	-	234
2018	153	26	49	9	-	237
2019	155	26	51	9	-	241
2020	158	26	53	9	-	246
2021	160	26	54	10	-	250
2022	162	26	56	10	-	254
2023	165	26	58	10	-	259
2024	167	27	59	10	-	263
2025	170	27	61	10	-	268
2026	172	27	62	10	-	271
2027	175	27	64	10	-	276
2028	178	27	66	10	-	281
2029	180	27	67	10	-	284
2030	183	27	69	10	-	289
Compound Annual Growth Rate						
2007 - 2012	2.5%	-4.2%	-8.4%	9.9%	-51.9%	-3.9%
2012 - 2013	1.5%	0.5%	2.5%	8.2%	-	1.3%
2012 - 2030	1.5%	0.5%	3.1%	1.2%	-	1.7%

SOURCES:Houston Airport System, *Statistical Report* http://www.fly2houston.com/TrafficStats, accessed October 2013; Houston Airport System, Revised FAA Form 5010-1 for 2011 and 2012 (Historical); Federal Aviation Administration, *Terminal Area Forecast* (Forecast), December 2012.

PREPARED BY: Ricondo & Associates, Inc., October 2013.

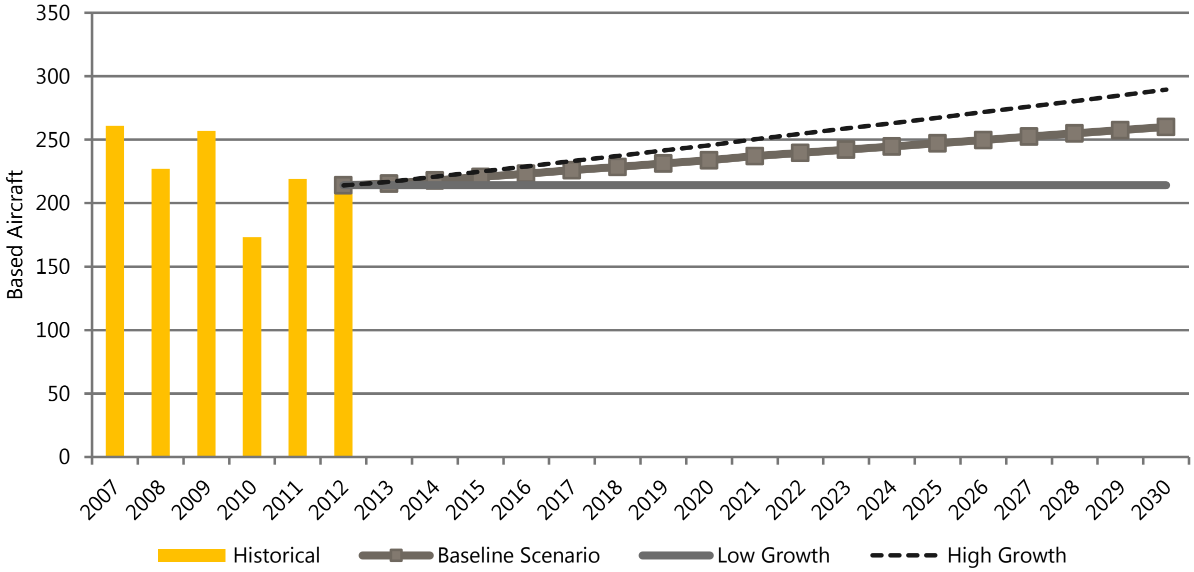
Exhibit 3-4: Total Aircraft Operations Growth Scenario Forecast Comparison



SOURCES: Houston Airport System, *Statistical Report* http://www.fly2houston.com/TrafficStats, accessed October 2013 (Historical); Ricondo & Associates, Inc. (Forecast), October 2013.

PREPARED BY: Ricondo & Associates, Inc., October 2013.

Exhibit 3-5: Based Aircraft Growth Scenario Forecast Comparison



SOURCES: Houston Airport System, *Statistical Report* http://www.fly2houston.com/TrafficStats, accessed October 2013 (Historical); Ricondo & Associates, Inc. (Forecast), October 2013.

PREPARED BY: Ricondo & Associates, Inc., October 2013.

4. Facility Requirements

The activity forecasts for EFD (summarized in Section 3) were compared with the existing capacity of each functional system at the Airport, as described in this section. If capacity gaps were identified, future facility requirements for the Airport were quantified.

The relationship between demand and capacity and how that relationship affects the planning of future facilities is complex. Numerous issues affect how efficiently a certain level of activity (i.e., demand) can be accommodated within a specific system or facility that has a maximum sustainable throughput (i.e., capacity). Acceptable levels of service or convenience vary by user, facility, and airport sponsor.

The purpose of the comparative analyses summarized in this section is to determine the relationship between demand and capacity in the context of various Airport systems, and to provide general assessments of the ability of existing facilities to accommodate future demand.

The analyses documented in this section are organized by functional system. For clarity, each system was assessed separately. Ultimately, however, the facility requirements for each system were combined in the Airport Development Plan. Four functional systems were considered:

- **Airfield Facilities** were considered to include airfield configuration, including runway orientation and the taxiway system, weather conditions, the aircraft fleet mix, and forecast operations. The ability of the existing airfield to accommodate forecast operational demand, in terms of runway capacity and design standards, was evaluated.
- **General Aviation and Airport Support Facilities** include:
    - FBO facilities
    - Corporate business operator facilities and T-hangars
    - Airport support facilities (i.e., Airport maintenance, Airport administration, operations, ARFF station, and fuel storage facility)
    - U.S. Customs and Border Protection facilities
- **Airport Ground Access** includes on- and off-Airport vehicular roadway, access, and circulation systems. The demand associated with these systems is driven by Airport user demand and the distribution of the various modes of transportation that serve the Airport and operate on the local roadways.

- **Airport Rail Access** addresses connecting vacant Airport land with the existing railroad right-of-way running along the western Airport boundary.

The methodologies used to determine facility requirements and capacity are in accordance with industry standards, with planning factors adjusted as appropriate to reflect actual Airport use characteristics. In calculating demand/capacity, the information presented in Sections 2 and 3 of this Master Plan Update were used, along with any additional information that more accurately reflects existing or future conditions. Planning experience at, and knowledge of, other airports was also used to estimate capacity. This approach ensured that capacity calculations would be sensitive to the specific requirements at EFD, and reflective of industry standards.

Consideration was also given to the siting of new development; this section provides a brief overview of the effects of introducing the following developments at EFD:

- Spaceport
- Air Cargo Facilities
- Aircraft Manufacturing Facilities
- Aircraft Maintenance, Repair, and Overhaul Facilities

4.1 Regulatory Changes

In 2012, the FAA issued AC 150/5300-13A, *Airport Design,* which was a major update of its previous AC on airport design. This update includes changes that affect the Airport. Change 1 to the updated AC has been published since.

One of the changes brought about by AC 150/5300-13A is the requirement for paved runway, taxiway, taxilane, and apron shoulders for those facilities accommodating ADG IV aircraft and higher, which applies to EFD, an ARC D-IV airport. The intent of the change is to protect jet engines that overhang the edge of the pavement from drawing in foreign objects resulting from the erosion of unprotected soils.

Also, a major overhaul of taxiway fillet requirements was introduced. It would be prudent to conduct a thorough taxiway fillets analysis at the Airport to evaluate compliance with the latest standards; however, such an analysis is not included in the scope of this Master Plan Update.

AC 150/5300-13A also revised land uses permitted inside the runway protection zone (RPZ). For example, public roadways are no longer permitted inside the RPZ. This change has a significant effect on the Runway 35L threshold at the Airport. Currently, the approach RPZ for Runway 35L intersects Old Galveston Road, which is a four-lane public roadway along the southwest boundary of the Airport. This roadway provides access to the west side of the Airport. The FAA plans to release further guidance on how to address existing public roadways within an RPZ. Therefore, no resolution regarding the public roadways (existing and future) within the EFD RPZs is provided in this Master Plan Update.

4.2 Airfield Facilities

4.2.1 AIRFIELD DESIGN STANDARDS

The planning and design of an airport and its airfield facilities are typically based on the airport's role and aircraft types using the airport. Airfield facilities must comply with planning and design standards, such as those set forth in AC 150/5300-13A, *Airport Design* (Change 1), to ensure that the range of aircraft projected to operate at the Airport can be accommodated.

The current ARC at EFD is D-IV. The following airfield limitations need to be addressed to upgrade the ARC to D-V:

- Separation would need to be increased between Taxiway H and Runway 17R-35L (currently only meets ADG IV standards);
- Runway and taxiway shoulders would need to be added; and
- Taxiway fillets would need to be evaluated for compliance with ADG V standards.

As part of the master planning process, the current ARC for the Airport was re-evaluated. The ARC is most often determined by the AAC and ADG of aircraft using or expected to use the airport on a regular basis (at least 500 operations a year); however, the FAA also considers local characteristics when determining an airport's ARC. Aircraft that use the EFD airfield on a regular basis are small general aviation aircraft, NASA-operated aircraft, and military aircraft. For each category, the most demanding aircraft type in terms of size and approach speed that use or is projected to use the Airport are as follows:

- General aviation aircraft: Gulfstream V or equivalent (ARC C-III) and Boeing 767-300 (ARC C-IV)
- NASA aircraft: McDonnell-Douglas C-9 zero gravity training aircraft (ARC C-III) and the Boeing 377 Super Guppy (ARC C-IV)[1]
- Military aircraft: Boeing 747-400 military charter aircraft (ARC D-V)

Although most general aviation aircraft serving the Airport with more than 500 annual operations are ARC A-I and B-I aircraft, larger general aviation aircraft, such as the Gulfstream V and the Boeing 767-300, also operate at the Airport. Additionally, NASA-operated aircraft, such as the McDonnell-Douglas C-9 and the Boeing 377 Super Guppy, operate at the Airport on a regular basis, but their annual operations may number less than 500. The Boeing 747 used for military charter operations is the most demanding aircraft in terms of airfield design standards, but it accounts for approximately 20 operations per year according to the Airport staff.

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[1] ftp://ftp.tc.faa.gov/NAPTF/AAS-100/AC%201505300-13%20Re-Write/App2/Aircraft%20Characteristics/WEBfiles/AirCharDBData1.htm; http://spaceflight.nasa.gov/station/assembly/superguppy/index.html; Accessed January 2014.

Based on discussions with HAS, it was determined that the current EFD ARC will remain D-IV; however, new airfield pavement is planned to be constructed to ADG V standards, unless it is in an area of the airfield exclusively used for small general aviation aircraft; in that case, ADG I or II design standards would be applied. The subsections that follow describe the assessment of the runways, taxiways, and airfield safety areas in relation to these standards.

4.2.2 RUNWAY SYSTEM

Based on current operations and field observations, several improvements to the existing runway system at the Airport that would increase safety and operational efficiency were identified. The runway length and runway shoulder requirements, the runway demand/capacity analysis, the effects of closing Runway 17L-35R, proposed Runway 4-22 exits, and requirements related to runway pavement strength are discussed in this section.

4.2.2.1 Runway Length

The FAA provides guidance on runway length requirements in AC 150/5325-4B, *Runway Length Requirements for Airport Design*. The determination of runway length requirements at an airport is based on the types of aircraft that use the airfield and on the frequency of their operations. At EFD, general aviation aircraft, military aircraft, and aircraft operated by NASA use the airfield.

General aviation aircraft account for the majority of operations at the Airport. Of the 214 based aircraft at the Airport in 2012, 65 percent were single-engine aircraft, 19 percent were jet aircraft, 12 percent were multi-engine aircraft, and 4 percent were helicopters. In the Low Growth Scenario described in Section 3, the number and share of based aircraft would remain the same through 2030. In the High Growth Scenario, the number of based aircraft would increase 1.7 percent annually. In this scenario, the share of single-engine aircraft would decrease to reach 64 percent in 2030 and the share of jet aircraft would increase to 24 percent.

Runway 17L-35R is used for training by the Flying Tigers Flight School, the U.S. Coast Guard and Army National Guard helicopters, and other flight schools not based at the Airport. The Flying Tigers Flight School owns 11 light single-engine aircraft and two twin-engine aircraft. The nearby flight schools using this runway were assumed to operate similar aircraft types as Flying Tigers. Runway 17L-35R is 4,609 feet long and is appropriate to accommodate touch-and-go operations and helicopter training operations.

Runways 17R-35L and 4-22 are 9,000 feet long and 8,001 feet long, respectively. The general aviation aircraft using these runways are single-engine aircraft, multi-engine aircraft, and jet aircraft. The aircraft requiring a long takeoff/landing runway length depart from/arrive on Runway 17R-35L. Based on observations and conversations with ATC staff, the aircraft types selected to represent the diverse general aviation aircraft fleet using the Airport are listed in **Table 4-1**. Table 4-1 also includes potential additions to the fleet of aircraft operating at the Airport, such as cargo aircraft or spacecraft, which could initiate operations during the planning period.

Table 4-1: Representative Aircraft Types

AIRCRAFT CATEGORY	REPRESENTATIVE AIRCRAFT
Single-engine Piston Aircraft	Grumman Cheetah
Multi-engine Piston Aircraft	King Air 200
Small Jet	Cessna Citation
Midsize Jet	Gulfstream 550
Large Jet	MD-82, Boeing 767-300
Jumbo Jet	Boeing 747-400
Cargo Aircraft	Boeing 757-200F, Boeing 767-300F, MD-11F, Boeing 747-400F
Spacecraft	Virgin Galactic White Knight II, Stratolaunch Carrier Aircraft

SOURCES: Ricondo & Associates, Inc.; Jacobsen/Daniels Associates, LLC, January 2014.
PREPARED BY: Ricondo & Associates, Inc., February 2014.

The *Ellington Spaceport Economics and Business Study*[2] attached in **Appendix D**, identified two preferred runway lengths to accommodate spaceport operations:

- A 10,000-foot-long runway would be required to accommodate spacecraft up to the size of the Virgin Galactic White Knight II (specifically, this runway length would allow for a landing immediately after takeoff, should the need arise, with a full load of fuel and oxidizer).
- A 12,000-foot-long runway would be required to accommodate the Stratolaunch Carrier Aircraft.

The takeoff and landing runway length requirements for each of these aircraft types (except the spacecraft) were evaluated using the following underlying assumptions:

- Maximum takeoff weight (MTOW) for takeoff length requirements and maximum landing weight (MLW) for landing length requirements
- Sea level altitude
- Zero wind
- Dry runway
- No runway slope
- When several flap configurations are available for a specific aircraft, the configuration providing the best performance was selected.
- When several engine types are available, the engine providing the best performance was selected.

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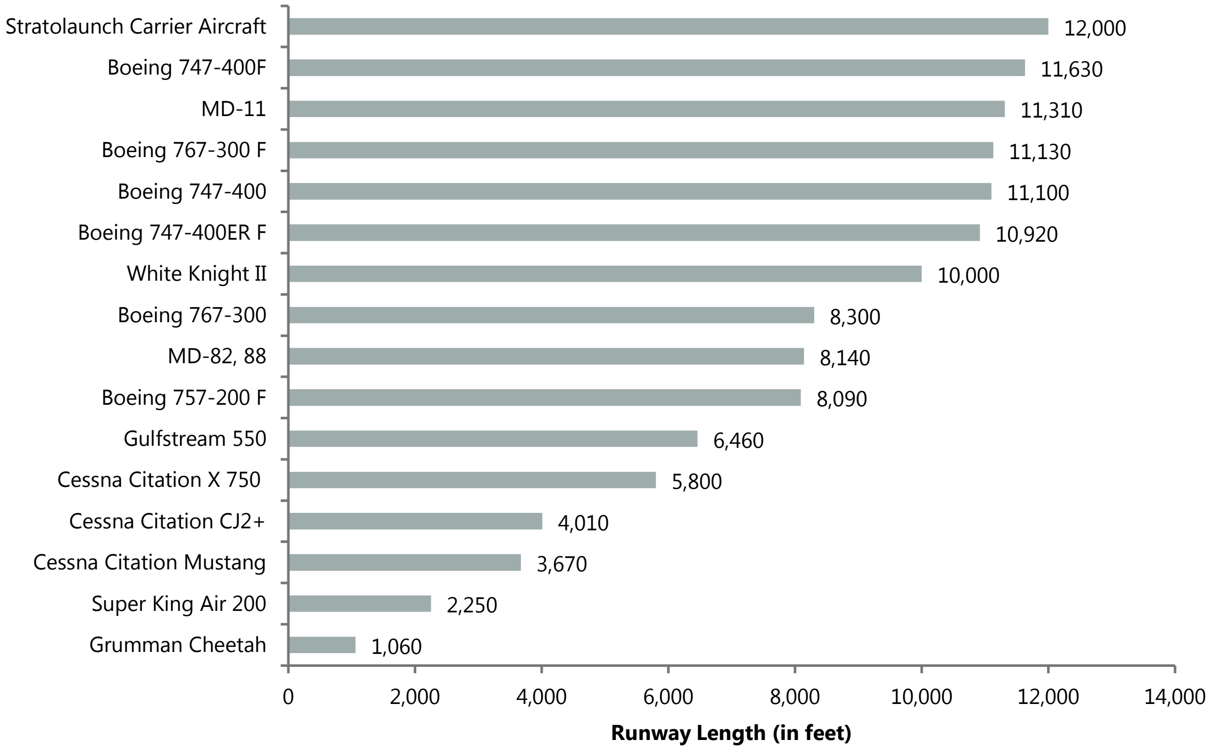
[2] XARC, *Ellington Spaceport Economics and Business Study*, August 2013.

- A temperature of 92°F (the mean maximum temperature during the hottest month at EFD)
- For large turbine-engine-powered aircraft, landing length requirements were adjusted to take into account that any aircraft should be able to land and stop within 60 percent of the effective runway length, according to 14 CFR Part 135.385 (b).

Exhibit 4-1 shows the takeoff length requirements for the representative aircraft types based on the assumptions presented above. All representative business jet aircraft, single-engine piston aircraft, and multi-engine piston aircraft at MTOW are able to depart from Runways 17R-35L and 4-22. Among passenger jet aircraft, the MD-82/-88 and the Boeing 767-300 are able to depart from Runway 17R-35L when they are at MTOW. However, at MTOW, the Boeing 747-400 and other freighter aircraft, except for the Boeing 757-200F, cannot take off from any runway at the Airport because it requires a runway longer than 9,000 feet. However, these runway length requirements were determined considering MTOW at an outside air temperature of 92°F, and it is reasonable to assume that some of these aircraft do/will not depart at MTOW, or depart in lower temperatures. In conclusion, the existing runway lengths at the Airport meet the takeoff requirements of the non-military and non-NASA aircraft types currently operating at the Airport, but would not meet the requirements for other aircraft types at MTOW that may serve the Airport in the future.

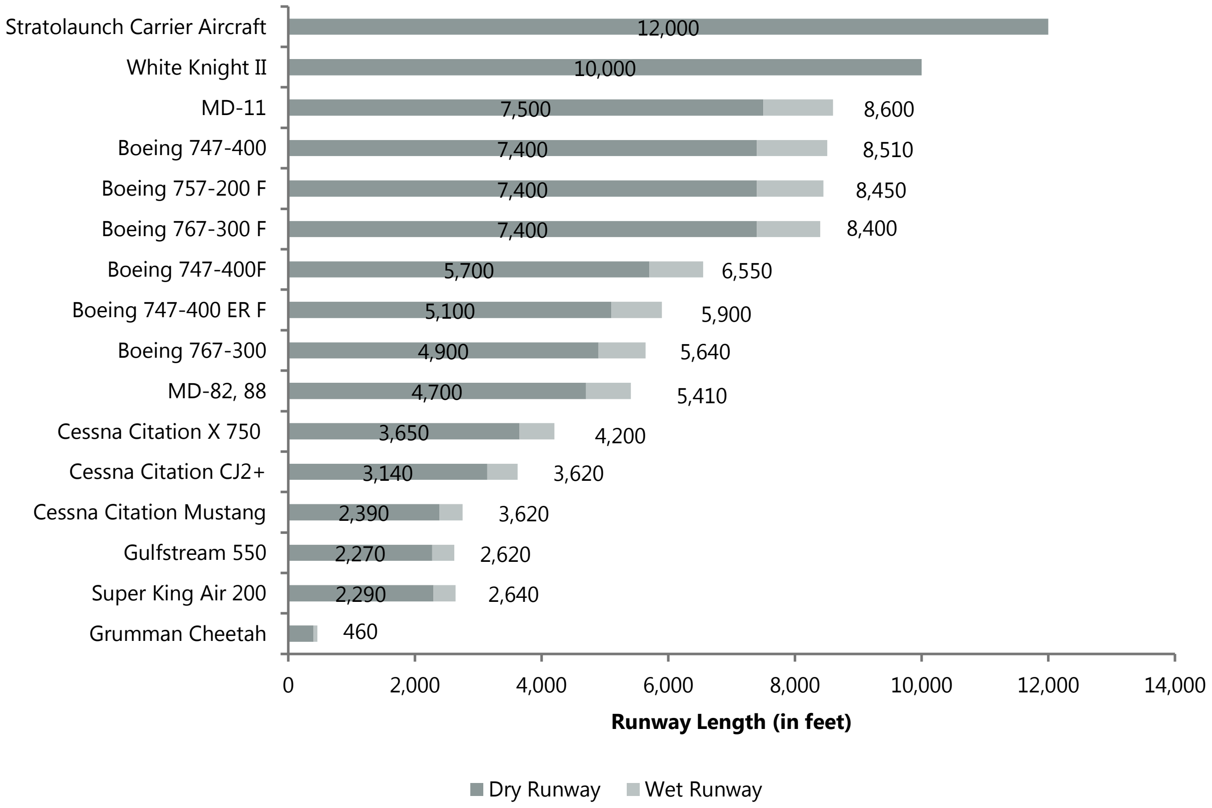
Exhibit 4-1: Takeoff Length Requirements at Maximum Takeoff Weight at 92°F



SOURCES: Aircraft Characteristics Manuals.
PREPARED BY: Ricondo & Associates, Inc., February 2014.

As shown on **Exhibit 4-2**, longer runways are needed to accommodate landings in wet conditions than in dry conditions. All representative aircraft types (except the two spacecraft) can land at MLW on either Runway 17R-35L or Runway 4-22 in dry and wet conditions. Therefore, considering landing performance only, the existing runways can accommodate all non-military and non-NASA aircraft currently operating at the Airport and other aircraft types evaluated in dry and wet conditions. A longer runway would be necessary to accommodate arrivals by the White Knight II or Stratolaunch Carrier spacecraft.

Exhibit 4-2: Landing Length Requirements at Maximum Landing Weight



SOURCES: Aircraft Characteristics Manuals.
PREPARED BY: Ricondo & Associates, Inc., February 2014.

The most common military aircraft operating at the Airport are the F-16 Falcon fighter jet, the U.S Air Force NK-135, the MQ-1B predator drone, and helicopters, such as the Eurocopter HH-65C and the AH-64 Apache. The aircraft operated by NASA at the Airport are the T-38 Talon jet, the Gulfstream shuttle training aircraft, the McDonnell-Douglas C-9, and the WB-57F. In addition, the Boeing 377 Super Guppy operated by NASA occasionally serves the Airport. As the characteristics manuals for these aircraft are not available to the public, no detailed runway length analysis was conducted. However, no issues related to the operation of these aircraft were identified; therefore, it was assumed that the current runway lengths at the Airport meet the takeoff and landing requirements of these aircraft.

The general aviation, military, and NASA aircraft currently operating at the Airport on a regular basis or occasionally are not expected to change significantly over the planning period. A runway extension would only be warranted if operations by large cargo aircraft or spacecraft were introduced at the Airport.

4.2.2.2 Runway Shoulders

According to FAA AC 150/5300-13A (Change 1), paved shoulders are required for runways, taxiways, taxilanes, and aprons accommodating ADG IV aircraft and higher. The intent is to protect jet engines that overhang the edge of the pavement from drawing in foreign objects resulting from the erosion of unprotected soils. As Ellington Airport serves ADG IV aircraft, paved shoulders should be added to runways, taxiways, taxilanes, and aprons to comply with FAA standards. Runways 4-22 and 17R-35L do not have shoulders; therefore, 25-foot-wide paved shoulders should be constructed along both sides of the runways. To comply with FAA standards, the shoulders must be paved at a width of 25 feet from the runway edge on both sides of the runway.

4.2.2.3 Runway Demand/Capacity Analysis

Analysis Methodology

In the runway demand/capacity analysis conducted for the Master Plan Update, the existing capacity of the airfield was determined and compared with forecast demand to determine any deficiencies that exist today or are expected to materialize as aircraft activity increases during the planning period (through 2030). The annual service volume (ASV) and peak hour methodologies detailed in FAA AC 150/5060-5, *Airport Capacity and Delay* (Change 2) were used to estimate the capacity of the existing airfield under a variety of scenarios and conditions. The various airfield capacities were then compared with forecast annual and peak hour operations, as presented in Section 3, “Aviation Activity Forecasts.”

Existing Runway Use/Operating Configurations

As defined by FAA guidance, runway use configuration refers to the number, location, and orientation of the active runways, the type and direction of operations, and the flight rules in effect at a given time. EFD has three runways available for use: two in a north-south orientation (17R-35L and 17L-35R) and one crosswind runway (4-22).

Runway 17R-35L is the primary runway at EFD. It is 9,000 feet long and 150 feet wide and is the longest runway at the Airport. It is supported by Taxiway H, a full-length parallel taxiway located west of the runway. The runway has six connector taxiways: one at either end (Taxiways A and F), one approximately at the midpoint of the runway (Taxiway C), Taxiway E, and two additional taxiways – Taxiways B and D – that cross the runway at an angle. Runway 17R-35L is used for both arrivals and departures; it is used for military aircraft training operations and, when traffic allows, can also be used for civilian aircraft training operations.

Runway 4-22 is the crosswind runway. It is 8,001 feet long and 150 feet wide. Runway 4 is accessible from Taxiway E, which is a lead-in taxiway that crosses Runway 17R-35L from southernmost apron and aligns with the extended runway centerline. Runway 22 is accessible from Taxiway G, located north of Runway 4-22. Additionally, Taxiway D is a perpendicular taxiway located approximately 1,280 feet from the Runway 4 threshold. Runway 4-22 is used primarily for arrivals and departures with limited training use.

Located 2,560 feet east of Runway 17R-35L, Runway 17L-35R is 4,609 feet long and 80 feet wide and is used almost exclusively for flight training. Runway 17L is accessible via Taxiway B. Taxiway C is located approximately 700 feet north of the Runway 35R threshold and Taxiway G connects Runway 17L-35R with Runway 22 and intersects Runway 17L-35R near its midpoint.

Operating at EFD presents some airspace challenges because of its proximity to William P. Hobby Airport and the restrictions associated with HOU's Class B airspace.[3] EFD is located approximately 7 miles southeast of HOU. The approach path to HOU's Runway 30L intersects the approach paths to EFD Runways 4 and 35L and HOU arrivals from the northeast interact with EFD departures from Runway 4 and 35L. As an example of operational challenges, controllers stated that control of jet aircraft on approach to EFD Runway 4 typically must be handed off from EFD controllers to HOU controllers and returned to EFD controllers before the aircraft lands.

At the time this section of the Master Plan Update was being prepared, recent operations data for EFD (by aircraft type) were not available. Subsequently, when analyzing runway use, limited site observations and anecdotal information from ATCT staff were relied upon, in addition to information in the 2004 Master Plan. It was estimated that Runway 17R-35L accommodates approximately 80 percent of all operations at EFD. Large jet aircraft operating at EFD typically use Runway 17R-35L because it is the longest runway at the Airport. Runway 4-22 is estimated to be used for the remaining operations, with the exception of flight training, which is predominantly conducted on Runway 17L-35R. Runway 17L-35R is primarily used by the Flying Tigers' fixed-wing flight training students and for training exercises by the U.S. Coast Guard and Texas Army National Guard helicopters. EFD ATC estimates that 80 percent of the general aviation traffic (61,683 operations in 2012) consists of touch-and-go operations on Runway 17L-35R.

Operations are conducted at EFD in both VMC and IMC. VMC occurs when the visibility is greater than or equal to 3 statute miles *and* the cloud ceiling is 1,000 feet AGL or higher. During VMC, pilots operate under VFR, essentially using visual means to maintain separation from other aircraft, objects, terrain, etc. IMC occurs when the prevailing visibility at an airport is less than 3 statute miles *or* the cloud ceiling is less than 1,000 feet AGL. During IMC, pilots operate under IFR, relying on FAA Air Traffic Control to provide separation services from other aircraft and terrain. Operating under IFR conditions requires additional pilot training and aircraft certifications beyond those required for operating under VFR conditions.

Precision instrument approaches are available to both ends of Runway 17R-35L, as well as Runway 22. Runway 4 has a nonprecision instrument approach. Runway 17L-35R is a visual runway and is, therefore, only used in VMC.

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[3] Class B airspace, which surrounds the busiest U.S. airports, has the most stringent rules of all airspace types in the United States in terms of pilot certifications and operating requirements. Before entering Class B airspace, pilots must obtain ATC clearance and should be prepared if clearance is denied. Both VFR and IFR traffic is controlled in Class B airspace through instructions from ATC.

Runway use data contained in the 2004 Master Plan for EFD were verified with Airport and EFD ATCT staff. According to this information, the Airport is in VMC 78 percent of the time and in IMC 22 percent of the time. During VMC, all runways may be used. During IMC, Runway 17L-35R is not used and Runway 4 is seldom used. The Airport operates in south flow (using Runways 17L, 17R, and 22) 85 percent of the time and in north flow (using Runways 35L, 35R, and 4) 15 percent of the time. In south flow, most aircraft arrivals and departures occur on Runway 17R, with Runway 22 being used when wind speed and direction preclude the use of Runway 17R. Flight training and touch-and-go operations occur on Runways 17L and 35R (only in VMC). Similarly, in north flow, most aircraft arrivals and departures occur on Runway 35L. Runway 4 is rarely used because of the airspace conflicts with HOU described previously.

Tenant Operations

Tenants at EFD are quite diverse, as are the types of aircraft operating on the airfield. While general aviation users represent the largest user segment at the Airport, a significant number of U.S. government operations (NASA, the Texas Air National Guard, the Texas Army National Guard, the U.S. Coast Guard), including helicopter operations, also occur at EFD. Activity by each of these tenants is summarized below.

General Aviation

Local and itinerant general aviation aircraft account for the majority of aircraft operations at EFD. These aircraft typically operate directly from their hangar space on the airfield or from the Landmark Aviation apron. Local and itinerant operations are conducted by several types of fixed-wing and rotor aircraft. Flight training is conducted by the Flying Tigers Flight School. The flight school offers flight training in addition to aircraft rental. The school has a fleet of light single-engine aircraft and twin-engine aircraft. Itinerant general aviation training activity is also generated from nearby flight schools at non-towered airports that send student pilots to EFD to practice radio communications.

U.S. Government/Military

EFD is the home of NASA’s Johnson Space Center’s flying operations and is a base for NASA’s administrative cargo transport and high-altitude training aircraft. NASA’s primary function at EFD is the training of astronauts for space flight. NASA’s based aircraft fleet at EFD includes T-38 Talon jets, the Gulfstream Shuttle Training Aircraft. EFD also houses NASA’s three WB-57F aircraft, used for atmospheric research and reconnaissance. Additionally, the Boeing 377 Super Guppy occasionally operates at the Airport. The Texas Air National Guard operates the MQ-1B Predator drone. The F-16 Falcon fighter jet is operated by the Oklahoma Air National Guard at EFD. The U.S. Coast Guard facility, known as “Coast Guard Air Station Houston,” operates Eurocopter HH-65C “Dolphins” Short-Range Recovery helicopters for search and rescue and port security operations. The Texas Army National Guard operates AH-64 Apache attack helicopters from its apron area. The majority of helicopter operations at EFD are estimated to be flown by either the Texas Army National Guard AH-64 Apache or U.S. Coast Guard HH-65C Dolphin helicopters.

Two civilian helicopter operations were observed during the May 2013 site visit. According to ATC personnel, when civilian helicopters arrive at EFD, they typically approach the airfield along the Runway 17R or 35L centerline. Once over the airfield, these helicopters are typically cleared to land directly on the civilian apron. Itinerant helicopter operations, with pilots who are not familiar with the airfield, are typically cleared to land on the helicopter pad (designated by an "H") located on Taxiway H near its intersection with Taxiway B. Helicopter training typically occurs on Runway 17L-35R in the form of touch-and-go and auto-rotation operations. Alternate training activity for the Texas Army National Guard helicopters typically occurs on the airfield at a site referred to as the "radar spot," which is located between Runways 17L-35R and 4-22.

Capacity Calculation Methodology and Assumptions

The actual capacity of an airfield or its throughput (operations per year) can vary depending on the number and orientation of the runways, runway configuration, aircraft fleet mix, and weather conditions. The ASV and peak hour capacity calculation methodologies detailed in FAA AC 150/5060-5, *Airport Capacity and Delay* (Change 2) were used to estimate the capacity of the existing airfield under a variety of scenarios and conditions. Key considerations taken into account when evaluating airfield capacity using the ASV methodology include:

- Runway use configurations
- Number of operations
- Aircraft mix
- Training activity on Runway 17L-35R
- Weather conditions (VMC vs. IMC)

Using this information for EFD, a reasonable estimate of airfield capacity was developed and compared with forecast activity.

An airport's aircraft mix index is a measure of the percentage of operations conducted by aircraft (1) over 12,500 pounds and up to 300,000 pounds, and (2) over 300,000 pounds. The higher the mix index, the greater the percentage of large aircraft operating at the airport. The mix index accounts for the interaction of various size aircraft, which affects capacity resulting from variations in ATC procedures, wake turbulence separation, approach speed, runway occupancy times, and other factors. The aircraft mix index is the primary input into the ASV capacity calculations.

Because recent operations data by aircraft type were not available for EFD, the existing based aircraft fleet mix, conversations with EFD ATCT staff, and onsite observations during May 2013 were used. The aircraft mix index is not expected to change significantly over time; therefore, the assumptions presented herein are considered representative of existing and future conditions at EFD.

Table 4-2 provides a summary of the existing based aircraft fleet mix at EFD, the percentages of aircraft types observed onsite, and the fleet mix percentages used in the ASV calculations. The assumed fleet mix percentages used for the ASV calculations are an average of the based aircraft and the observed fleet mix. The rationale behind this assumption is that, although based aircraft are a valid indicator of the types of aircraft operating at EFD, they do not reliably indicate the percentage of operations by any aircraft type. Therefore, onsite observations were also considered.

Table 4-2: Based Aircraft Fleet Mix

AIRCRAFT CATEGORY	PERCENTAGE OF BASED AIRCRAFT	PERCENTAGE OF AIRCRAFT TYPE OBSERVED [1/]	FLEET MIX PERCENTAGE USED FOR ANNUAL SERVICE VOLUME CALCULATIONS
Single Engine/Rotor	47%	40%	44%
Multi-engine	12%	17%	15%
Small Jet	29%	8%	9%
Midsize Jet		5%	7%
Large Jet		5%	7%
Military Fixed Wing	12%	25%	18%

NOTE:

1/ During 2 days in May 2013.

SOURCES: FAA Airport IQ 5010 Database; Field Observations by Jacobsen/Daniels Associates, LLC, May 2013.
PREPARED BY: Jacobsen/Daniels Associates, LLC, January 2014.

For purposes of calculating the aircraft mix index, the percentage of based aircraft was assumed to be reflective of the percentage of aircraft operations. The following assumptions regarding aircraft weight were used to calculate the aircraft mix index for the Airport:

- All single-engine/rotor aircraft are under 12,500 pounds and represent 44 percent of all operations
- 50 percent of multi-engine aircraft are over 12,500 pounds and 50 percent are below 12,500 pounds. Therefore, multi-engine aircraft over 12, 500 pounds represent 7.5 percent of all operations and multi-engine aircraft under 12,500 pounds represent 7.5 percent of all operations.
- 75 percent of jet aircraft are over 12,500 pounds and 25 percent are below 12,500 pounds. Therefore, jet aircraft under 12,500 pounds represent 6 percent of all operations and jet aircraft over 12,500 pounds represent 17 percent of all operations.
- 75 percent of military fixed-wing aircraft are over 12,500 pounds and 25 percent are over 300,000 pounds. Therefore, military fixed-wing aircraft over 12,500 pounds represent 13.5 percent of all operations and military fixed-wing aircraft over 300,000 pounds represent 4.5 percent of all operations.

The FAA Airport IQ 5010 database indicates that EFD has 197 based aircraft.[4] Using the fleet mix assumptions and percentages of each weight category, the calculation of the aircraft mix index is shown below. It was assumed that this index applies to both VMC and IMC, as the only users that do not operate in IMC are flight training students and these users fly aircraft that are under 12,500 pounds and. Therefore. have no effect on the aircraft mix index. For Ellington Airport, the mix index is calculated based on the following formula:

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[4] Federal Aviation Administration, *Airport Master Records and Reports*, http://www.gcr1.com/5010web/, accessed February 21, 2014.

Mix Index = (C + 3D)

C – Percentage of aircraft over 12,500 pounds and up to 300,000 pounds = 38 percent

D – Percentage of aircraft over 300,000 pounds = 5 percent

EFD Aircraft Mix Index = (38+ (3*5)) = 53

Demand/Capacity Analysis

Two methodologies set forth in FAA AC 150/5060-5, *Airport Capacity and Delay* (Change 2), were used, as well as a number of runway use configurations, to estimate the annual capacity and peak hour capacity of the EFD airfield.

- Chapter 2, "Capacity and Delay Calculations for Long Range Planning," provides calculations for determining hourly airport capacity, ASV, and aircraft delay for long-range planning.
- Chapter 4, "Special Applications," allows for restricting a parallel runway to use by small aircraft only. This application was considered because Runway 17L-35R is used as a general aviation training runway.

Using these two methodologies, four different operating scenarios were analyzed to determine the airfield capacity based on weather conditions and runway use configurations (listed below). For each scenario, the selected methodology is indicated, as well as the relevant diagrams from FAA AC 150/5060-5, *Airport Capacity and Delay* (Change 2). When winds preclude the use of Runways 17L-35R and 17R-35L, and only Runway 4-22 is operational, the capacity of the airfield is greatly reduced. Based on an analysis of the wind data for EFD, this scenario was determined to be an infrequent occurrence and was not considered in this analysis.

- Scenario 1 (South or North Flow) – Chapter 2, Diagram 11 – Considered the capacity of the existing airfield (Runways 17L-35R, 17R-35L, and 4-22 would be used for arrivals and departures). Runway 17L-35R was not assumed to be limited to small aircraft. VMC was assumed.
- Scenario 2 (South or North Flow) – Chapter 2, Diagram 3 – Considered the capacity of the airfield if Runways 17L-35R and 17R-35L were used for arrivals and departures and Runway 4-22 was not used. Runway 17L-35R was not assumed to be limited to small aircraft. VMC was assumed.
- Scenario 3 (South or North Flow) – Chapter 2, Diagram 9 – Considered the capacity of the airfield if Runways 17R-35L and 4-22 were used for arrivals and departures and Runway 17L-35R was not used given the lack of precision approach capability. IMC was assumed.
- Scenario 4 (South or North Flow) – Chapter 4, Diagram 10 - The methodology was applied to limit one of the parallel runways to small aircraft only. VMC was assumed given the lack of precision approach capability on Runway 17L-35R.

Table 4-3 depicts the results of the capacity analyses for each scenario.

Table 4-3: Annual Service Volume and Hourly Capacity Estimates

CAPACITY SCENARIO	ANNUAL SERVICE VOLUME (OPERATIONS PER YEAR)	HOURLY CAPACITY (OPERATIONS PER HOUR)	
		VMC	IMC
1	275,000	126	65
2	275,000	126	65
3	215,000	77	56
4	-	123	n/a

NOTE: No ASV is provided in AC 150/5060-5 for Scenario 4.

SOURCE: FAA Advisory Circular 150/5060-5, *Airport Capacity and Delay* (Change 2), September 23, 1983.
PREPARED BY: Jacobsen/Daniels Associates, LLC, January 2014.

Table 4-4 provides the weighted ASV and weighted average of hourly capacity considering that VMC occurs 78 percent of the time and IMC occurs 22 percent of the time. Considering that the runway use configuration varies, the occurrence of VMC and IMC and north and south flow configurations can usually be applied to obtain a weighted average of airfield capacity. As the capacity of the airfield in north and south flows is the same, it is the VMC versus IMC component that affects operations.

Table 4-4: Weighted Peak Hour Capacity Estimates

CAPACITY SCENARIO	WEIGHTED ANNUAL SERVICE VOLUME (OPERATIONS PER YEAR)	WEIGHTED HOURLY CAPACITY (OPERATIONS PER HOUR)
1	261,800	113
2		113
3		72
4	Not Applicable	--

SOURCE: FAA Advisory Circular 150/5060-5, *Airport Capacity and Delay* (Change 2), September 23, 1983.
PREPARED BY: Jacobsen/Daniels Associates, LLC, January 2014.

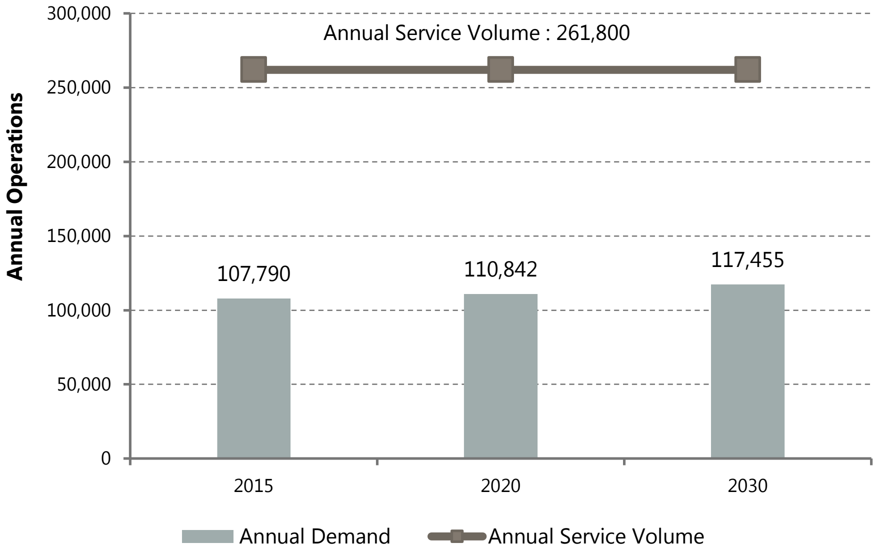
Table 4-5, **Exhibit 4-3,** and **Exhibit 4-4** present comparisons of the weighted annual and hourly capacity with the forecast operations from Section 3. Forecast operations are not expected to reach the existing capacity of the EFD airfield within the planning period.

Table 4-5: Demand/Capacity Comparison

	PLANNING YEAR		
	2015	**2020**	**2030**
Existing Capacity (Operations)			
Weighted Annual Capacity	261,800	261,800	261,800
Weighted Hourly Capacity	72-113	72-113	72-113
Forecast Demand (Operations)			
Annual Demand	107,796	110,842	117,455
Hourly Demand	51	53	56

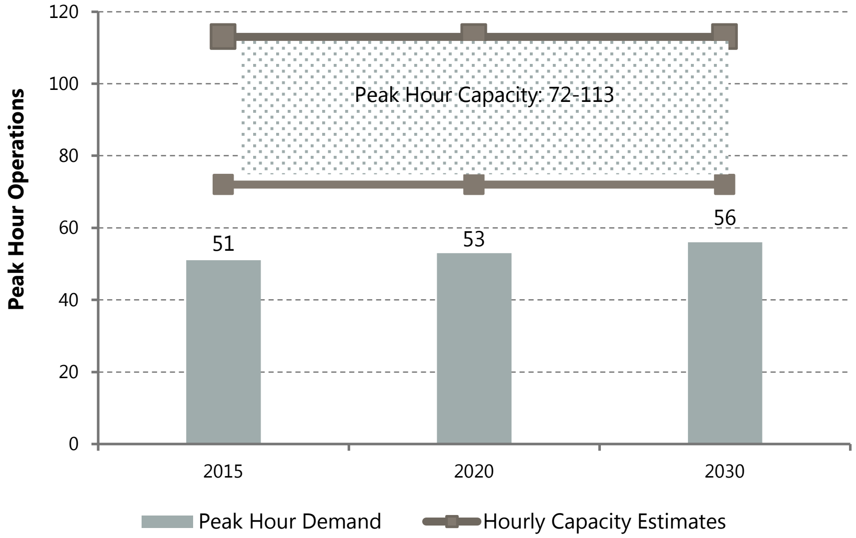
SOURCE: FAA Advisory Circular 150/5060-5, *Airport Capacity and Delay* (Change 2), September 23, 1983.
PREPARED BY: Jacobsen/Daniels Associates, LLC, January 2014.

Exhibit 4-3: Annual Demand/Capacity Comparison



SOURCE: FAA Advisory Circular 150/5060-5, *Airport Capacity and Delay* (Change 2), September 23, 1983.
PREPARED BY: Jacobsen/Daniels Associates, LLC, January 2014.

Exhibit 4-4: Peak Hour Demand/Capacity Comparison



SOURCE: FAA Advisory Circular 150/5060-5, *Airport Capacity and Delay* (Change 2), September 23, 1983.
PREPARED BY: Jacobsen/Daniels Associates, LLC, January 2014.

4.2.2.4 Effects of Closing Runway 17L-35R

As discussed in later sections of this Master Plan Update, HAS is considering the closure of Runway 17L-35R to decrease operating and maintenance (O&M) expenses at EFD and also to increase the amount of land available for future development. Therefore, the effect of closing the runway on airfield demand/capacity was addressed. The potential impacts associated with the potential closure of Runway 17L-35R is described in this subsection from two perspectives: airfield capacity and tenant operations. Operational safety and development opportunities are also discussed.

Airfield Capacity

If Runway 17L-35R were closed, airfield operations would be similar to Scenario 3, defined in Section 4.2.2.3. Scenario 3 can be applied to both south and north flow operations, in both VMC and IMC. In this scenario, only Runways 17R-35L and 4-22 would be operational, reflecting airfield capacity without Runway 17L-35R.

Under this scenario, VMC hourly capacity was calculated to decrease from the current 126 operations to 77 operations, and IMC hourly capacity was calculated to decrease from 65 operations to 56 operations. ASV was calculated at 215,000 operations without Runway 17L-35R. When comparing future operations as presented in Table 4-5, hourly capacity begins to approach demand at the end of the planning period in 2030. Under VMC, hourly demand would be approximately 72 percent of hourly capacity in 2030. Under IMC, hourly demand would reach hourly capacity. However, as Runway 17L-35R is not used in IMC, this situation would occur whether the runway is closed or not. The number of annual operations forecast in 2030 (117,455) would be well below the calculated average ASV of 215,000 operations.

Tenant Operations

General Aviation Tenants

Interviews with EFD ATCT staff and onsite observations indicated that Runway 17L-35R is primarily used for general aviation touch-and-go training operations and military helicopter training operations. The runway is also used for general aviation departures when the military is flying training patterns (circling the airfield on a prescribed course at prescribed altitudes) on Runway 17R-35L. This is an infrequent occurrence.

The use of Runway 17L-35R allows ATCT staff to separate slow GA aircraft from high-speed jet aircraft. Military and other jet aircraft have higher approach speeds and require increased in-trail separation from non-jet traffic to avoid overtaking the slower aircraft during arrival and departure. Capacity is affected when ATC controllers are required to integrate fast and slow traffic into a single arrival/departure stream. As Runway 17L-35R accommodates small GA aircraft only, interactions between high speed jets and small single-engine aircraft flying training patterns simultaneously are simplified.

According to discussions with Airport and ATCT staff, one of the reasons that Flying Tigers moved its flight school from HOU to EFD in early 2009 was because EFD had a runway that was primarily used for touch-and-go training. Its students train at EFD, as well as at other nearby airports. In addition, flight schools at nearby airports without an ATCT send students to EFD for radio communications experience. If a separate touch-and-go training runway were no longer available, it is likely that at least some of the training operations would be moved from EFD to alternate airports.

There do not seem to be any obvious effects of closing Runway 17L-35R on other GA tenants, such as the fixed base operator, corporate tenants, or other users.

Military Tenants

The Texas Army National Guard AH-64 Apache helicopters and the U.S. Coast Guard HH-65C Dolphin helicopters are other significant users of Runway 17L-35R for training. Helicopter flight training generally consists of flying in the traffic pattern doing touch-and-go operations, auto-rotations, and other activities on and off the ground. Helicopter training is conducted during both day and night and during peak and off-peak periods.

Direct coordination with the military would be required to understand the potential effects of closing Runway 17L-35R. Rotors kick up foreign object debris over grass areas; as such, after it rains, the ground may be too soft for safe landings. Therefore, helicopter training would need to be conducted on another runway or other paved area. Conducting the training on one of the other runways, specifically during peak periods, would likely affect airfield capacity and additional analysis would be required to evaluate the potential effects.

Operational Safety

The closure of Runway 17L-35R would eliminate aircraft taxiing on the runway to/from Runway 22. FAA guidance recommends avoiding "dual purpose" pavements, such as a runway used as a taxiway. Therefore, safety at Ellington Airport would be increased by the closure of Runway 17L-35R.

Development Opportunities

The closure of Runway 17L-35R would make the northeast quadrant of the Airport available for development. Although there is no short-term need for additional development space at EFD, it is an option being considered by HAS.

4.2.2.5 Runway 4-22 Exits

Currently, Runway 4-22 only has three exits: one at each end of the runway and one located 1,265 feet from the Runway 4 threshold, at Taxiway D. Very few aircraft landing on Runway 4 can exit at Taxiway D. As a result, aircraft either taxi to the end of the runway and use Taxiway G, or perform a 180-degree turn on the runway and taxi back to Taxiway D. Similarly, the first exit available for arrivals on Runway 22 is Taxiway D, located 6,716 feet from the landing threshold. To decrease runway occupancy times and eliminate 180-degree turns on the runway, new taxiway exits for Runway 4-22 are recommended.

The development of exit taxiways for Runway 4-22 would improve the operational efficiency of the runway and increase capacity by reducing runway occupancy times. Potential exit locations for Runway 4-22 are identified in this subsection, along with the requirements for a taxiway system to support Runway 4-22.

Analysis Methodology

Potential exit taxiway locations were identified by considering the type of aircraft that use the runway and the distance required to slow those aircraft to a speed at which they can safely exit the runway. Although the number of operations on Runway 4-22 will certainly influence the cost/benefit of constructing exits, this analysis was focused on identifying the most appropriate locations for exits without consideration of the cost or frequency of use.

Three methodologies were used to assess potential locations for Runway 4-22 exits:

- Methodology 1 – using FAA Advisory Circular 150/5300-13A guidance
- Methodology 2 – focusing on aircraft performance characteristics
- Methodology 3 – using the FAA's Runway Exit Design Interactive Model (REDIM)

The results of each methodology are summarized below. All three methodologies take into consideration the existing aircraft fleet mix operating at the Airport. In each methodology, it was assumed that all aircraft (with the exception of rotor and certain military aircraft) in the fleet mix would operate on Runway 4-22. Furthermore, the assumptions regarding the percentage of operations for each aircraft/aircraft category that uses Runway 4-22 were the same as those assumed for all operations at EFD.

For this analysis, it was assumed that all runway exits would be right-angle exits. FAA guidelines in AC 150/5300-13A recommend right-angled runway exits for airports where the design peak hour traffic is less than 30 operations, which is applicable to EFD. Indeed, the forecast of peak hour operations (see Section 3) for 2030 indicates 56 operations during the peak hour for the entire airfield, from which it can be assumed that peak hour operations on Runway 4-22 only would be less than 30. High-speed (or acute-angled) exits are designed to allow landing aircraft to exit the runway as they continue to decelerate. These types of exits were not considered during the alternatives development.

Existing Conditions and Use of Runway 4-22

As previously described, it was assumed that the Airport operates under VFR 78 percent of the time and under IFR 22 percent of the time. It was also assumed that the Airport operates in south flow (using Runways 17L, 17R, and 22) 85 percent of the time and in north flow (using Runways 35L, 35R, and 4) 15 percent of the time.

EFD ATCT representatives estimated that Runway 4-22 is used approximately 20 percent of the time. In north flow, controllers indicated that they typically use Runway 4 when wind direction and speed dictate. They highlighted the difficulty for jet aircraft to land on Runway 4 while trying to remain outside of HOU airspace. Flight through the HOU airspace requires switchovers between the EFD ATCT and the HOU ATCT on approach. During south flow operations, controllers indicated that Runway 22 was used whenever wind direction and speed dictate, and also to take advantage of the ILS approach to the Runway 22 end.

Fleet Mix

Table 4-6 provides a summary of the 2012 based aircraft fleet mix, percentages of aircraft types observed onsite, and the fleet mix percentages used for this analysis, as well as the representative aircraft for each aircraft category. For purposes of identifying exit taxiway locations, helicopter and glider activity was not included in the fleet mix percentage calculations. When considering military activity at EFD, aircraft types vary significantly, ranging from high performance jets, such as the F-16, to large aircraft, such as the U.S. Air Force NKC-135 and Boeing 377 Super Guppy. The large military aircraft operate infrequently at the Airport and were assumed to use Runway 17R-35L. If the aircraft were required to use Runway 4-22 because of weather conditions or a temporary closure of Runway 17R-35L, it is likely that the full length of the runway would be required; therefore, the large aircraft are not reflected in the representative aircraft list for determining potential runway exit locations.

The fleet mix used in the subsequent analysis consists of the average between the based aircraft at EFD and the observed fleet mix. The rationale behind this assumption is that, although based aircraft are a valid indicator of the types of aircraft operating at EFD, they do not reliably indicate the percentage of operations. Therefore, the onsite observations were also considered.

Table 4-6: Aircraft Fleet Mix

AIRCRAFT CATEGORY	PERCENTAGE OF BASED AIRCRAFT	PERCENTAGE OF AIRCRAFT TYPES OBSERVED (2 DAYS IN MAY 2013)	FLEET MIX ASSUMPTION	REPRESENTATIVE AIRCRAFT
Single Engine	47%	40%	44%	Grumman Cheetah
Multi-engine	12%	17%	15%	King Air 300/350
Small Jet	29% (all civilian jets)	8%	9%	Cessna Citation
Midsize Jet		5%	7%	Gulfstream V
Large Jet		5%	7%	MD-80
Military	12%	25%	18%	F-16

SOURCES: FAA Airport IQ 5010 Database; Field Observations by Jacobsen/Daniels Associates, LLC, May 2013.
PREPARED BY: Jacobsen/Daniels Associates, LLC, January 2014.

Runway Exit Analysis

To maximize the operational capacity of a runway, it is critical to place runway exits at optimal locations. Exit locations that provide for the greatest percentage of the fleet mix to exit the runway as quickly as possible enable the runway to serve more aircraft in a given period of time, including the peak hour. As mentioned previously, three methodologies—FAA AC 150/5300-13A guidance, aircraft performance characteristics, and REDIM analysis—were used to evaluate the optimal exit locations for Runway 4-22. These evaluations were augmented by onsite observations and discussions with EFD ATCT staff regarding taxiway exit use on Runway 17R-35L, which is similar in length for purposes of this analysis and has several exits.

Methodology 1 - FAA Advisory Circular 150/5300-13A Guidance

FAA AC 150/5300-13A provides data on the percentages of aircraft observed exiting existing runways at specific exits for various aircraft types. Although this information is somewhat generic in that it represents a collection of comprehensive observations of aircraft operating on various runways, it can be useful in comparing recommended runway exit locations.

Table 4-9 of AC 150/5300-13A provides cumulative percentages of aircraft observed exiting a runway at specific exits, measured from the landing threshold. The data are provided for single-engine, multi-engine, large, and heavy aircraft. Furthermore, data are provided for both wet and dry runway surface conditions. For each of the representative aircraft in the EFD fleet mix, **Table 4-7** identifies the required distance from the landing threshold to enable 100 percent of landings on the runway to use the exit. These distances apply to either Runway 4 operations or Runway 22 operations. The Advisory Circular does not provide information that could easily be applied to the small jet, midsize jet, or military categories; therefore, those distances are not identified in the table.

Table 4-7: Runway Exit Locations (Advisory Circular 150/5300-13A Guidance)

		DISTANCE FROM RUNWAY THRESHOLD TO ACCOMMODATE 100 PERCENT OF LANDINGS	
AIRCRAFT TYPE	REPRESENTATIVE AIRCRAFT	WET RUNWAY (FEET)	DRY RUNWAY (FEET)
Single Engine	Grumman Cheetah	4,000	3,000
Multi-engine	King Air 300/350	5,000	4,500
Small Jet	Cessna Citation	-	-
Midsize Jet	Gulfstream V	-	-
Large Jet	MD-80	8,000	7,000
Military	F-16	-	-

SOURCE: FAA Advisory Circular 150/5300-13A, *Airport Design,* (Change 1), February 24, 2014.
PREPARED BY: Jacobsen/Daniels Associates, LLC, January 2014.

Methodology 2 - Aircraft Performance Characteristics

The second methodology used to determine runway exit locations is the use of aircraft performance characteristics. **Table 4-8** presents the approximate landing lengths required for the representative aircraft in the EFD fleet mix. These lengths are based on the aircraft characteristics manuals provided by each aircraft manufacturer and are approximated to accommodate different aircraft models, engine types, wet/dry runway conditions, etc.

Table 4-8: Runway Exit Locations (Aircraft Characteristics Manuals)

AIRCRAFT TYPE	REPRESENTATIVE AIRCRAFT	APPROXIMATE LANDING LENGTH REQUIRED (FEET)
Single Engine	Grumman Cheetah	1,000 - 1,500
Multi Engine	King Air 300/350	2,500 - 4,500
Small Jet	Cessna Citation	3,500
Midsize Jet	Gulfstream V	3,000
Large Jet	MD-80	5,000
Military	F-16	3,000

SOURCES: Airplane Characteristics Manuals.
PREPARED BY: Jacobsen/Daniels Associates, LLC, January 2014.

Methodology 3 - Runway Exit Design Interactive Model Analysis

REDIM is a computer model designed to maximize runway performance. It uses the runway-specific fleet mix to estimate the weighted average runway occupancy time based on existing and recommended exit locations. In this analysis, REDIM was used to identify the optimal runway exit locations.

Because Runway 4-22 currently has so few exit taxiways, the REDIM analysis was conducted using the "New Runway" category of analysis. This means that no existing exits were input into the model and, therefore, the model provides an "unbiased" assessment of optimal runway exit locations. While there is currently no parallel taxiway to the runway, it was assumed that any future parallel taxiway would be constructed to ADG V standards. The following assumptions were included in the model:

- Fleet mix – As depicted in Table 4-6
- Exit angle – 90 degrees (high speed exits were not considered)
- Runway-taxiway separation – 400-feet (ARC D-V)
- Wind speed – 0 knots
- Wind direction – Not applicable
- Airport elevation – 9 feet above MSL
- Temperature – 32°C
- Runway width/length – 8,001 feet/150 feet
- Percentage of wet vs. dry conditions – 50 percent/50 percent
- Aircraft weight factors and exit speeds – Standard factors from model
- Total number of exit locations on runway – Six (includes runway ends)

Table 4-9 provides a summary of the exit locations recommended by REDIM. Each runway end was considered separately; therefore, the required distances are the same for each runway end.

Table 4-9: Runway Exit Location Ranges

LANDING THRESHOLD TO EXIT DISTANCE (FEET)
0
1,640 – 1,722
2,871 – 2,953
3,855 – 3,937
7,218 – 7,464
8,001

SOURCES: Jacobsen/Daniels Associates, LLC, based on Runway Exit Design Interactive Model software, June 2013.
PREPARED BY: Jacobsen/Daniels Associates, LLC, January 2014.

Recommended Runway Exit Locations

Of the three methodologies, it is believed that the results of the REDIM analysis provide the most meaningful and pertinent results and, therefore, should be used to inform plans for the future placement of runway exits. **Exhibit 4-5** depicts the exit locations for both landing directions. As shown, existing Taxiway D does not align with any of the recommended taxiway exit locations. Although Taxiway D is not ideally positioned to serve as an exit for Runway 22 arrivals based on the REDIM analysis, it does not mean that the taxiway does not have utility nor is it being recommended that Taxiway D be abandoned. Taxiway D's use in the overall taxiway system, including as a connector taxiway to a potential parallel taxiway north of Runway 4-22, should be included among the alternatives evaluated. Finally, the taxiway exit locations identified by the REDIM analysis will likely require validation as other potential facility expansions or alterations to the airfield are identified during the development of alternatives. Additional study and research, including fleet mix assessment, may be required to determine a final preferred alternative.

4.2.2.6 Pavement Strength

Pursuant to FAA AC 150/5320-6D, *Airport Pavement Design and Evaluation*, runway pavement needs to be able to support frequent operations of aircraft that currently operate at the airport, as well as aircraft projected to operate at the airport in future years.

Runway pavement strength can be expressed in terms of load-bearing capacity under single-wheel, dual-wheel, dual-tandem-wheel, and double-dual-tandem-wheel loading conditions. The aircraft gear type and configuration dictates how the aircraft weight is distributed on the pavement and determines pavement response to loading. Examination of gear configuration, tire contact areas, and tire pressure in common use areas indicates that pavement strength is related to aircraft MTOW.

The largest aircraft that uses the Airport on a regular basis is the Boeing 377 Super Guppy. This aircraft has dual-wheel landing gear and a MTOW of 170,000 pounds. Runway 17R-35L can support the pavement loading imposed by this aircraft.

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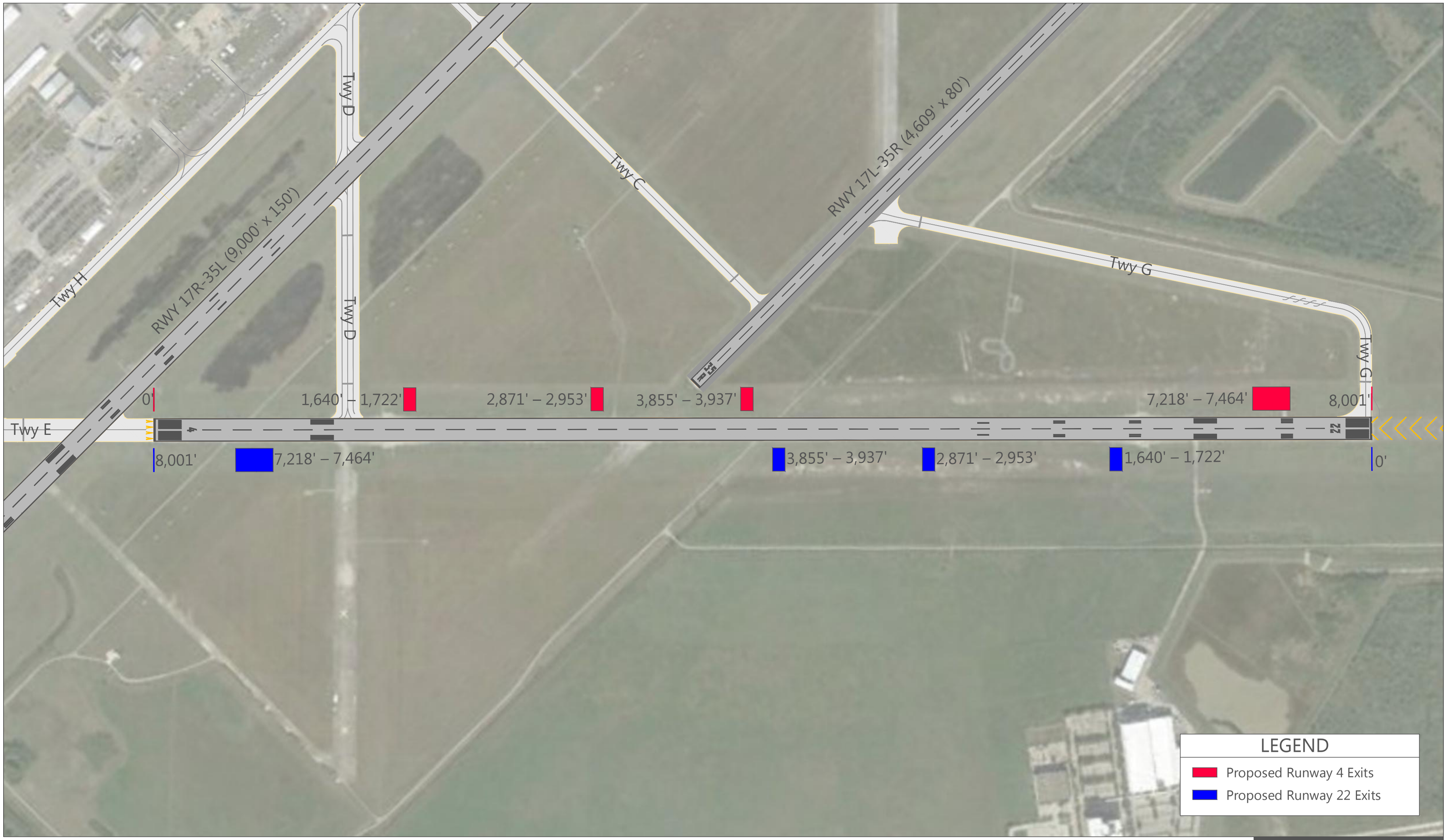

SOURCE: Runway Exit Design Interactive Model (REDIM) analysis performed by Jacobsen/Daniels Associates, LLC, February 2014.
PREPARED BY: Jacobsen/Daniels Associates LLC., February 2014.

EXHIBIT 4-5

NORTH 0 1,000'

Proposed Runway 4-22 Exits

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The runway pavement strength is appropriate to accommodate all general aviation, military, and NASA aircraft currently using and projected to use the Airport through the planning period. No additional pavement strength should be required for any runway through the planning period, given the aircraft types projected to use the Airport. It should be noted that pavement design typically allows for aircraft weighing more than the design pavement strength to occasionally operate on the pavement. This is of particular importance for large fire-fighting tankers or larger widebody charter aircraft that may occasionally use the Airport.

A pavement evaluation study[5] was conducted in July 2014, quantifying the remaining structural life of pavements at EFD. A summary of airfield pavement findings is presented in **Appendix E**. Several sections of pavement were identified as having a remaining structural life of less than five years; these are Runway 17L-35R, as well as sections along Taxiways B and G. These sections will require intensive maintenance or replacement in the short term. All other runway and taxiway pavement has a remaining structural life over 20 years.

4.2.3 TAXIWAY NETWORK

The existing taxiway network at EFD was evaluated to determine improvements required to meet FAA design standards or necessary to increase safety and airfield capacity. The requirements also take into account the forecast demand at the Airport to ensure that all taxiways are optimized for future use.

4.2.3.1 Taxiway Design Considerations

Associated Surfaces

Taxiways associated with Runways 17R-35L, 4-22, and 17L-35R meet the taxiway object free area width of 259 feet and 131 feet for ARC D-IV and ARC B-II, respectively, and the taxiway safety area width requirements of 171 feet and 79 feet for ARC D-IV and ARC B-II, respectively.

Shoulders

According to AC 150/5300-13A (Change 1), paved shoulders are required for taxiways and taxilanes accommodating ADG IV aircraft and higher. The intent is to protect jet engines that overhang the edge of the pavement from drawing in foreign objects resulting from the erosion of unprotected soils. As Ellington Airport serves ADG IV aircraft, the shoulders of all taxiways accommodating ADG IV aircraft should be paved to comply with FAA standards. Currently, Taxiway D is the only taxiway with paved shoulders. All other taxiways should have 30-foot-wide paved shoulders, except for Taxiway K and Taxilane J, which accommodate smaller aircraft.

Geometry

Non-standard taxiway geometry is discussed and identified in this subsection, and depicted on **Exhibit 4-6**.

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[5] Woolpert, *Ellington Airside Pavement Evaluation*, July 2014.

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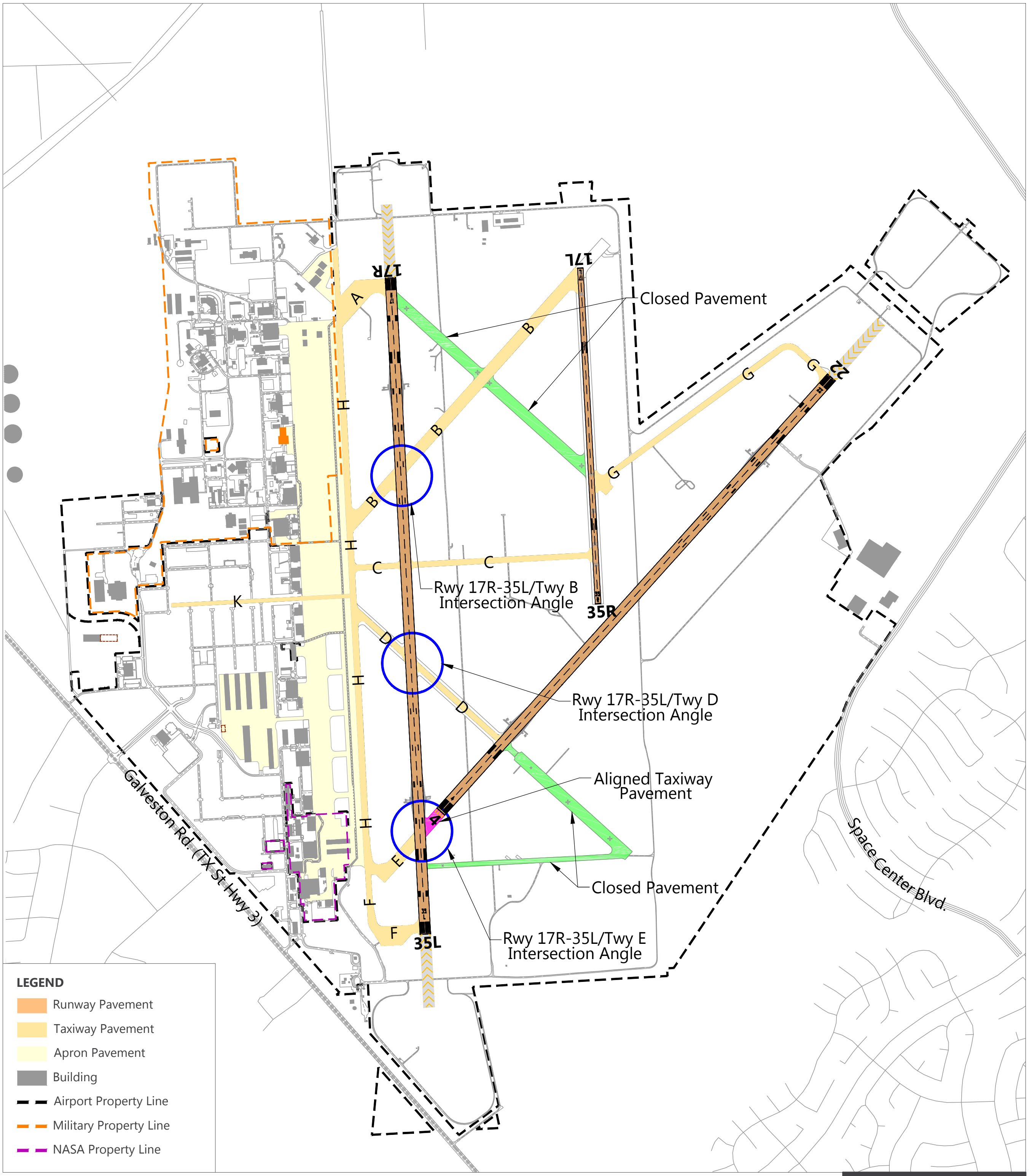

SOURCES: Ricondo and Associates, Inc., Ellington Airport, Draft Airport Layout Plan, June 2014; Ricondo & Associates, Inc., July 2015.
PREPARED BY: Ricondo & Associates, Inc., July 2015.

EXHIBIT 4-6

NORTH
0 2,000 ft.

Non-Standard Taxiway Geometry

Drawing: \\ricondo.com\public\Dallas\Project\Houston Airport System\Ellington Airport\2014 Master Plan Update\04 - Requirements\Exhibits\CAD\Exh 4-6_Taxiway Safety Issues.dwg Layout: 4-6 - Existing Taxiwaty Safety Issues Plotted: Sep 25, 2015, 11:21AM

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Runway-Taxiway Intersection Angle:

In its early history, the airfield at Ellington Airport had several intersecting runways. The pavement from these original runways is still present on the airfield. Some of it is still being used in the form of active taxiways that have been rehabilitated (Taxiways B and D), and some of it consists of closed pavement. Because of this early airfield layout, existing active Taxiways B, D and E intersect with Runway 17R-35L at 45-degree angles (acute angle). Currently, the FAA recommends that taxiways intersect a runway at a right angle to provide for optimal pilot visibility when entering the runway. Acute angle runway exits provide for greater efficiency in runway usage, but should not be used as runway entrance or crossing points.

Location of Runway Crossings:

In AC 150/5300-13A (Change 1), the FAA recommends avoiding "high energy" intersections, which are intersections in the middle third of the runway. By limiting runway crossings to the outer thirds of the runway, the portion of the runway where a pilot can least maneuver to avoid a collision is kept clear. There are currently two runway crossings in the middle third of Runway 17R-35L, at Taxiways C and D. Proposed taxiway layouts should eliminate these runway crossings to the maximum extent possible.

Closed Pavement and Confusing Airfield Layout:

The original airfield at EFD has left very visible marks in the form of closed pavements and a sometimes confusing layout. Closed pavement may be confusing to pilots unfamiliar with the airfield, especially considering the intersecting pattern of pavement at Ellington Airport.

Aligned Taxiway:

An aligned taxiway is one with a centerline that coincides with a runway centerline, such as Taxiway E and Runway 4. Taxiway E used to be a portion of Runway 4, and was created as a result of the shortening of Runway 4. This alignment places a taxiing aircraft in a direct line with aircraft landing or taking off. The resultant inability to use the runway while the taxiway is occupied, along with the possible loss of situational awareness by a pilot, precludes the design of these taxiways. In AC 150/5300-13A (Change 1), the FAA recommends that existing aligned taxiways be removed as soon as practicable. Any abandoned pavement should preferably be removed, but at a minimum appropriately marked. Proposed taxiway layouts should eliminate this aligned taxiway to the maximum extent possible.

4.2.3.2 Taxiway Network to Support Runway 4-22

Factors to be considered when developing requirements for the Runway 4-22 taxiway network include:

- Convenience/operational safety of taxiing routes to/from Runway 4-22
- Taxiway access to areas of potential development

The current airfield configuration limits aircraft access to Runway 4-22 and requires circuitous taxiing routes along Taxiway C, Runway 17L-35R, and Taxiway G for aircraft departing on Runway 22. Aircraft departing on Runway 4 have a more direct taxiing route via Taxiway E, which is aligned with the extended Runway 4 centerline; however, this runway/taxiway alignment is prohibited by the FAA (per the most recent versions of

AC 150/5300-13) and should be eliminated. Aircraft landing on Runway 4 must either roll out to the Runway 22 end and reach the west ramp areas using Taxiways G and C, or perform a 180-degree turn and back-taxi to Taxiway D. Aircraft landing on Runway 22 use Taxiway D or roll out to the end of the runway and use Taxiway E. Taxi routes to/from Runway 4-22 are highlighted on **Exhibit 4-7**.

Additionally, development of the southeast quadrant of EFD would require taxiway access to this area. A parallel taxiway to Runway 4-22 on the southeast side would provide such access. It is also recommended that a parallel taxiway to Runway 4-22 be tied in with the Runway 35L end, not only to eliminate the aligned taxiway condition created by the portion of Taxiway E east of Runway 17R-35L, but also to eliminate a runway crossing in the middle third of Runway 17R-35L, at Taxiway D.

4.2.4 AIRFIELD SAFETY AND PROTECTION AREAS

The FAA design standards for various airfield safety and protection areas, as they relate to the Airport, are discussed in this subsection. These areas, introduced in Section 2, are illustrated on the Airport Layout Plan (ALP) Existing and Future Sheets provided in **Appendix F.** Airfield safety and protection areas evaluated for the Airport include the RSA, OFA, OFZ, RPZ, and building restriction line (BRL).

4.2.4.1 Runway Safety Areas

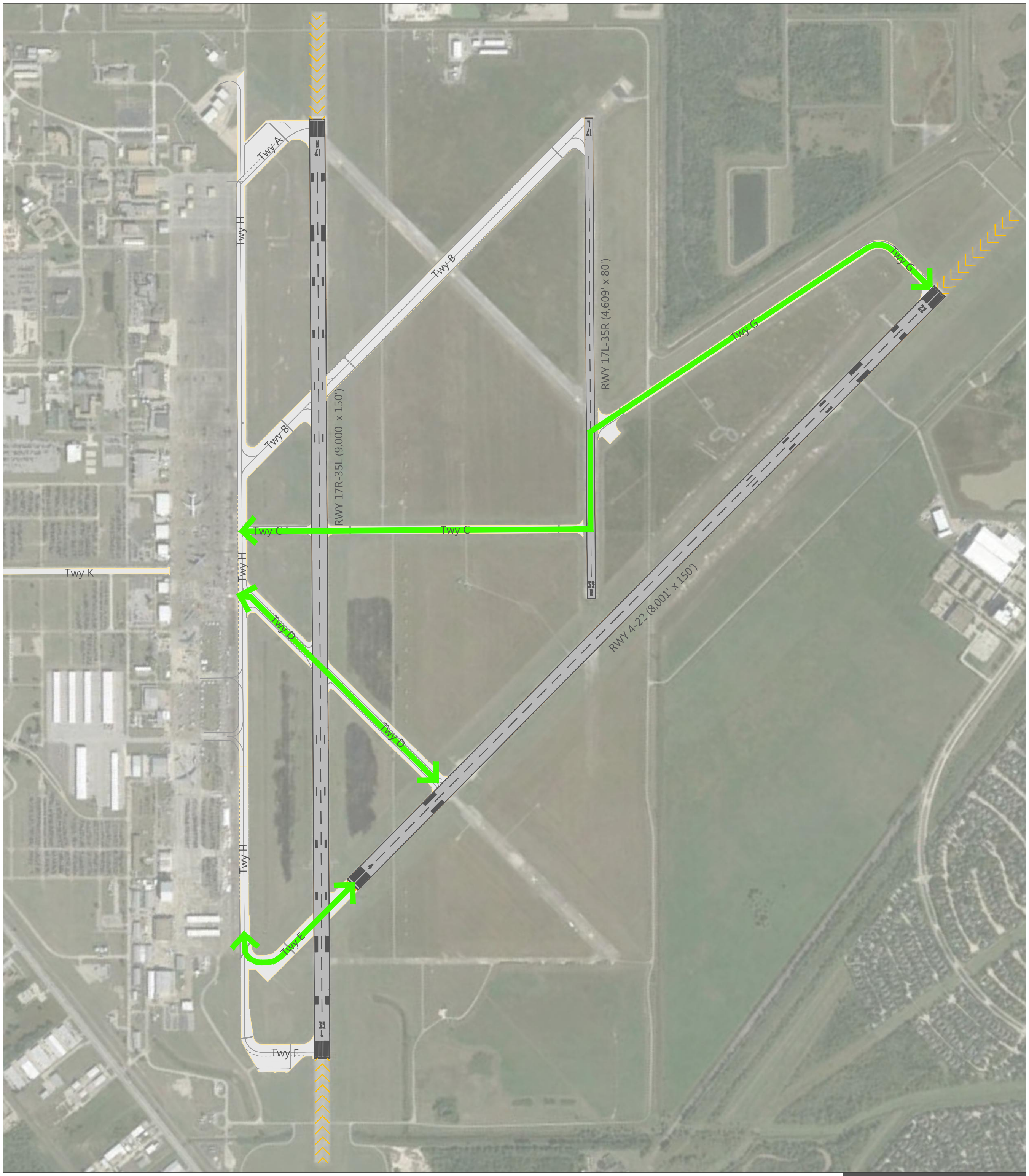
The RSA is a rectangular area centered on the runway centerline, which, under normal (dry) conditions, is capable of supporting aircraft without causing structural damage to the aircraft or injury to its occupants, if an aircraft were to inadvertently leave the paved runway surface. For the RSA to serve this function, the FAA requires it to be (1) cleared and graded, (2) drained by grading or storm sewers to prevent water accumulation, and (3) free of objects, except those that need to be located in the RSA because of their function (e.g., approach lighting).

Based on FAA design criteria for RDC D-IV, the RSA for Runways 17R-35L and 4-22 should be 500 feet wide (i.e., 250 feet on either side of the runway centerline) and extend 1,000 feet beyond each runway end. Design criteria for RDC B-II visual runways (Runway 17L-35R) specify an RSA with a width of 150 feet that extends 300 feet beyond each runway end. Currently, the RSAs for all runways meet the applicable design criteria.

4.2.4.2 Runway Object Free Areas

The ROFA is a rectangular area centered on the runway centerline, which is required to be clear of objects protruding above the RSA edge elevation, with the exception of those objects that are essential to air navigation or aircraft ground maneuvering.

For runways with an RDC of D-IV (Runways 17R-35L and 4-22), the ROFAs should be 800 feet wide and extend 1,000 feet beyond each runway end. For RDC B-II runways (Runway 17L-35R), the ROFA must be 500 feet wide and extend 300 feet beyond each runway end. The ROFA length beyond the end of the runway never exceeds the standard RSA length beyond the runway end. All runways at EFD meet the applicable ROFA design criteria. No changes except those that may be dictated by future runway development are anticipated to be required through the planning period.



SOURCE: Airport Traffic Control Tower Staff, Ellington Airport, Interviewed by Jacobsen/Daniels Staff, May 2013.
PREPARED BY: Jacobsen/Daniels Associates LLC, September 2015.

EXHIBIT 4-7

NORTH 0 1,400 ft.

Taxi Routes To/From Runway 4-22

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4.2.4.3 Obstacle Free Zone

The OFZ is a volume of airspace centered on the runway centerline, defined by the FAA as:

> the airspace below 150 feet above the established airport elevation and along the runway, and extended runway centerline that is required to be clear of all objects, except for frangible navigational aids that need to be located in the OFZ because of their function, in order to provide clearance protection for aircraft landing or taking off from a runway, and for missed approaches.

The OFZ is intended to protect an aircraft's transition from ground to airborne operations (and vice versa). Airports with nonprecision instrument approach procedures are only required to comply with the runway component of the OFZ criteria, whereas airports with precision instrument approach procedures or approach lighting systems are required to comply with additional requirements. FAA criteria prohibit taxiing, parked aircraft, and object penetrations within OFZs, except for frangible navigational aids with locations that are fixed by function. Applicable elements of the Airport's OFZ are described as follows:

- Runway OFZ – The runway OFZ is typically 400 feet wide for runways serving large aircraft (Runways 17R-35L and 4-22) and 250 feet wide for nonprecision and visual approach runways serving smaller aircraft (Runway 17L-35R). All OFZs extend 200 feet beyond the runway ends. All runways at EFD meet their respective runway OFZ design criteria.
- Precision OFZ – The precision OFZ is a volume of airspace above an area beginning at the threshold of and centered on the extended runway centerline, 200 feet long by 800 feet wide. It applies to runway ends that have instrument approaches with vertical guidance, which include Runways 17R, 35L, and 22 at EFD. For example, the wing of an aircraft holding on Taxiway G for takeoff clearance may penetrate the precision OFZ; however, neither the fuselage nor the tail of the aircraft may infringe on the precision OFZ.
- Inner Approach OFZ – The inner approach OFZ is a volume of airspace centered on the approach area that applies only to runways equipped with approach lighting. Therefore, the inner approach OFZ applies to Runways 22, 17R, and 35L at EFD. The inner approach OFZ begins 200 feet from the runway threshold and extends 200 feet beyond the last unit in the approach lighting system. It has the same width as the runway OFZ and rises at a slope of 50:1 away from the runway end. Any objects that penetrate the inner approach OFZ must be listed on the Airport Obstruction Chart.
- Inner transitional OFZ – The inner transitional OFZ is a defined volume of airspace along the sides of the runway and inner approach OFZ. It applies only to runways with lower than 0.75-statute-mile approach visibility minimums. Both instrument approaches published for Runway 22 have visibility minimums less than 0.75 statute mile. Therefore, Runway 22 is the only runway at the Airport subject to inner transitional OFZ object clearance requirements. Any objects that penetrate the inner transitional OFZ must be listed on the Airport Obstruction Chart.

4.2.4.4 Runway Protection Zones

The RPZ is a trapezoidal area centered on the extended runway centerline. The length and width of the RPZ are contingent on the size of aircraft operating on the runway as well as the type of approach (i.e., visual or instrument) and the available approach minimums. The RPZs are designed to enhance the protection of people and property on the ground. To achieve this goal, the FAA recommends that the airport sponsor own or otherwise control the property in the RPZ. This area should be free of land uses that create glare and smoke. Additionally, the FAA recommends that airport sponsors keep the RPZs clear of incompatible land uses, specifically residences, fuel storage facilities, places of public assembly (e.g., churches, schools, office buildings, and shopping centers), and public roadways.

The FAA provides dimensional criteria for RPZs that are based on runway approach visibility minimums and the AAC associated with each runway. RPZ dimensions for each runway end at EFD are provided in **Table 4-10**. As the Airport does not have any displaced thresholds or declared distances, the departure RPZs are located within the approach RPZs of all runways.

Table 4-10: Approach Runway Protection Zone Dimensions

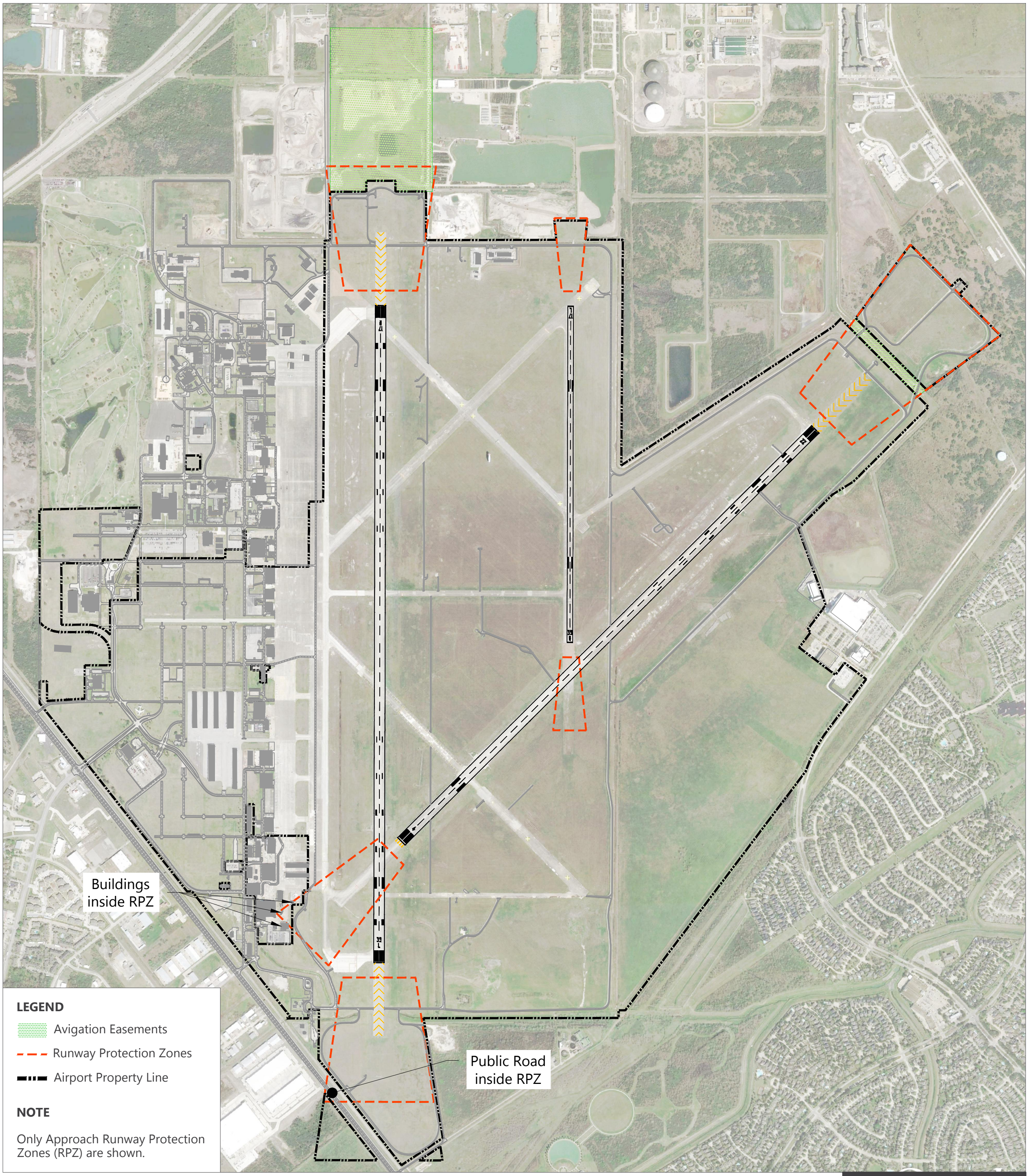
RUNWAY	INNER WIDTH (FEET)	OUTSIDE WIDTH (FEET)	LENGTH (FEET)	DISTANCE FROM THRESHOLD (FEET)
17L	250	450	1,000	200
35R	250	450	1,000	200
17R	1,000	1,510	1,700	200
35L	1,000	1,510	1,700	200
4	500	1,010	1,700	200
22	1,000	1,750	2,500	200

SOURCES: Ricondo & Associates, Inc., March 2014; FAA Advisory Circular 150/5300-13A, *Airport Design* (Change 1), February 24, 2014
PREPARED BY: Ricondo & Associates, Inc., March 2014.

Currently, most RPZs at EFD are within the Airport property boundary, except for:

- A portion of the Runway 22 approach RPZ
- A portion of the Runway 17R approach RPZ
- A portion of the Runway 4 approach RPZ
- A portion of the Runway 35L approach RPZ

Runway 22 and 17R approach RPZs are protected by two avigation easements that ensure HAS control of the Airport over those areas. However, no easement exists for the Runway 4 and 35L approach RPZs and incompatible structures are located within these RPZs. These include Texas State Highway 3, a public highway that runs through the Runway 35L RPZ. In accordance with AC 5300/150-13A, public roadways are not permitted within RPZs. Structures are also located within the Runway 4 approach RPZ, on NASA property. **Exhibit 4-8** depicts the existing RPZs and identifies RPZ areas not owned by HAS, avigation easements, and incompatible structures currently located within the RPZs.



SOURCE: Ricondo & Associates, Inc., March 2014.
PREPARED BY: Ricondo & Associates, Inc., September 2015.

EXHIBIT 4-8

Noncompliant Structures within Existing Runway Protection Zones

Drawing: Y:\04 - Requirements\Exhibits\CAD\Exh 4-7 & 4-8_RPZ Penetrations.dwg_Layout: Exh 4-8_Sep 17, 2015, 3:18pm

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Over one acre of NASA property is located in the RPZ and three structures, located on NASA property, are partially or completely within the RPZ (see **Exhibit 4-9)**. Although structures and buildings, including commercial/industrial buildings, are not permitted within an RPZ, these structures were in the RPZ when the City purchased the Airport and they were grandfathered in.

4.2.4.5 Building Restriction Lines

BRLs provide the necessary safety clearances between buildings or other fixed objects and the airport's runways and taxiways. The FAA requires that BRLs be established to identify suitable building area locations on an airport. The BRLs should prevent encroachment of the RPZ, ROFA, the runway visibility zone (if one is required), navigational aid critical areas, imaginary surfaces prescribed under 14 CFR Part 77, *Safe, Efficient Use, and Preservation of the Navigable Airspace,* and areas required for terminal instrument approach procedures. In some cases, minimum taxiway clearance requirements dictate the locations of BRLs. The minimum clearance requirement for a taxiway accommodating ADG IV aircraft is 129.5 feet. As previously mentioned, EFD is an ADG IV airport.

The locations of BRLs based on minimum taxiway clearance requirements, navigational aid critical areas, runway visibility zones, and ATC line-of-sight requirements should be determined on an individual basis. Unless minimum taxiway obstacle clearance or ATC line-of-sight requirements dictate otherwise, BRLs are typically located laterally and parallel to a runway.

There are no BRL penetrations at EFD.

4.2.5 AIRFIELD LIGHTING

The Runway 17R approach end is equipped with a medium-intensity approach lighting system with sequenced flashers. To increase the usability of the airfield during poor weather conditions, HAS is planning to upgrade the MALSF to a MALSR, therefore decreasing the visibility minimums for approaches to Runway 17R.

4.2.6 AIRFIELD MARKING AND SIGNAGE

Requirements for airfield markings are described in FAA AC 150/5340-1L, *Standards for Airport Markings*. Markings on the airfield include runway, taxiway, and other markings.

Similar to runway lighting, runway markings are determined by the types of approaches to the runway. The types of markings on each runway at EFD are appropriate, given the approaches served. Additionally, all markings are reported to be in good condition. Other markings on the airfield, such as taxiway markings, hold position markings, and other required markings, also meet requirements.

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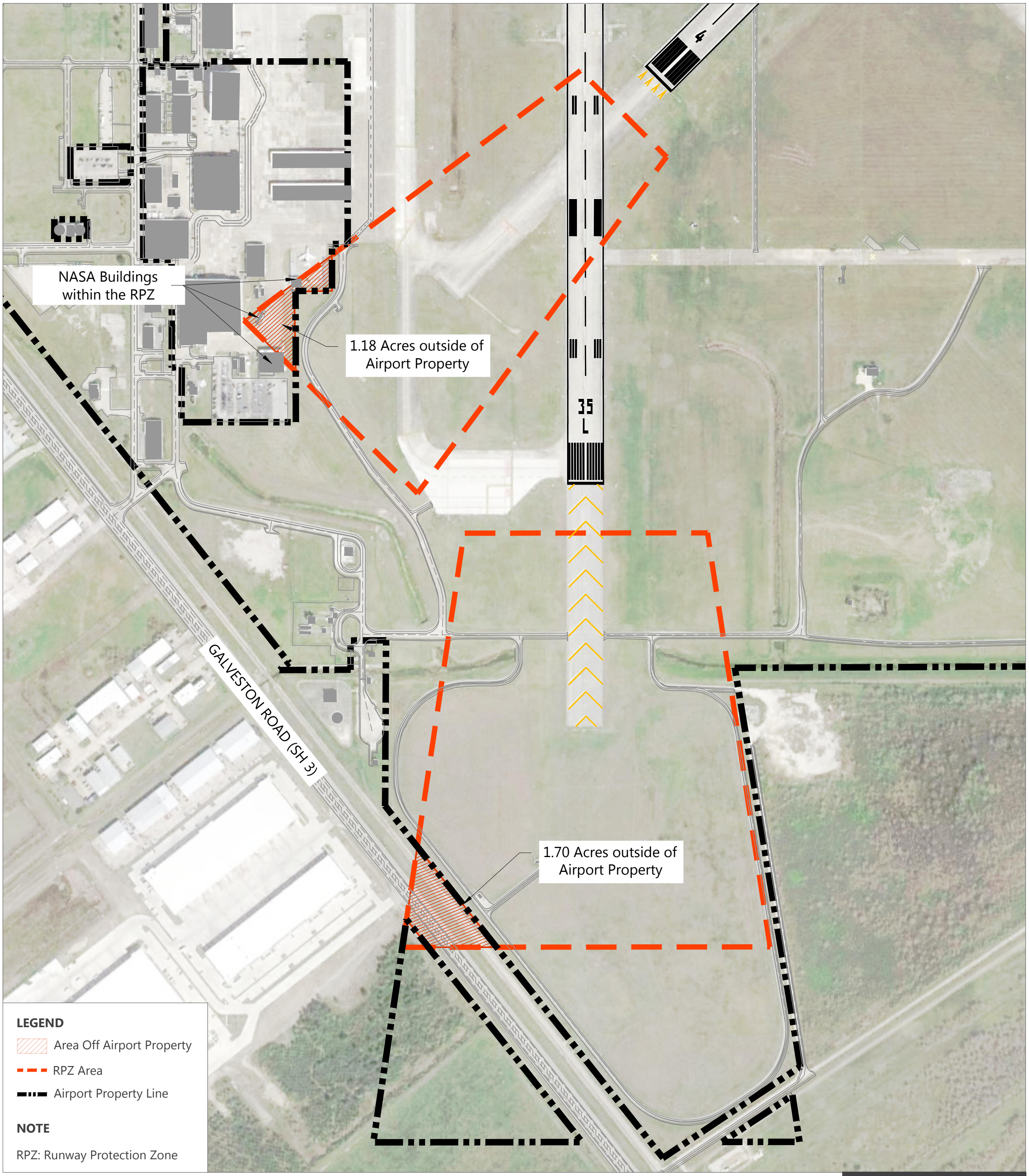

LEGEND

▨ Area Off Airport Property

RPZ Area

Airport Property Line

NOTE

RPZ: Runway Protection Zone

SOURCE: Ricondo & Associates, Inc., February 2014.
PREPARED BY: Ricondo & Associates, Inc., September 2015.

EXHIBIT 4-9

Noncompliant Structures within the Runway 4 Approach Runway Protection Zone

Drawing: Y:\04 - Requirements\Exhibits\CAD\Exh 4-7 & 4-8_RPZ Penetrations.dwg_Layout: Exh 4-9_Sep 17, 2015, 3:21pm

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The designation markings for Runways 17L, 35R, 17R, and 35L do not meet the criteria specified in AC 150/5340-1L, where the runway designator number is defined as the whole number nearest the one-tenth of the magnetic azimuth along the runway centerline when viewed from the direction of approach. As of December 2013, Runways 17L and 17R had magnetic azimuths of 178.8 degrees (179 degrees) and Runways 35L and 35R had magnetic azimuths of 358.8 degrees (359 degrees). In accordance with AC 150/5340-1L, if a magnetic azimuth ends in a number greater than "5," the runway designator number should be rounded up. Given the magnetic azimuth of each runway end, Runways 17L and 17R should be redesignated as Runways 18L and 18R, and Runways 35L and 35R should be redesignated as Runways 36L and 36R.

Guidance for type and location requirements for various airport signage is specified in FAA AC 150/5340-18F, *Standards for Airport Sign Systems*. No required signage improvements were identified for existing facilities at EFD.

4.2.7 NAVIGATIONAL AIDS

As described in Section 2, navigational aids at the Airport include visual navigational aids and electronic navigational aids. All existing visual navigational aids comply with FAA standards and no additional visual aids should be required at the Airport through the planning period.

The existing instrument approach procedures published for the Airport (as described in Section 2) are adequate given the type and number of operations forecast for the Airport. Therefore, no additional electronic navigational aids should be required at the Airport through the planning period. Any future instrument approach procedures developed for the Airport will likely be based on satellite technology, which is unlikely to require the installation of any physical equipment at the Airport.

4.3 General Aviation and Airport Support Facilities

4.3.1 FIXED BASE OPERATOR

Landmark Aviation, the sole FBO servicing aircraft owners and pilots at the Airport, has plans to add new hangar facilities at the Airport in order to expand the services it offers customers.

Currently, there are no plans for a second FBO, but additional GA demand could translate into future opportunities to provide competitive FBO services at the Airport.

4.3.2 APRON AND HANGARS

Itinerant and based aircraft parking and storage demand drives requirements for general aviation apron space and hangars.

4.3.2.1 Itinerant Aircraft Parking

Itinerant aircraft aprons are intended to accommodate short-term aircraft parking, usually less than 24 hours. Such aprons should provide easy access to the FBO and fueling facilities, and be configured to allow for safe and efficient taxiing movements between parking positions and the airfield.

The requirements for itinerant aircraft parking positions were derived using the guidance provided in AC 150/5300-13A (Change 1). Using the peak activity forecasts presented in Section 3, PMAD itinerant aircraft operations for the Airport were used to calculate the number of aircraft parking positions needed to accommodate itinerant aircraft based on forecast demand. It is important to note that approximately 80 percent of itinerant general aviation operations at EFD are touch-and-go flight training operations originating at other airports and, therefore, do not need parking. The itinerant aircraft parking position demand at the Airport is presented in **Table 4-11**.

Table 4-11: Itinerant Aircraft Parking Position Demand

	ANNUAL ITINERANT GENERAL AVIATION OPERATIONS			OPERATIONS REQUIRING PARKING		
YEAR	TOTAL	TOUCH-AND-GO ONLY	OPERATIONS REQUIRING PARKING	PEAK MONTH OPERATIONS [1/]	PEAK MONTH AVERAGE DAY OPERATIONS [2/]	TOTAL REQUIRED PARKING POSITIONS [3/]
2012	40,094	32,075	8,019	842	27	16
2015	41,352	33,082	8,270	868	28	17
2020	43,526	34,821	8,705	914	29	18
2025	45,798	36,638	9,160	962	31	19
2030	48,172	38,538	9,634	1,012	33	20

NOTES:

1/ The peak month (October) represents 10.5 percent of annual operations (see Section 3, "Aviation Activity Forecasts").

2/ Peak month operations divided by 31 days in October.

3/ Assuming that 50 percent of itinerant non-touch-and-go aircraft require parking positions at any one time plus a 10 percent reserve.

SOURCE: Ricondo & Associates, Inc., March 2014.
PREPARED BY: Ricondo & Associates, Inc., March 2014.

The itinerant aircraft parking area requirement was calculated by multiplying the number of required parking spaces by the average amount of ramp area needed to accommodate one aircraft. When determining apron area requirements, provision must be made for the aircraft parking area as well as the taxilanes leading to the parking positions. Usually, to determine the area required for the movement of aircraft between parking positions, half the width of the respective ADG taxilane OFA and a 10-foot clearance between each aircraft parking position is applied. However, the ADG of itinerant aircraft were not recorded for the Airport. Based on discussions with Airport staff, it was determined that approximately 20 percent of itinerant aircraft are ADG III, 40 percent are ADG II, and 40 percent are ADG I.

Using this approach, the following assumptions were made relating to ramp area requirements for each ADG:

- 4,500 square feet were assumed for each ADG I aircraft (primarily single- and small multi-engine aircraft, and a limited number of small business jets).
- 8,300 square feet were assumed for each ADG II aircraft (most small, midsize, and heavy business jets).
- 19,500 square feet were assumed for each ADG III aircraft (large business jets, such as the Gulfstream V or Global Express)

The resulting itinerant aircraft apron requirements for the Airport are presented in **Table 4-12**.

Table 4-12: Itinerant Aircraft Parking Requirements

	ADG I		ADG II		ADG III		TOTAL	
YEAR	NUMBER OF AIRCRAFT PARKING POSITIONS	APRON AREA (SQUARE FEET)	NUMBER OF AIRCRAFT PARKING POSITIONS	APRON AREA (SQUARE FEET)	NUMBER OF AIRCRAFT PARKING POSITIONS	APRON AREA (SQUARE FEET)	NUMBER OF AIRCRAFT PARKING POSITIONS	APRON AREA (SQUARE FEET)
2012	7	29,333	6	54,104	3	63,555	17	146,992
2015	7	30,254	7	55,801	3	65,549	17	151,604
2020	7	31,844	7	58,735	4	68,996	18	159,575
2025	8	33,506	7	61,801	4	72,597	19	167,904
2030	8	35,243	8	65,004	4	76,361	20	176,608

NOTE: ADG = Airplane Design Group.

SOURCE: Ricondo & Associates, Inc., March 2014.
PREPARED BY: Ricondo & Associates, Inc., March 2014.

By 2030, approximately 176,608 square feet of apron area are anticipated to be required to accommodate itinerant aircraft parking demand at the Airport, about 30,000 square feet more than the 2012 requirement. As described in Section 2, the apron that can be used by itinerant aircraft consists of approximately 905,000 square feet of pavement, suggesting that additional general aviation apron area is not required through the planning period.

4.3.2.2 Based Aircraft Parking and Storage

The requirements for based aircraft parking (i.e., outdoor aircraft tiedown positions) and based aircraft storage in T-hangars or conventional hangars are summarized in this subsection. At the Airport, T-hangars are indoor aircraft storage facilities; some T-hangars can accommodate up to three aircraft. Conventional hangars are large private hangars used to store more than three aircraft. According to HAS staff, at the time of the anlaysis, approximately 10 percent of aircraft based at the Airport were parked at tiedown positions and 90 percent were stored in hangars.

The following assumptions were made to estimate the future demand for each type of facility at EFD. Future demand was based on the forecasts of based aircraft presented in Section 3.

- HAS will not increase the number of tiedown positions available for based aircraft parking (currently 22). Tiedown positions occupy premium real estate, and demand for T-hangar storage far exceeds demand for tiedown storage.
- Strong demand is expected for T-hangar facilities; there is currently a waiting list of 40 requests for small and large T-hangars. Additionally, some owners of aircraft currently parked in conventional hangars seek T-hangars to reduce their storage costs.
- In the Baseline Scenario, the number of based jet aircraft is expected to increase an average of 3.1 percent per year, and will drive the demand for conventional hangars.

Based on discussions with Airport staff, the number of aircraft parked at tiedown positions, in small or large T-hangars, or in conventional hangars was estimated for each aircraft type. **Table 4-13** shows the breakdown of based aircraft storage locations by aircraft type.

Table 4-13: Based Aircraft Parking and Storage Distribution by Aircraft Type

	PARKED AT TIEDOWN POSITIONS	PARKED ON FBO APRON	STORED IN SMALL T-HANGARS	STORED IN LARGE T-HANGARS	STORED IN CONVENTIONAL HANGARS
Single-engine Piston Aircraft	14%	-	72%	9%	5%
Multi-engine Piston Aircraft	12%	-	-	60%	28%
Jet Aircraft	-	2%	-	8%	90%
Helicopters	-	-	-	12%	88%
Gliders	-	-	-	100%	-

SOURCES: Houston Airport System, March 2014; Ricondo & Associates, Inc., March 2014.
PREPARED BY: Ricondo & Associates, Inc., March 2014.

The distributions presented above were assumed to remain valid through 2030, i.e., the number of based aircraft of each aircraft type will increase according to the forecasts presented in Section 3, but the storage distribution shown in the table is anticipated to remain unchanged.

Based Aircraft Apron

Based aircraft parked at outdoor tiedown positions are mostly single- and multi-engine aircraft. Additionally, these aircraft can be parked closer to each other than itinerant aircraft because based aircraft are usually not maneuvered shortly after they are parked. For these two reasons, the apron area dedicated to based aircraft is usually smaller than that reserved for itinerant aircraft. At the time of the analysis, 22 HAS tiedown positions were available at EFD, as well as tiedown positions for flight training aircraft. Out of the 22 HAS positions available, 12 were occupied (10 by single-engine aircraft and 2 by multi-engine aircraft).

It is expected that the jet aircraft parked on the FBO apron will be moved inside a conventional hangar when space becomes available, and no apron parking requirements for based jet aircraft will be developed.

It is HAS policy not to increase the number of tiedown positions available through the planning period. Indeed, aircraft owners typically prefer T-hangars for small aircraft and, therefore, HAS will pursue the development of additional T-hangars for aircraft storage.

T-Hangars

T-hangars are facilities used for the permanent storage of aircraft. One small T-hangar usually accommodates one single-engine aircraft. However, two single-engine aircraft (one low-wing aircraft and one high-wing aircraft) may fit in a small T-hangar. Large T-hangars can accommodate one multi-engine piston aircraft, one small jet, or up to three single-engine piston aircraft.

The demand for T-hangars is based on the number of aircraft based at the Airport and on local weather conditions. Airports in warm weather regions, for instance, tend to have a lower demand for T-hangars than for apron parking. The Airport currently has 66 small and 24 large T-hangars, which are 1,500 square feet and 3,200 square feet, respectively. The surplus of current and future demand for T-hangars is anticipated to be accommodated in new T-hangars. The existing small T-hangars can be used to store a Cessna 172R Skyhawk, which is a typical GA single-engine piston aircraft. The existing large T-hangars can be used to store a Beechcraft Baron G58, which is a typical twin piston aircraft.

The future T-hangar requirements at EFD are based on the forecasts of based aircraft provided in Section 3. Projections by aircraft type are used in this analysis. The following assumptions were made:

- Each new T-hangar will be equipped with an apron area for maneuvering purposes with the same square footage as the hangar area.
- Each new hangar will be used to store only one aircraft.
- The new T-hangars will be the same size of the existing T-hangars.

To determine future requirements for small T-hangars, it was further assumed that 101 single-engine piston aircraft (out of the 140 single-engine piston aircraft currently based at the Airport) will be stored in small T-hangars. This means that two aircraft will be stored in every other small T-hangar. **Table 4-14** presents the requirements for small T-hangars at the Airport through 2030.

Table 4-14: Small T-Hangar Requirements

YEAR	NUMBER OF SINGLE-ENGINE BASED AIRCRAFT STORED IN SMALL T-HANGARS	NUMBER OF NEW SMALL T-HANGARS	TOTAL SMALL T-HANGAR AREA (SQUARE FEET)	TOTAL SMALL T-HANGAR AND APRON AREAS (SQUARE FEET)
2012	101	0	0	0
2015	102	1	3,000	3,000
2020	106	5	7,500	15,000
2025	109	8	12,000	24,000
2030	113	12	18,000	36,000

SOURCE: Ricondo & Associates, Inc., March 2014.
PREPARED BY: Ricondo & Associates, Inc., March 2014.

To determine future requirements for large T-hangars, it was assumed that 32 aircraft are currently stored in the 24 existing large T-hangars at EFD. These aircraft include 12 single-engine piston aircraft, 15 multi-engine piston aircraft, 3 jet aircraft, 1 helicopter, and 1 glider. **Table 4-15** presents the requirements for large T-hangars at the Airport through 2030.

Table 4-15: Large T-Hangar Requirements

	STORED IN LARGE T-HANGARS				REQUIREMENTS		
YEAR	NUMBER OF PISTON AIRCRAFT [1/]	NUMBER OF JET AIRCRAFT	NUMBER OF HELICOPTERS	NUMBER OF GLIDERS	NUMBER OF NEW LARGE T-HANGARS	TOTAL NEW T-HANGAR AREA (SQUARE FEET)	TOTAL T-HANGAR AND APRON AREAS (SQUARE FEET)
2012	27	3	1	1	0	0	0
2015	17	4	1	0	1	3.200	6,400
2020	28	5	1	0	2	6.400	12,800
2025	28	6	1	0	3	9,600	19,200
2030	28	7	1	0	5	16.000	32,000

NOTE:

1/ Includes single-engine and multi-engine piston aircraft.

SOURCE: Ricondo & Associates, Inc., March 2014.
PREPARED BY: Ricondo & Associates, Inc., March 2014.

Conventional Hangars

Conventional hangars are aircraft storage facilities that can accommodate multiple aircraft and/or activities such as maintenance. It was assumed that the average size of future large conventional hangars will be 30,000 square feet and that the apron area required for each conventional hangar will equal the area of the hangar. Additionally, to estimate the number of hangars that will be required though 2030, it was assumed that:

- Each single-engine piston requires an area of 1,500 square feet in the hangar.
- Each multi-engine piston aircraft requires an area of 2,500 square feet in the hangar.
- Each jet aircraft requires an area of 10,000 square feet in the hangar.

Conventional hangars can store single-engine piston aircraft, multi-engine piston aircraft, and jet aircraft. **Table 4-16** presents the requirements for conventional hangars at the Airport through 2030.

Table 4-16: Conventional Hangar Requirements

	STORED IN CONVENTIONAL HANGARS				REQUIREMENTS		
YEAR	NUMBER OF SINGLE-ENGINE PISTON AIRCRAFT	NUMBER OF MULTI-ENGINE PISTON AIRCRAFT	NUMBER OF JET AIRCRAFT	NUMBER OF HELICOPTERS	ADDITIONAL CONVENTIONAL HANGAR AREA REQUIRED (SQUARE FEET)	NUMBER OF NEW CONVENTIONAL HANGARS	NEW CONVENTIONAL HANGAR AND APRON AREA (SQUARE FEET)
2012	7	7	36	7	0	0	0
2015	7	7	40	8	44,900	2	89,800
2020	7	7	48	8	126,275	5	252,550
2025	8	7	55	9	207,325	7	414,650
2030	8	7	62	9	279,700	10	559,400

SOURCE: Ricondo & Associates, Inc., March 2014.
PREPARED BY: Ricondo & Associates, Inc., March 2014.

4.3.3 AIRFIELD SERVICES COMPLEX

The Airport's consolidated maintenance and storage complex (the Airfield Services Complex) is located along the northern boundary of the Airport, east of the Runway 17R end. The ASC has undergone several expansions to accommodate its functions at the Airport. According to Airport staff, the current size of the ASC is adequate and no additional expansion is anticipated throughout the planning period. However, it was indicated that a remodeling will be necessary within the planning period.

4.3.4 AIRPORT ADMINISTRATION FACILITIES

As described in Section 2, "Inventory of Existing Conditions," HAS Administration offices are located in Building W-440 on Aerospace Avenue. Building W-440, which is approximately 21,000 square feet, consists of HAS offices and meeting areas, and also houses the Houston Police Department. The current facility is adequate for current needs and Airport staff indicated that there is space to grow in the current facility when additional office space is required. Therefore, no expansion is anticipated throughout the planning period.

4.3.5 AIRCRAFT RESCUE AND FIRE-FIGHTING FACILITY REQUIREMENTS

The FAA assigns specific ARFF requirements for airports certified under 14 CFR Part 139 based on the airport's ARFF index. The index is based on the longest air carrier/commercial aircraft that serves the airport with five or more average daily departures. Existing ARFF equipment at EFD, as described in Section 2, meets the requirements for Index A, which applies to aircraft less than 90 feet in length (e.g., G-450 and ERJ-135). Based on fleet mix projections and operations forecasts presented in Section 3, the Airport should continue to maintain Index A requirements through the planning period

In accordance with 14 CFR Part 139, airport ARFF stations must be located such that the first responding piece of ARFF equipment can reach the midpoint of the furthest air carrier runway from its assigned post within 3 minutes from the time the alarm is sounded, have all onboard personnel in full protective gear, and begin application of the applicable fire-fighting agent. The location of the existing EFD ARFF station allows ARFF crews to satisfy these requirements.

The existing ARFF station is in good condition and adequately accommodates all required ARFF equipment and personnel. No ARFF upgrades or additional ARFF facilities/equipment are anticipated to be required during the planning period, except for any necessary vehicle replacement or facility maintenance.

4.3.6 GENERAL AVIATION ACTIVITY CENTER/CUSTOMS FACILITY

Although Ellington Airport is a convenient general aviation alternative to HOU, it lacks facilities to process large numbers of passengers. Additionally, HAS has expressed interest in having an onsite Customs facility. Therefore, a General Aviation Activity Center is recommended to accommodate various customers (e.g., large charter aircraft, low-cost airlines, international general aviation passengers). Such a facility would provide waiting areas for passengers and meeters and greeters, immigration and Customs services, restrooms, and potentially a restaurant.

4.3.7 AIRPORT TRAFFIC CONTROL TOWER

Proper siting of an ATCT is based on criteria described in FAA Order 6480.4, *Airport Traffic Control Tower Siting Criteria*. Mandatory siting requirements include maximum visibility of airborne traffic patterns, complete visibility of all airport surface areas used for the movement of aircraft that are under the control of ATCT personnel, sufficient area to accommodate required personnel, vehicle parking, and other facilities, as dictated by location requirements, compliance with 14 CFR Part 77, *Objects Affecting Navigable Airspace*, and located so that there is or will be no degradation of existing or planned electronic navigational aids. The FAA Order also states that depth perception of all surface areas to be controlled should be available.

Although the existing ATCT is sited in an adequate location, it is in poor condition and is in need of replacement.

4.3.8 SELF-SERVE FUELING FACILITY

4.3.8.1 Benefit/Cost Analysis

Based on a business assessment[6] conducted on behalf of HAS, a self-serve fueling facility delivering 100LL fuel would benefit both aircraft owners and HAS. The assessment documentation states that one FBO typically serves approximately 50,000 operations per year. As shown in **Table 4-17**, Landmark Aviation (formerly Southwest Airport Services) currently serves approximately 47,000 annual operations. Therefore, it was assumed that another fueling option would increase the level of service experienced by pilots desiring to refuel at EFD.

Table 4-17: Number of Aircraft Served Annually by the Fixed Base Operator

	2012 ANNUAL OPERATIONS
General Aviation Based Aircraft Operations	21,589
General Aviation Itinerant Aircraft Operations (Non-Touch-and-Go) 1/	8,019
Air Taxi	8,827
NASA	8,335
Estimated Total Operations Serviced by FBO	46,770

NOTE:

1/ Itinerant aircraft conducting touch-and-go operations represent approximately 80 percent of itinerant aircraft operations at EFD, and it was assumed that these aircraft do not refuel at EFD.

SOURCES: Houston Airport System *Statistical Report*, accessed October 2013; Ricondo & Associates, Inc., April 2014.
PREPARED BY: Ricondo & Associates, Inc., April 2014.

In addition to the low initial investment cost ($90,000) and low annual maintenance cost ($1,500, of which half is covered by TxDOT), several intangible benefits are associated with a self-serve fueling facility at the Airport. Such a facility would:

- Provide the general aviation flying community with cost-effective 24 hours per day, 7 days per week fuel service.
- Provide pilots with a sense of independence in taking care of their own aircraft.
- Reduce the amount of time piston aircraft pilots wait to be serviced by an FBO fuel truck
- Increase itinerant general aviation activity 10 percent annually because of convenience and lower fuel costs.
- Provide anticipated monthly revenue of $17,000 to HAS.
- Have an anticipated pay-off period of 5 months.

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[6] USA Shelco, *EFD Self-Serve Fueling Facility Business Assessment*, 2012.

The business assessment report is provided in **Appendix G**.

4.3.8.2 Selected Site

A site for the proposed self-serve fueling facility was identified in the southwest quadrant of the Airport, adjacent to the HAS T-hangars, as depicted on Exhibit 2-18. The facility became operational in spring 2015.

4.3.9 FUEL STORAGE FACILITIES

General aviation fuel storage facility requirements are based on forecast annual operations at the Airport and the average fuel consumption per aircraft operation. Military fuel requirements are not included in this analysis. A self-serve fueling facility is scheduled to become operational at EFD in summer 2014. It will be located at the end of Taxilane J, and have a capacity of 12,000 gallons. It was assumed in this analysis that this facility is already in operation. As discussed in Section 2.4.4, the capacity of the current fuel tanks used for GA, air taxi, and NASA operations is 188,000 gallons, including 54,000 gallons of Jet-A fuel, 24,000 gallons of aviation gasoline (avgas), and 110,000 gallons of Jet Propellant 8 (JP8) fuel.

Aircraft operators that potentially buy fuel at the Airport and that were considered in this analysis include air taxi operators, NASA, and general aviation aircraft operators not conducting touch-and-go operations. HAS records indicate that fuel flowage at EFD in 2012 amounted to approximately 3,142,000 gallons (excluding military activity), of which approximately 920,000 gallons were Jet-A fuel, 132,000 gallons were avgas, and 2,090,000 gallons were JP8 fuel.

Table 4-18 summarizes the current fuel storage capabilities of the FBO and planned self-serve fueling facility. The annual fuel demand shown represents FBO fuel demand in 2012.

Table 4-19 presents the results of the demand/capacity analysis for the fuel storage facilities operated by Landmark Aviation and HAS. The table presents the calculation of the average fuel demand per operation, the average daily fuel demand for the PMAD in 2012 and 2030, and the number of days that the fuel supply could serve PMAD demand. The storage capacities of the fuel trucks were also considered.

2012 aircraft operations include the following GA operations:

- Air taxi
- GA local
- 20 percent of GA itinerant (the remaining 80 percent were assumed to only conduct touch-and-go operations at the Airport and these operations would not stop for fuel).

Table 4-18: General Aviation Fuel Storage Capacity Summary (in gallons)

FUEL/FACILITY	FUEL TANKS	FUEL TRUCKS	TOTAL CAPACITY	ANNUAL FUEL USE [1/]
JET-A:				
Landmark Aviation	**54,000**	**10,000**	**64,000**	**919,021**
AVGAS:				
Landmark Aviation	12,000	1,950	13,950	132,220
HAS Self-Serve Fueling Facility	12,000	0	12,000	[2/]
	24,000	**1,950**	**25,950**	**132,220**
JP8:				
Landmark Aviation	**110,000**	**20,000**	**130,000**	**2,090,942**

NOTES:

1/ FBO fuel use based on HAS fuel records for January through December 2012.

2/ No annual fuel use was entered for the self-serve fueling facility. The annual total is included in the Landmark Aviation total.

SOURCES: Houston Airport System, April 2014; Ricondo & Associates, Inc.; April 2014.
PREPARED BY: Ricondo & Associates, Inc., April 2014.

Table 4-19: General Aviation Fuel Storage Demand/Capacity

	JET-A	AVGAS	JP8
2012 Aircraft Operations	20,238	18,196	8,335
2012 Fuel Demand (gallons)	919,021	132,220	2,090,942
2012 Average Fuel Demand per Operation (gallons/operation)	**45**	**7**	**251**
2012 PMAD Operations	69	62	28
2012 PMAD Fuel Demand (gallons)	3,113	448	7,082
2030 PMAD Operations	94	69	28
2030 PMAD Fuel Demand (gallons)	4,284	503	7,024
Existing Fuel Capacity (gallons)	64,000	25,950	130,000
2012 Fuel Supply (days)	21	58	18.5
2030 Fuel Supply (days)	15	52	18.5
Recommended Fuel Supply (days)	**3 days**	**3 days**	**3 days**

NOTE: PMAD = Peak month, average day.

SOURCES: Houston Airport System, HOU Fuel Records, April 2014.
PREPARED BY: Ricondo & Associates, Inc., April 2014.

For general planning purposes, a minimum of 3 days of fuel supply is recommended for general aviation facilities. As shown in Table 4-19, the Jet-A fuel storage capacity for 2030 is projected to be approximately 15 days, while the avgas storage capacity is projected to be approximately 52 days. NASA flight activity is anticipated to remain constant through the planning period, and the current JP8 fuel storage capacity provides an 18.5-day supply. As such, the capacity of all general aviation fuel storage facilities is anticipated to meet demand through the planning period.

It should be noted that this demand/capacity analysis included consideration of the overall fuel storage capacities for the entire Airport. Ultimately, the desire or need to develop new fueling facilities may be identified by individual Airport tenants. There are currently no plans for the only FBO at the Airport, Landmark Aviation, to increase fuel storage capacity.

4.3.10 GROUND SUPPORT EQUIPMENT STORAGE AND STAGING

Ground support equipment is used to service aircraft and support their operations, including fueling, aircraft mobility, and loading/unloading. GSE at the Airport is owned by the FBO and is stored/parked at the FBO facilities. With increased aircraft operations forecast at the Airport, the GSE storage and staging areas may require expansion to accommodate additional equipment. It was assumed that future demand for GSE storage and staging areas will be accommodated within the footprint of future facility expansion.

4.4 Airport Ground Access

Ground access facilities include the regional and local roadways, Airport access roadways, vehicle circulation roads, and parking facilities. Facility requirements and improvements have been identified, where applicable, for each of these functional areas, as discussed in the following subsections.

Roadway improvements are already planned in the southwest quadrant of the Airport to improve user and tenant access, such as extending Challenger 7 Parkway to Brantly Avenue (this improvement will consist of widening and renaming Morton Avenue and Hutchinson Road). Additional improvements were identified, as described below.

4.4.1 NORTH ACCESS ROAD

Access to the west side of the Airport (military and general aviation facilities) is via three intersections with Old Galveston Road: Hillard Street, Challenger 7 Parkway, and Brantly Avenue. Occasionally, all three intersections are blocked by trains stalled along Old Galveston Road, preventing ingress to and egress from the west side of the Airport. To provide additional access points, a new north access road connecting with Beltway 8 has been under discussion, although development of a fuel tank farm west of the Airport is constraining the roadway alignment to a narrow stretch of land between the fuel tank farm and the Pasadena Golf Course.

An interchange would also be required at Beltway 8 if direct connections to eastbound and westbound lanes are required, and would provide a direct connection between the Airport and the regional freeway system.

4.4.2 SOUTHEAST QUADRANT ACCESS

Access to the southeast quadrant of the Airport is currently via Clear Lake City Boulevard and Space Center Boulevard. If this area of the Airport is developed, it is recommended that a spur road be constructed from Old Galveston Road, along the southeast boundary of the Airport. This spur road would provide improved access to this area of the Airport, and keep new Airport traffic from using Clear Lake City Boulevard. This spur road is also referred to as the "Ellington Bypass." To prevent the Ellington Bypass from being blocked by trains, a fly over is also proposed.

4.4.3 ROADWAY INTERSECTIONS

Three roadway intersections along Old Galveston Road provide access to the Airport property:

- Old Galveston Road at Hillard Street,
- Old Galveston Road at Challenger 7 Parkway, and;
- Old Galveston Road at Brantly Avenue.

A fourth intersection, Old Galveston Road at Clearlake City Boulevard, located south of the Airport property line, is also used by Airport vehicular traffic heading east of the Airport.

Table 4-20 summarizes the LOS of each of these four intersections at three levels of activity: existing, 2020 and 2030, based on the forecasts prepared in Section 3. **Appendix H** provides the *EFD Traffic Analysis Report* prepared by Gunda Corporation in May 2015, detailing analyses and findings summarized in Table 4-20.

Table 4-20: Roadway Intersections Level of Service

	EXISTING		2020		2030	
INTERSECTIONS	AM PEAK HOUR	PM PEAK HOUR	AM PEAK HOUR	PM PEAK HOUR	AM PEAK HOUR	PM PEAK HOUR
Old Galveston Road at Hillard Street	B	B	B	C	C	C
Old Galveston Road at Challenger 7 Parkway	C	D	C	**F**	D	**F**
Old Galveston Road at Brantly Avenue	A	B	A	B	A	B
Old Galveston Road at Clearlake City Blvd.	**F**	**F**	**F**	**F**	**F**	**F**

SOURCE: Gunda Corporation, *EFD Traffic Analysis Report*, May 2015.
PREPARED BY: Ricondo & Associates, Inc., May 2015.

The City of Houston considers LOS D acceptable during peak hours. As shown in Table 4-20, the intersection of Old Galveston Road at Clearlake City Boulevard is already operating at LOS F, while the intersection of Old Galveston Road at Challenger 7 Parkway is anticipated to start operating at LOS F in 2020. Roadway design improvements will be evaluated in Section 5 to try to meet LOS D during the planning horizon.

4.5 Airport Rail Access

Development of the southeast quadrant of the Airport may also require construction of a rail spur from the Union Pacific Railroad line, which runs on the east side of Old Galveston Road, into the southeast quadrant. Rail access may be necessary to transport large parts or containers.

4.6 New Development Siting Considerations

The introduction of new activities on Airport property requires evaluation of compatible land uses to ensure that existing tenants are not adversely affected, or that future development is not restricted. Some basic characteristics and requirements for each type of potential development at Ellington Airport are discussed below.

4.6.1 SPACEPORT

The development of a spaceport at the Airport would require some airfield improvements, such as a runway extension and new taxiway connectors.

4.6.1.1 Site

Based on the findings of the *Ellington Spaceport Economics and Business Study*, the vacant site located in the southeast quadrant of the Airport is recommended for development of a spaceport. This site provides approximately 380 acres of greenfield development area, and is located in proximity to roadway access, rail access, and utilities.

4.6.1.2 Runway

Runway 17R is the primary runway at the Airport, with south flow being the predominant flow of operations. At 9,001 feet long, Runway 17R-35L is the longest runway at the Airport and it is the runway that would be used by spacecraft for takeoff and landing. Depending on the type of spacecraft operating at the Airport, Runway 17R-35L may need to be extended. Preliminary studies for the development of a spaceport at the Airport recommend a 10,000-foot-long runway to accommodate most spacecraft. However, if the Stratolaunch Carrier Aircraft were to initiate operations at the Airport, Runway 17R-35L would not only need to be extended to 12,000 feet, but it would also need to be widened from 150 feet to 200 feet.

4.6.1.3 Taxiway Network

To minimize development costs, early spaceport operations could use Runway 4-22 to reach the oxidizer loading area and departure runway, although taxiing on runways is not recommended. As spaceport operations grow and additional hangars are developed in the southeast quadrant of the Airport, additional taxiways, including full-length parallel taxiways to Runways 4-22 and 17R-35L, may be needed to support spaceport operations without excessive effects on other Airport operations.

To ensure compatibility with other activities potentially taking place in the southeast quadrant, such as cargo delivery in widebody aircraft, it is recommended that the taxiway network supporting spaceport operations meet ADG V design standards. ADG V taxiways would accommodate most spacecraft taxiing operations. However, if the Stratolaunch Carrier Aircraft were to operate at the Airport, taxiway requirements would be more demanding than those for smaller spacecraft. As the Stratolaunch Carrier Aircraft has a 135-foot-wide main gear, 165-foot-wide taxiways would be required to maintain the main gear on pavement (based on a 15-foot taxiway edge safety margin). Additionally, the taxiway shoulders should be 25 feet wide to ensure that the inner engines would be above a clear surface and that the risk of debris ingestion would be minimized. If taxiways parallel to Runways 17R-35L or 4-22 are required, the separation between the runway and taxiway centerlines should be 550 feet for independent runway and taxiway operations. For all other spacecraft, ADG V standards, which include 75-foot-wide taxiways, 25-foot-wide shoulders, and a lateral separation of 400 feet between the runway centerline and parallel taxiway centerline, would apply.

4.6.1.4 Oxidizer Loading Area

On the way to the departure runway, spacecraft typically taxi to an oxidizer loading area, where oxidizer fuel is loaded onto the spacecraft, as close to departure time as possible, to minimize the risk of explosion. Once the oxidizer fuel is loaded onto the spacecraft, an inhabited building distance (IBD) of 1,250 feet from the spacecraft becomes effective. All buildings within the IBD are required to be evacuated until the spacecraft has departed. To minimize the effects of the IBD, an initial oxidizer loading area is proposed on Taxiway B, between the two parallel runways. This loading area is anticipated to be approximately 22,500 square feet.[7] Long-term Airport development needs and growth of spaceport operations may require relocation of the oxidizer loading area and construction of a supporting taxiway network.

4.6.2 AIR CARGO FACILITIES

Siting requirements for an air cargo facility include an area that can accommodate large cargo buildings and apron, with convenient roadway access and convenient access to the airfield's longest runway. The runway length needs to be able to accommodate the typical payloads and types of cargo aircraft that would operate at the Airport. Another consideration is the provision of all-weather runway approach capability to maintain on-time performance, which is critical in the cargo industry.

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[7] RS&H, Inc., *Environmental Assessment for the Houston Spaceport at Ellington Airport*, February 2014, Page 2-12.

4.6.3 AIRCRAFT MANUFACTURING FACILITIES

Siting requirements for an aircraft manufacturing facility include an area that can accommodate large buildings and apron, with convenient roadway and rail access, proximity to utilities, and proximity to ports. The runway length needs to be able to accommodate large cargo aircraft that may deliver aircraft parts.

4.6.4 AIRCRAFT MAINTENANCE, REPAIR, AND OVERHAUL FACILITIES

Siting requirements for an aircraft maintenance, repair, and overhaul facility include an area that can accommodate large buildings and apron, and that provides sufficient distance from residential areas to minimize noise complaints. The runway length needs to be able to accommodate large cargo aircraft that may deliver aircraft parts.

5. Alternatives Development

A key objective of the master planning process is to identify alternative development strategies to accommodate forecast aviation activity or to help achieve other established development goals.

Section 3 provides a summary of forecast aviation activity at EFD. The forecasts were based primarily on continued incremental growth in general aviation activity. Section 4 identifies the additional facilities that would be required to accommodate forecast activity. Generally speaking, the nature and quantity of facilities required to accommodate forecast GA, cargo, and military aircraft activity at EFD are not very significant.

HAS has adopted a number of "wildly important goals" (WIG) for its three airports and associated management teams. One of these goals is to foster the development of currently vacant land at EFD. Various aeronautical activities are being considered, including aircraft manufacturing, air cargo handling and distribution, and, most notably, spaceport operations. HAS management has already made significant progress in exploring these possibilities. Several planning initiatives have been completed (or are ongoing) that must be integrated into this master planning process and the identification of development alternatives. Because most of the development alternatives are in early conceptual stages, it is expected that many alternatives discussed in this section will continue to be modified and refined prior to final design and construction.

5.1 Summary of Requirements and Future Development Priorities

Section 4 provided information on how the forecasts of aviation activity (summarized in Section 3) were translated into facility requirements for the master planning period (through 2030). These requirements, described below, are key to developing alternatives that will adequately meet future needs:

- **Airfield requirements** include the construction of additional exit taxiways for Runway 4-22 and improvement of the airfield operational safety (including runway and taxiway intersection configuration and RPZ penetrations). Additionally, airfield alternatives that include the potential decommissioning of Runway 17L-35R and the airfield changes needed to accommodate spacecraft or cargo/manufacturing operations at the Airport will be considered. These changes include the extension of Runway 17R-35L, the construction of a full-length parallel taxiway to Runway 4-22, and the extension of existing taxiways. All new airfield pavement recommended as part of this Master Plan Update would be built to ADG V standards.

- **Aviation support requirements** consist of additional T-hangars, conventional hangars, and associated vehicle parking areas and the construction of a General Aviation Activity Center for use as a passenger processing terminal. In addition, alternatives will include the development of vacant on-Airport lands and diversify diversification of activity at the Airport.
- **Landside requirements** consist of improved roadway access to the Airport. The primary focus of future landside requirements is on providing improved access to the southeast quadrant of the airfield (where spaceport operations or other aeronautical activity would be centered). It is also important to consider alternatives that help minimize the potential for the three Airport entrance roads to be blocked by a unit-train that is occasionally temporarily parked on the rail line adjacent to the west side of the Airport.

As mentioned, HAS has been actively pursuing possible opportunities to develop areas of the airport that currently are vacant or underdeveloped. The primary goal of attracting development to EFD is to improve the financial stability of the Airport, but also to increase aeronautical or nonaeronautical activity. Potential development opportunities that are being considered by HAS include the following:

- **Spaceport** – Of the initiatives being pursued by HAS, the spaceport initiative is the most ambitious and yet most likely initiative for large-scale development. Subsequently, it has been investigated in greater detail than other initiatives. The Houston Spaceport gained FAA licensing in June 2015 at Ellington Airport. The vision for attracting spaceport operations to EFD includes substantial nonaeronautical development, including, but not necessarily limited to, incubator space, education facilities, office space, and retail and hotel facilities.
- **Aircraft Manufacturing** – HAS is very aware that EFD could be an ideal location for aircraft manufacturing facilities, whether for final assembly or some element of component construction. HAS regularly discusses potential opportunities with aircraft manufacturing companies. Most notably, when The Boeing Company announced interest in relocating portions of its Boeing 777X manufacturing program away from Seattle, HAS was able to demonstrate that EFD could readily accommodate even the largest-scale aircraft manufacturing facilities.
- **Air Cargo** – EFD was once the regional home for United Parcel Service (UPS). UPS moved its operations to IAH about a decade ago, in part because EFD could not provide Category III ILS approach capability. Although UPS moved its operations to IAH, there is interest in the possibility of renewing air cargo service at the Airport. An upgrade of the existing ILS at EFD would be beneficial to such an operation. Other than the possible constraint of the limited ILS, there are no operational or policy-related constraints to air cargo operations at EFD in the future.

The overall goal of this Master Plan Update is to identify a development strategy that provides the specific facility requirements associated with forecast activity, and that provides for a *range* of potential activity. HAS has clearly indicated that its current strategy is to place highest priority on the development of spaceport operations at EFD.

5.2 Airport Development Opportunities

As depicted on Exhibit 2-5, Airport property is divided into four quadrants: northwest, southwest, southeast, and northeast. The northwest quadrant is reserved for military facilities and is not considered to be available for development. The southwest quadrant has large areas of vacant land that are available for development, but these areas are not contiguous and, therefore, limit the types of development that could be accommodated. The southeast quadrant is vacant and has a large amount of contiguous land available for development, while the northeast quadrant is potentially available for development in the medium to long term. **Exhibit 5-1** shows the areas available for development on and off Airport, with the relative time frame (short term or long term) for development availability, as well as potential land uses.

An area of land off-Airport, along the northern Airport boundary, consists of approximately 37 acres of land available for build-to-suit facilities. The owners of the property have prepared various proposals for aeronautical development in recent years. Most recently, the owners have focused on potential air cargo and warehousing operations. Although HAS does not own the land, HAS has indicated the willingness to accommodate through-the-fence operations. This area is labeled as short-term off-Airport development on Exhibit 5-1. If there is a need for additional development space in the long term, the land located along the northeast Airport boundary is vacant and expected to remain so. This land would be a prime location for the expansion of aeronautical development requiring airfield access. This area is labeled as long-term off-Airport development on Exhibit 5-1.

The following subsections describe the various development opportunities that HAS would like to pursue at Ellington Airport, and where the development would be best accommodated.

5.2.1 SPACEPORT FACILITIES

Based on several discussions, HAS management has prioritized the pursuit of a spaceport, at EFD, along with educational facilities and incubator space. HAS obtained a Spaceport license for Ellington Airport in June 2015. The *Ellington Spaceport Economics and Business Study,* dated August 2013, recommended the southeast quadrant of the Airport as the preferred site to accommodate spaceport facilities. This recommendation is based on the efficiency of airfield access from the site, the immediate availability of vacant land, and the large amount of acreage that would be available for long-term development. Appendix D provides the *Ellington Spaceport Economics and Business Study,* as well as various conceptual spaceport layouts. The conceptual layouts should not be interpreted as final facility layouts or as specific facility requirements (some elements of the layouts would violate FAA airport design criteria, for example). Rather, the layouts are intended to demonstrate the nature and magnitude of future development that is possible in the southeast quadrant, and also to illustrate general land use zones within the quadrant that should guide future facility planning.

Note, for example, the location of educational facilities (or incubator space and office space) in the areas adjacent to the existing Boeing and NASA facilities and adjacent to Space Center Boulevard, and the location of more industrial facilities to the south with the potential for rail-spur access.

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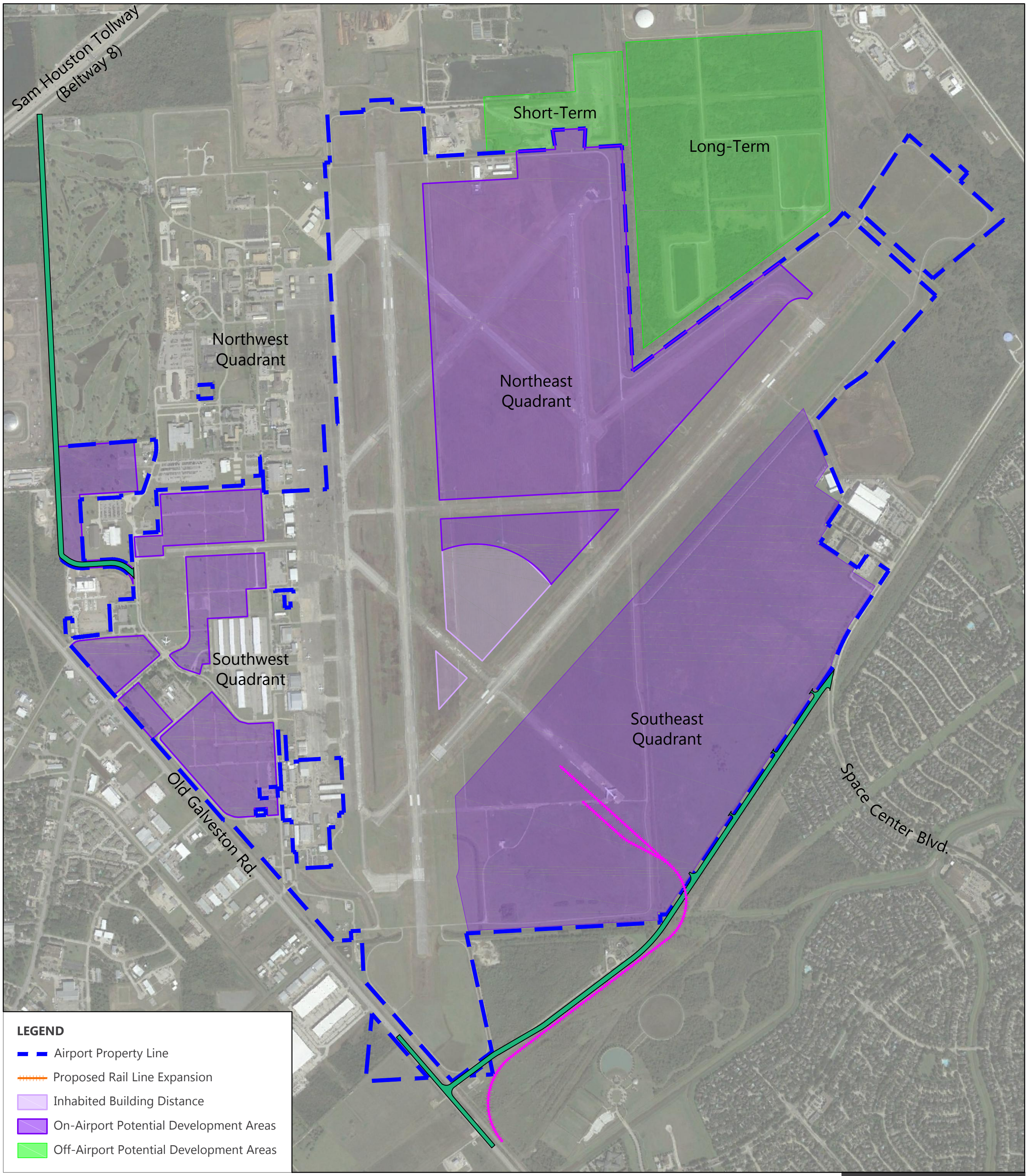

SOURCES: Ricondo and Associates, Inc., Ellington Airport, Draft Future Airport Layout Plan, April 2014; Google Earth Pro 2014; Terra Metrics, October 31, 2013 (aerial photography - for visual reference only, may not be to scale); Ricondo & Associates, Inc., April 2014.
PREPARED BY: Ricondo & Associates, Inc., September 2015.

EXHIBIT 5-1

NORTH

0 2,000 ft.

Potential Development Areas

Drawing: Z:\Houston\1-EFD\EFD Master Plan 2012\05_Alternatives Development\Facilities Planned and Under Construction\CAD\EFD-Map of Facilities Planned and Under Construction - 2012_20150227.dwg Layout: 5-1 - Potential Development Areas Plotted: Sep 17, 2015, 03:45PM

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5.2.2 EDUCATIONAL FACILITIES/INCUBATOR SPACE

The proximity of Ellington Airport to the Johnson Space Center (approximately 7 miles) makes it a prime location for incubator space. Incubator space allows for a wide range of functions and services to be introduced at the Airport. These include, but are not necessarily limited to, engineering, education, avionics, research and development, testing, and even prototype development of parts, all relating to the aviation or private space travel industries. Such facilities are recommended to be developed adjacent to the spaceport in the southeast quadrant.

5.2.3 GENERAL AVIATION HANGARS

The demand for aircraft storage at Ellington Airport exceeds available facilities. A hangar developer has expressed interest in developing several T-hangars along Taxiway K, and HAS is considering the development of several conventional aircraft hangars south of its existing T-hangars. Both these areas are located in the southwest quadrant of the Airport.

5.2.4 AIR CARGO FACILITIES

Ellington Airport could accommodate widebody cargo aircraft with minimal improvements required. Plans to upgrade instrument approach capability to Runway 17R would also improve all-weather operations at EFD.

5.2.5 AIRCRAFT MANUFACTURING FACILITIES

Should the spaceport not materialize, the southeast quadrant would also be well suited for aircraft manufacturing facilities. Ellington Airport is considered a prime location for such facilities: the specialized work force is abundant in the Houston area, the Port of Houston is located within 20 miles of the Airport, and a rail line runs along the southeast quadrant of the Airport.

5.2.6 AIRCRAFT MAINTENANCE, REPAIR, AND OVERHAUL FACILITIES

HAS has expressed interest in attracting an aircraft maintenance, repair, and overhaul (MRO) provider to Ellington Airport. The Airport has wide areas of land available for large aircraft hangars and other MRO facilities, such as engine run-up enclosures, and could accommodate the noise generated during MRO operations in the northeast quadrant.

5.3 Airfield Layout Alternatives

The existing airfield layout and pavement condition require modifications to accommodate potential development plans. Recommended runway and taxiway improvements are described in this subsection.

5.3.1 RUNWAY 17R-35L EXTENSION

As discussed in Section 4, “Facilities Requirements,” the current length of Runway 17R-35L (9,001 feet) restricts operations by large cargo aircraft, and would not be sufficient for some spacecraft operations. A runway extension would be required if such operations are initiated at the Airport. Based on the runway length requirements analysis discussed in Section 4, two optimal runway lengths were identified:

- A 10,000-foot-long runway would accommodate spacecraft up to the size of the Virgin Galactic White Knight II and would increase the maximum payload of cargo aircraft.
- A 12,000-foot-long runway would accommodate large all-cargo aircraft configurations at MTOW, as well as operations by the largest spacecraft to date (i.e., the Stratolaunch Carrier Aircraft). Although it is not currently planned that Ellington Airport will accommodate the Stratolaunch Carrier Aircraft, alternatives were identified to ensure the feasibility of a 12,000-foot-long runway if needed.

The runway extension alternatives are listed below and subsequently discussed further.

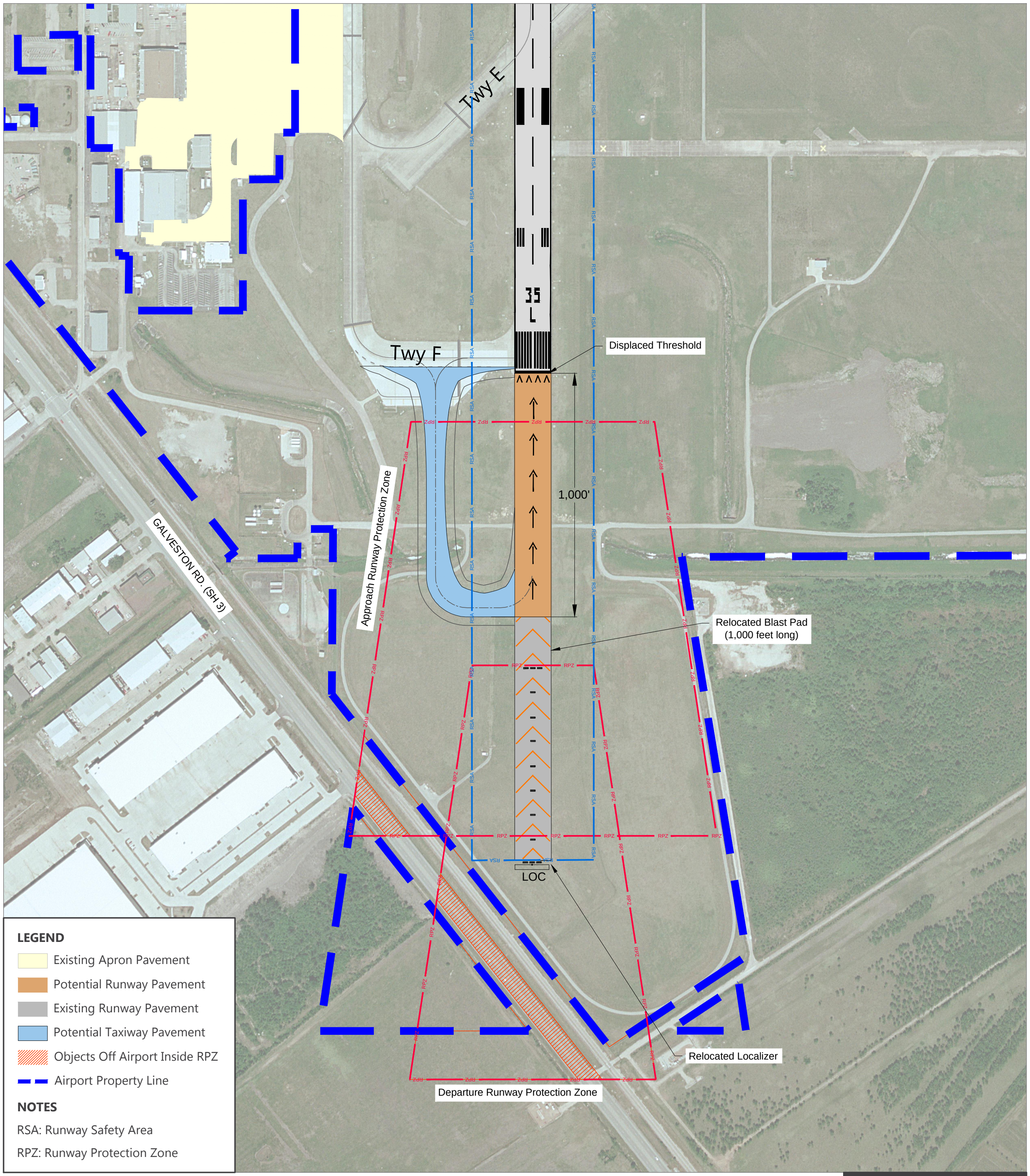
- Runway 17R-35L extended to 10,000 feet:
  - Under Alternative 1A, the runway would be extended 1,000 feet to the south.
  - Under Alternative 1B, the runway would be extended 1,000 feet to the north.
- Runway 17R-35L extended to 12,000 feet:
  - Under Alternative 2A, the runway would be extended 3,000 feet to the north.
  - Under Alternative 2B, the runway would be extended 2,000 feet to the north and 1,000 feet to the south.

It is important to note that spacecraft operations were assumed to be conducted in the South Flow runway operating configuration only. South Flow is the primary operating configuration at the Airport and occurs 85 percent of the time. South Flow also allows fully loaded departing spacecraft to be directly aligned with the preferred departure route over sparsely populated areas south of the Houston area until reaching open waters. Therefore, in developing and evaluating runway and taxiway layout alternatives, spacecraft departures from and arrivals to Runway 17R were considered.

5.3.1.1 10,000-Foot-Long Runway Alternatives

Alternative 1A, illustrated on **Exhibit 5-2,** consists of a 1,000-foot extension of Runway 17R-35L to the south. In this alternative, Runway 35L would have a 1,000-foot displaced threshold, with the landing threshold remaining in its existing location. In extending Runway 17R-35L 1,000 feet to the south, the Runway 17R departure RPZ would be shifted south, resulting in penetration of the RPZ by Old Galveston Road.

In accordance with FAA AC 150/5300-13A (Change 1), public roadways are not permitted within the RPZ. This alternative would only be feasible if Old Galveston Road were realigned or tunneled, which would entail considerable cost.



SOURCES: Ricondo & Associates, Inc., Ellington Airport, Draft Airport Layout Plan, April 2014; Ricondo & Associates, Inc., March 2014.
PREPARED BY: Ricondo & Associates, Inc., September 2015.

EXHIBIT 5-2

NORTH

0 600 ft.

Runway 17R-35L Extension
Alternative 1A

Drawing: Z:\Houston\1-EFD\EFD Master Plan 2012\05_Alternatives Development\3-Airfield\Rwy 17R-35L Extension\CAD\Exh 5-2 & 5-3_Runway17R35LExtensionAlternatives.dwg_Layout: 05-2_Alternative 1A_Sep 17, 2015, 3:55pm

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Alternative 1B, illustrated on **Exhibit 5-3,** consists of a 1,000-foot extension of Runway 17R-35L to the north. The Runway 17R threshold would be moved to the new runway end to provide for a full 10,000 feet of landing length. In extending Runway 17R-35L 1,000 feet to the north, the arrival and departure RPZs would be shifted 1,000 feet north. Although the relocated RPZs would be off Airport property, no land use issues are anticipated with the property located in the expansion footprint.

Under both Alternatives 1A and 1B, the 1,000-foot-long blast pads protecting the current thresholds as well as the localizer antennas and the approach lights would need to be relocated, 1,000 feet to the south in Alternative 1A and 1,000 feet to the north in Alternative 1B. The main benefit of Alternative 1A consists of extending Runway 17R-35L to 10,000 feet without having to relocate the Runway 17R landing threshold and associated navigational aids. Therefore, in South Flow – the predominant flow of operations at the Airport – the oxidizer loading area for spacecraft under Alternative 1A would be closer to the departure threshold than to the relocated threshold under Alternative 1B. However, it is anticipated that the FAA would not permit shifting the Runway 17R departure RPZ onto Old Galveston Road.

5.3.1.2 12,000-Foot-Long Runway Alternatives

Alternative 2A, illustrated on **Exhibit 5-4,** consists of a 3,000-foot extension of Runway 17R-35L to the north that would result in a 12,000-foot-long runway. Additionally, the runway would be widened from 150 feet to 200 feet and the runway markings would be modified accordingly. The 1,000-foot blast pad and the localizer antenna would be relocated. Land acquisition north of Runway 17R-35L would be required under this alternative as portions of the lengthened runway and the RPZs would be outside of the current Airport property boundary. The relocated RPZs would encompass several existing off-Airport structures, including a church (Greater Harvest Community Church) and two industrial hangars that belong to RSH Sand and Trucking Co, Inc. These structures are prohibited within an RPZ and would have to be relocated. Additionally, Genoa Red Bluff Road, a public four-lane roadway, runs through the RPZ for approximately 1,000 feet and would have to be rerouted.

Alternative 2B, illustrated on **Exhibit 5-5,** consists of a 2,000-foot-long runway extension to the north and a 1,000-foot-long runway extension to the south. Land acquisition or control would be required, as the extended runway and the RPZs would be partially outside the current Airport property boundary. In extending Runway 17R-35L 1,000 feet to the south, the departure RPZ would be shifted south, resulting in Old Galveston Road penetrating the relocated RPZ. On the north end, land acquisition would be required as portions of the extended runway and portions of the RPZ would be outside the current Airport property boundary.

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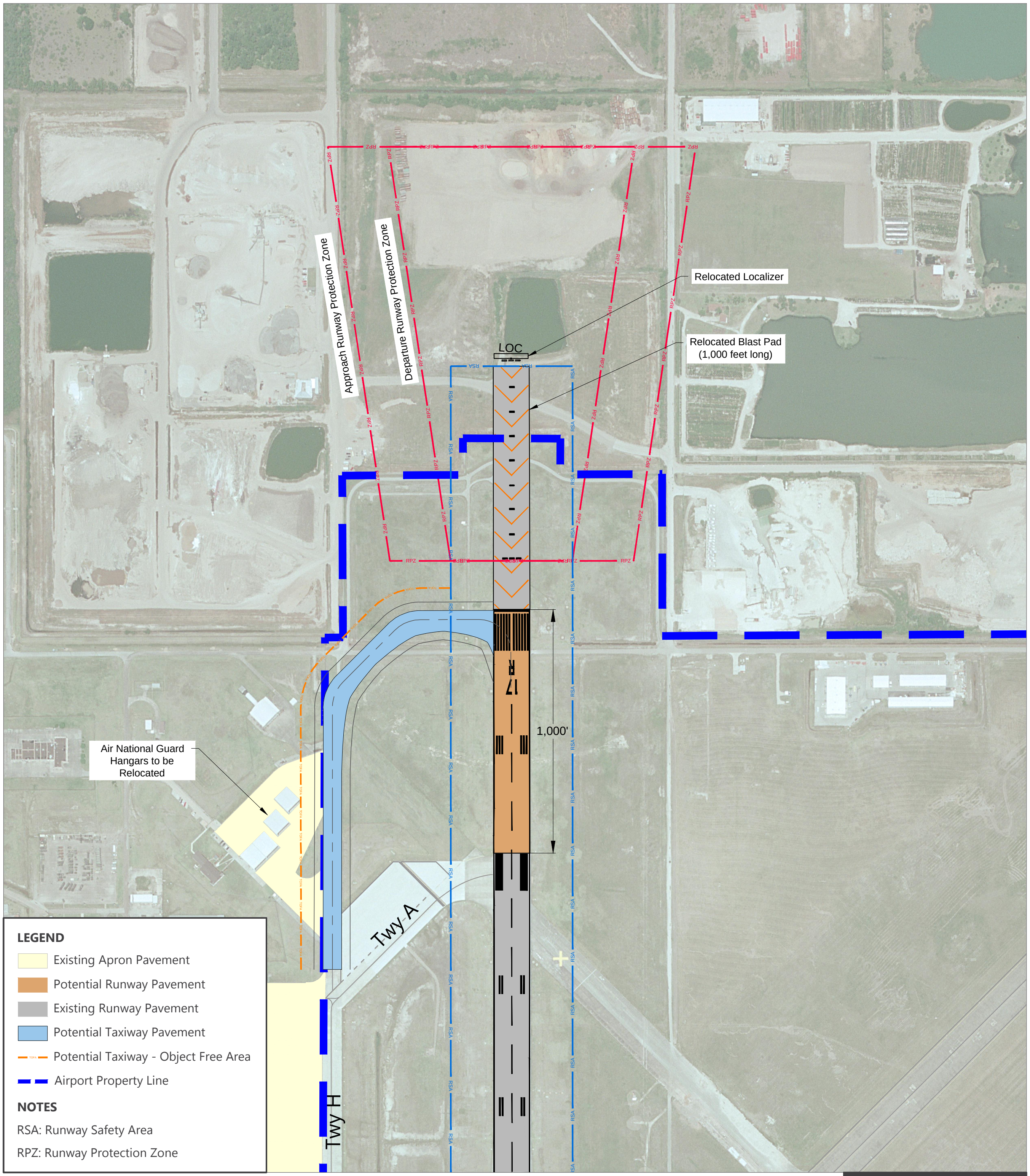

SOURCES: Ricondo & Associates, Inc., Ellington Airport, Draft Airport Layout Plan, April 2014; Ricondo & Associates, Inc., March 2014.
PREPARED BY: Ricondo & Associates, Inc., September 2015.

EXHIBIT 5-3

NORTH

0 600 ft.

Runway 17R-35L Extension
Alternative 1B

Drawing: Z:\Houston\1-EFD\EFD Master Plan 2012\05_Alternatives Development\3-Airfield\Rwy 17R-35L Extension\CAD\Exh 5-2 & 5-3_Runway17R35LExtensionAlternatives.dwg_Layout: 05-3_Alternative 1B_Sep 17, 2015, 3:58pm

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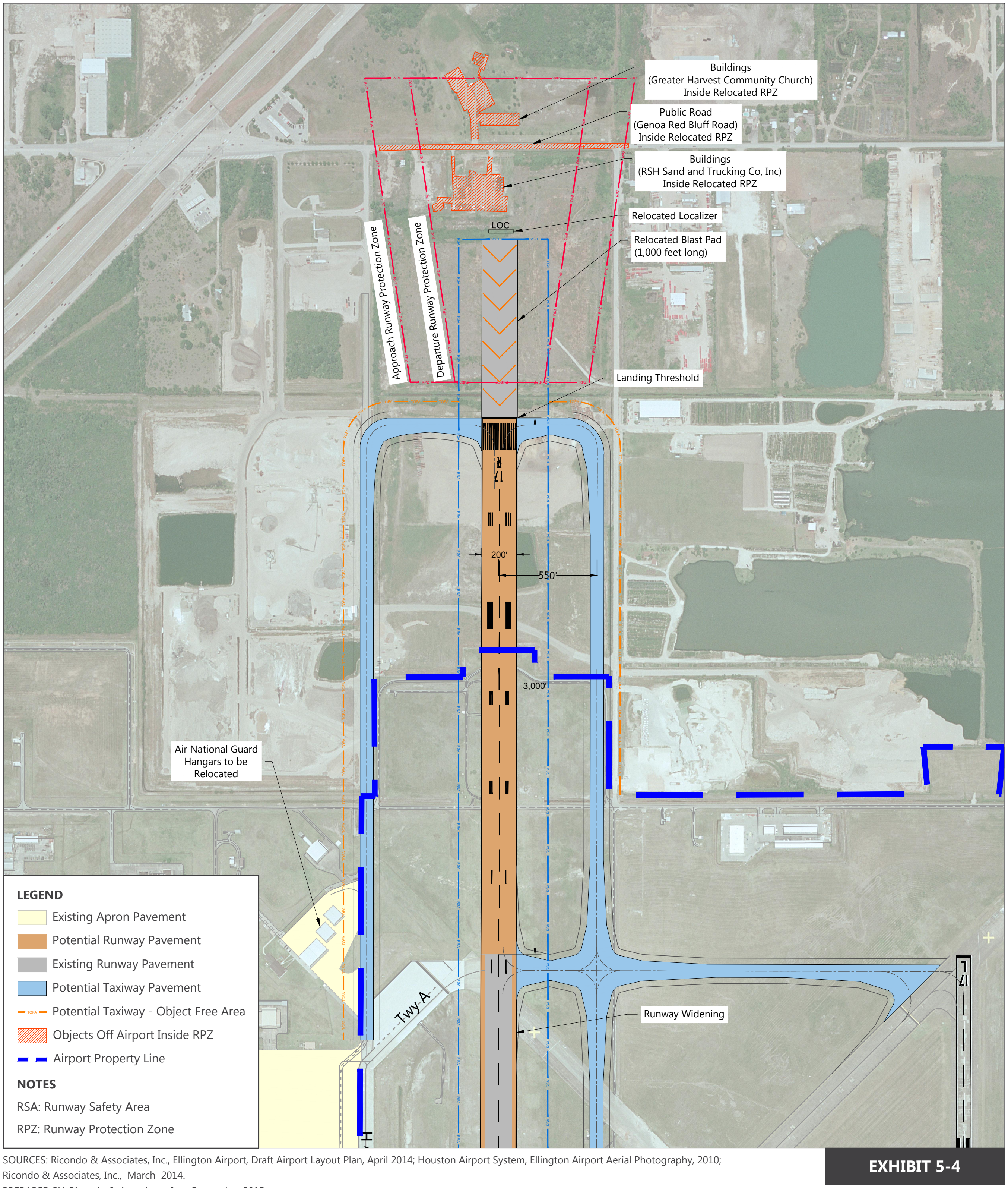

SOURCES: Ricondo & Associates, Inc., Ellington Airport, Draft Airport Layout Plan, April 2014; Houston Airport System, Ellington Airport Aerial Photography, 2010; Ricondo & Associates, Inc., March 2014.

PREPARED BY: Ricondo & Associates, Inc., September 2015.

EXHIBIT 5-4

NORTH

0 800 ft.

Runway 17R-35L Extension
Alternative 2A

Drawing: Z:\Houston\1-EFD\EFD Master Plan 2012\05_Alternatives Development\3-Airfield\Rwy 17R-35L Extension\CAD\Exh 5-4_Runway17R35LExtensionAlternatives_Alternative 2A.dwg_Layout: 05-4-Alternative 2A_Sep 17, 2015, 4:25pm

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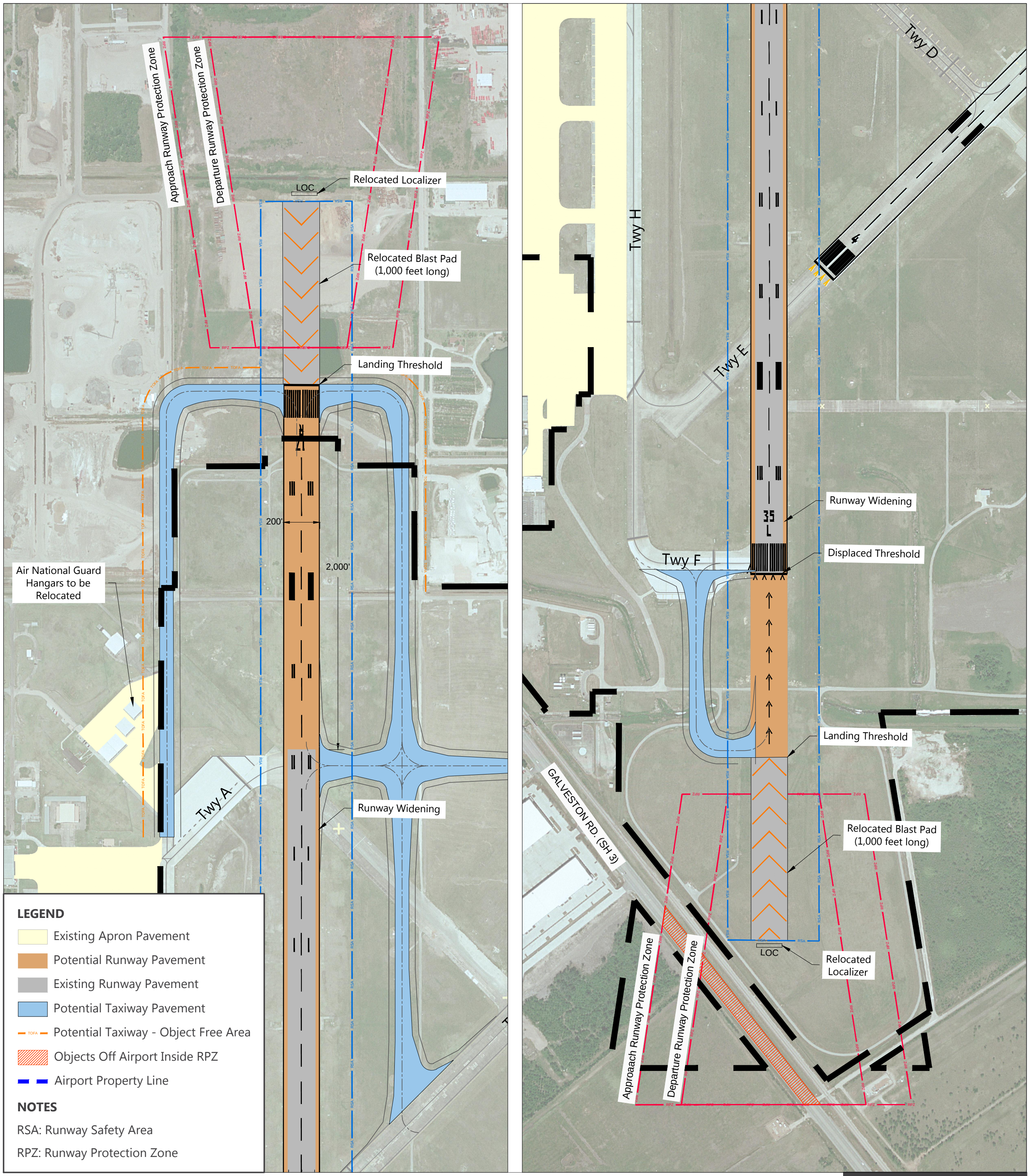

SOURCES: Ricondo & Associates, Inc., Ellington Airport, Draft Airport Layout Plan, April 2014; Houston Airport System, Ellington Airport Aerial Photography, 2010; Ricondo & Associates, Inc., March 2014.
PREPARED BY: Ricondo & Associates, Inc., September 2015.

EXHIBIT 5-5

NORTH

0 800 ft.

Runway 17R-35L Extension Alternative 2B

Drawing: Z:\Houston\1-EFD\EFD Master Plan 2012\05_Alternatives Development\3-Airfield\Rwy 17R-35L Extension\CAD\Exh 5-5_Runway17R35LExtensionAlternatives_Alternative 2B.dwg_Layout: 05-5_Alternative 2B_Sep 17, 2015, 4:44pm

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5.3.1.3 Runway Extension Alternatives Summary

Tables 5-1 and **5-2** summarize the characteristics of the four alternatives for extending Runway 17R-35L.

Table 5-1: 10,000-Foot-Long Runway Alternatives Summary

CRITERIA	ALTERNATIVE 1A	ALTERNATIVE 1B
Direction and Length of Extension	1,000 feet to the south	1,000 feet to the north
Displaced Threshold	Yes	No
Runway Width	150 feet	150 feet
South Flow Takeoff Run Available	10,000 feet	10,000 feet
South Flow Landing Distance Available	10,000 feet	10,000 feet
On-Airport Structures to Be Relocated	For Runway 35L: 1,000-foot blast pad Localizer antenna Approach lights	For Runway 17R: 1,000-foot blast pad Localizer antenna Approach lights
Land Acquisition Required	Yes (11.2 acres)	Yes (39 acres)
Impacts of Relocated RPZ(s)	Old Galveston Road in approach and departure RPZs	Vacant land acquisition
Loaded Spacecraft Taxiing Distance (South Flow)	4,800 feet	5,800 feet

Sources: FAA Advisory Circular 150/5300-13A, *Airport Design* (Change 1),February 2014; Ricondo & Associates, Inc., March 2014.
Prepared by: Ricondo & Associates, Inc., March 2014.

Table 5-2: 12,000-Foot-Long Runway Alternatives Summary

CRITERIA	ALTERNATIVE 2A	ALTERNATIVE 2B
Direction and Length of Extension	3,000 feet to the north	2,000 feet to the north, 1,000 feet to the south
Displaced Threshold	No	No
Runway Width	200 feet	200 feet
South Flow Takeoff Run Available	12,000 feet	12,000 feet
South Flow Landing Distance Available	12,000 feet	12,000 feet
On-Airport Structures to Be Relocated	For Runway 17R: 1,000-foot blast pad Localizer antenna Approach lights	For Runways 17R and 35L: 1,000-foot blast pad Localizer antenna Approach lights
Land Acquisition Required	Yes (108 acres)	Yes (85 acres)
Impacts of Relocated RPZ(s)	- Genoa Red Bluff Road for a length of 1,500 feet - A church - Two industrial hangars	Old Galveston Road in approach and departure RPZs for a length of 1,000 feet
Loaded Spacecraft Taxiing Distance (South Flow)	7,800 feet	6,800 feet

Sources: FAA Advisory Circular 150/5300-13A, *Airport Design* (Change 1),February 2014; Ricondo & Associates, Inc., March 2014.
PREPARED BY: Ricondo & Associates, Inc., March 2014.

5.3.1.4 Preferred Runway Extension Alternative

The preferred alternative is to extend Runway 17R-35L to 10,000 feet as shown in Alternative 1B, because it would not impact any public structures and would meet all likely spaceport operations, except operations by the Stratolaunch Carrier Aircraft.

If it is determined that Runway 17R-35L should be extended to 12,000 feet, the preferred alternative would be Alternative 2A. Although Alternative 2A would impact existing structures off-Airport (a church and industrial hangars), it would be easier and more cost effective to relocate those facilities than to relocate Old Galveston Road.

5.3.1.5 Taxiway Access to Runway Extension

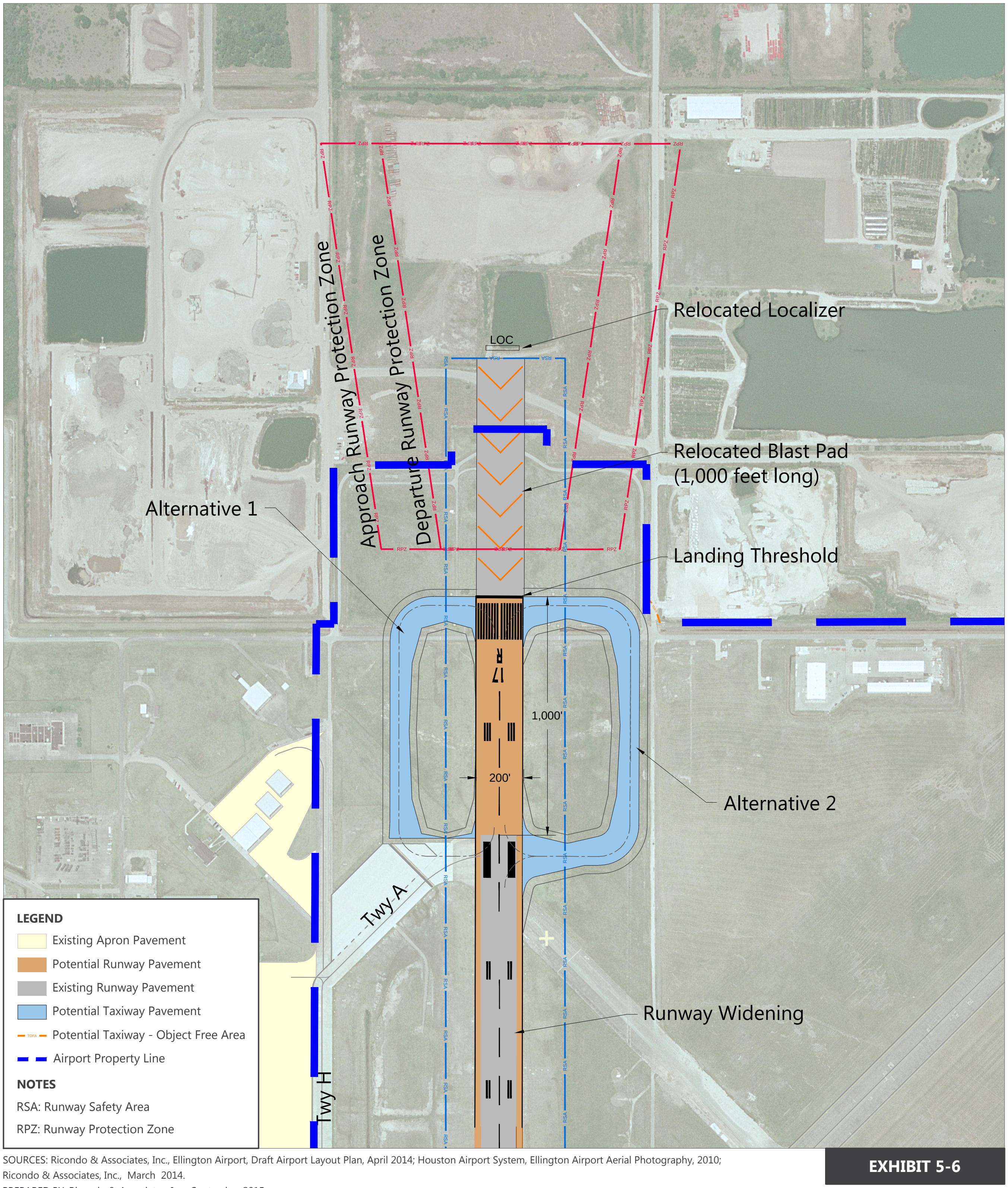
Exhibit 5-6 depicts two taxiway alternatives providing access to the extended Runway 17R end. Alternative 1 shows an extension of existing Taxiway H, on the west side of the runway, with a perpendicular taxiway connector to the runway end. Similarly to existing Taxiway H, the taxiway extension would meet ADG IV taxiway-to-object separation standards. The runway-taxiway separation, however, would be reduced to the standard of 400 feet to avoid impacting the ANG hangars located to the northeast of existing Taxiway A. Taxiway access could be provided from the east side of the runway, as shown in Alternative 2. This alternative consists of building a parallel taxiway along the runway extension, on the east side, connecting with existing Taxiway A. The runway-to-taxiway separation would meet the ADG V standard of 400 feet.

Alternative 1 is the preferred alternative, as it not only provides for streamlined and efficient taxi operations from the southeast and southwest quadrants to the new runway end, but it also avoids the need for runway crossings to access the Runway 17R departure end.

5.3.2 RUNWAY 17L-35R PLANS

Based on discussions with HAS, major maintenance of Runway 17L-35R has already been discontinued. When minor repairs no longer maintain the runway in a safe condition for aircraft and rotorcraft operations, the runway is planned to be decommissioned. The *EFD Pavement Condition Assessment,* conducted in July 2014 by API, shows that the Runway 17L-35R pavement remaining structural life is less than five years.

For the purposes of developing alternatives, it was assumed that Runway 17L-35R will remain active in the short term, but will be decommissioned in the medium or long term. The timing of runway decommissioning will depend on when it reaches the end of its structural life (without major maintenance), or when it is determined that the land can be used for a more profitable use, whichever comes first.



LEGEND

- 🟨 Existing Apron Pavement
- 🟧 Potential Runway Pavement
- ⬜ Existing Runway Pavement
- 🟦 Potential Taxiway Pavement
- - - Potential Taxiway - Object Free Area
- ▬ ▬ Airport Property Line

NOTES

RSA: Runway Safety Area

RPZ: Runway Protection Zone

SOURCES: Ricondo & Associates, Inc., Ellington Airport, Draft Airport Layout Plan, April 2014; Houston Airport System, Ellington Airport Aerial Photography, 2010; Ricondo & Associates, Inc., March 2014.

PREPARED BY: Ricondo & Associates, Inc., September 2015.

EXHIBIT 5-6

NORTH

0 800 ft.

Runway 17R-35L Extension
Parallel Taxiway Alternatives

Drawing: Z:\Houston\1-EFD\EFD Master Plan 2012\05_Alternatives Development\3-Airfield\Rwy 17R-35L Extension\CAD\Exh 5-6_Runway17R35LExtension_Alternatives.dwg_Layout: 05-6-Parallel Taxiway Alternatives_Sep 17, 2015, 4:58pm

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5.3.3 MITIGATION OF NON-STANDARD TAXIWAY GEOMETRY

Exhibit 5-7 highlights the proposed mitigation alternatives to non-standard taxiway geometry.

5.3.3.1 Runway-Taxiway Intersection

In its early history, the airfield at Ellington Airport had several intersecting runways. The pavement from these original runways is still present on the airfield. Some of it is still being used in the form of active taxiways that have been rehabilitated (Taxiways B and D), and some of it consists of closed pavement. Because of this early airfield layout, existing active Taxiways B, D and E intersect with Runway 17R-35L at 45-degree angles. Currently, the FAA recommends that taxiways intersect a runway at a 90-degree angle to provide for optimal pilot visibility. Although no immediate improvements are recommended to modify the angle at which Taxiways B and D intersect with Runway 17R-35L, consideration should be given to eliminating the nonstandard intersection angles when developing new taxiways and designing a taxiway network with the recommended 90-degree angles. The realignment of Taxiway E into a perpendicular taxiway connector is proposed in conjunction with the elimination of the aligned taxiway condition described in Section 5.3.3.3.

5.3.3.2 Location of Runway Crossings

Taxiways C provides access to the Runway 22 end via Taxiway G, and relocating it outside the middle third of the runway would result in significant operational impacts to airport users. Taxiway D is proposed to be realigned into a right-angle taxiway, but will still be located in the middle third of the runway.

5.3.3.3 Closed Pavement and Confusing Airfield Layout

Ideally, closed pavement should be completely removed. If it cannot be removed, it should be painted green to increase situational awareness or, at a minimum, appropriately marked with yellow “Xs”, as is the case today.

5.3.3.4 Aligned Taxiway E

Not only is Taxiway E intersecting Runway 17R-35L at a 45-degree angle, it is also an aligned taxiway (along the extended Runway 4-22 centerline). Closure of Taxiway E would eliminate both issues, but would adversely impacts Airport tenants, by requiring longer taxi times to the Runway 4 end, and as a result requiring more fuel. In order to mitigate these adverse impacts, proposed taxiway improvements include the realignment of Taxiway E to an east-west alignment across Runway 17R-35L, intersecting the runway at a 90-degree angle, and providing a more direct taxi route to the Runway 4 end compared to a taxi route via Taxiway F.

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SOURCES: Ricondo and Associates, Inc., Ellington Airport, Draft Airport Layout Plan, June 2014; Ricondo & Associates, Inc., July 2015.
PREPARED BY: Ricondo & Associates, Inc., July 2015.

EXHIBIT 5-7

NORTH 0 1,500 ft.

Taxiway Geometry Mitigation Alternatives

Drawing: Y:\Houston Airport System\Ellington Airport\2014 Master Plan Update\05 - Alternatives\Exhibits\Exh 5-7_Taxiway Geometry Mitigation Alternatives.dwg Layout: 5-7 - Twy Geometry Mitigation Alternative Plotted: Sep 25, 2015, 09:22AM

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5.3.4 RUNWAY 4-22 TAXIWAY ACCESS

A full-length parallel taxiway with a series of taxiway exits along the runway is recommended for Runway 4-22 to:

- Simplify access to the runway
- Address high runway occupancy times
- Eliminate unsafe taxiway/runway configuration at Runway 4 end intersection with Taxiway E (aligned taxiway)
- Meet FAA standards, which require a full-length parallel taxiway for any runway with approach minimums lower than 0.5 statute mile

5.3.4.1 Taxiway Location

Construction of a full-length parallel taxiway is recommended on the southeast side of Runway 4-22 to provide access to potential development in the southeast quadrant of the Airport. Additionally, it is recommended that the parallel taxiway to Runway 4-22 be connected to the Runway 35L end of Runway 17R-35L to allow the closure of the portion of Taxiway E east of Runway 17R-35L, which is considered an unsafe taxiway/runway layout in accordance with FAA guidance.

5.3.4.2 Runway Centerline to Taxiway Centerline Separation

The Runway 4-22 centerline to parallel taxiway centerline separation is based on the size of aircraft using the runway and taxiway. The parallel taxiway is also recommended to be connected to the Runway 35L end to streamline Airport operations. Three alternatives for separation were identified.

Alternative 1

Alternative 1 is depicted on **Exhibit 5-8** and consists of a runway to taxiway centerline separation of 400 feet, in accordance with ADG V standards. This alternative would allow both the runway and the taxiway to accommodate independent ADG V aircraft operations, which would serve aircraft manufacturers, MRO and cargo operators, and most spacecraft operations. The BRL, located 1,030 feet from the Runway 4-22 centerline, would result in a maximum building height of 76.5 feet AGL. Alternative 1 would provide for a total of 380 acres of developable land in the southeast quadrant of the Airport. Operations of larger aircraft/spacecraft would require airfield use restrictions.

Alternative 2

Alternative 2 is depicted on **Exhibit 5-9** and consists of a runway to taxiway centerline separation of 550 feet to accommodate independent ADG V aircraft operations on the runway and Stratolaunch Carrier Aircraft operations on the parallel taxiway. The BRL, which would be located 1,330 feet from the Runway 4-22 centerline, would result in a maximum building height of 119.3 feet AGL along the Runway 4-22 BRL and a maximum building height of 57.6 feet AGL along the Runway 17R-35L BRL. Alternative 2 would provide for a total of 314 acres of developable land in the southeast quadrant of the Airport.

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SOURCES: Ricondo and Associates, Inc., Ellington Airport, Draft Future Airport Layout Plan, April 2014; Google Earth Pro 2014; Terra Metrics, October 27, 2012 (aerial photography - for visual reference only, may not be to scale)
Ricondo & Associates, Inc., April 2014.
PREPARED BY: Ricondo & Associates, Inc., April 2014.

AGL - Above Ground Level
BRL - Building Restriction Line

NORTH

0 2,000 ft.

EXHIBIT 5-8

Runway 4-22 Parallel Taxiway
Alternative 1

Drawing: Z:\Houston\1-EFD\EFD Master Plan 2012\05_Alternatives Development\3-Airfield\Southeast Quadrant Taxiway Access\Stratolauncher Taxiway Impacts-2007_20150202.dwg Layout: 5-8_Rwy 4-22 Parallel Twy - Alt. 1 (Option 2-SC2500) Plotted: Sep 25, 2015, 09:27AM

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SOURCES: Ricondo and Associates, Inc., Ellington Airport, Draft Future Airport Layout Plan, April 2014; Google Earth Pro 2014; Terra Metrics, October 27, 2012 (aerial photography - for visual reference only, may not be to scale)
Ricondo & Associates, Inc., April 2014.
PREPARED BY: Ricondo & Associates, Inc., April 2014.

AGL - Above Ground Level
BRL - Building Restriction Line

NORTH 0 2,000 ft.

EXHIBIT 5-9

Runway 4-22 Parallel Taxiway
Alternative 2

Drawing: Z:\Houston\1-EFD\EFD Master Plan 2012\05_Alternatives Development\3-Airfield\Southeast Quadrant Taxiway Access\Stratolauncher Taxiway Impacts-2007_20150202.dwg Layout: 5-9_Rwy 4-22 Parallel Twy - Alt. 2 (Option 1A-SC2500) Plotted: Sep 25, 2015, 09:29AM

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Alternative 3

Alternative 3 is depicted on **Exhibit 5-10** and is similar to Alternative 1, except that it consists of a runway to taxiway separation of 550 feet only for the portion of the taxiway parallel to Runway 17R-35L. This alternative would accommodate a Stratolaunch Carrier Aircraft hangar/apron on the southwest end of the apron. Operation of the Stratolaunch Carrier Aircraft on the parallel taxiway to Runway 4-22 would result in Runway 4-22 use restrictions. The BRL, located 1,030 feet from the Runway 4-22 centerline, would result in a maximum building height of 76.5 feet AGL along the Runway 4-22 BRL and a maximum building height of 57.6 feet AGL along the Runway 17R-35L BRL. Alternative 3 would provide for a total of 373 acres of developable land for a spaceport.

Preferred Alternative

Alternative 1 was selected as the preferred alternative, as HAS currently has no plans to accommodate aircraft or spacecraft larger than ADG V at EFD. If larger aircraft were ever to operate at the Airport, it is anticipated that such operations would be rare, and occasional airfield use restrictions would not adversely affect airfield capacity. The preferred alternative is depicted on **Exhibit 5-11**, which also depicts the recommended Runway 4-22 exits based on the results of the runway exit analysis discussed in Section 4. Exhibit 5-11 also incorporates the proposed closure of the angled Txiway E, and its realignment perpendicular to Runway 17R-35L.

As a result of implementing Alternative 1, several navigational aids and their associated equipment shelters would have to be relocated. The Runway 22 glide slope antenna and the Runway 4-22 transmissometers, as well as their equipment shelters, could be moved farther southeast, while the Runway 35L glide slope antenna and equipment shelter could be moved farther east, as depicted on the Future ALP sheet in Appendix F.

5.3.5 TAXIWAY NETWORK

Potential taxiway development to support both spaceport operations and any other development that may occur on the airfield are discussed in this section. The alternatives considered were intended to minimize costs, especially in the short term, when spacecraft operations would be infrequent.

5.3.5.1 Development Considerations

Spaceport

The *Ellington Spaceport Economics and Business Study*[1] recommends the development of a spaceport in the southeast quadrant of the Airport. As discussed in Section 5.3.1.4, if spaceport operations were initiated at EFD, a 1,000-foot-long runway extension is recommended on the north end of Runway 17R-35L. To support this runway extension, taxiway network alternatives were developed to provide an adequate route connecting the spaceport with the Runway 17R end.

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[1] XARC, *Ellington Spaceport Economics and Business Study*, August 2013.

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SOURCES: Ricondo and Associates, Inc., Ellington Airport, Draft Future Airport Layout Plan, April 2014; Google Earth Pro 2014; Terra Metrics, October 27, 2012 (aerial photography - for visual reference only, may not be to scale)
Ricondo & Associates, Inc., April 2014.
PREPARED BY: Ricondo & Associates, Inc., April 2014.

AGL - Above Ground Level
BRL - Building Restriction Line

NORTH

0 2,000 ft.

EXHIBIT 5-10

Runway 4-22 Parallel Taxiway
Alternative 3

Drawing: Z:\Houston\1-EFD\EFD Master Plan 2012\05_Alternatives Development\3-Airfield\Southeast Quadrant Taxiway Access\Stratolauncher Taxiway Impacts-2007_20150202.dwg Layout: 5-10_Rwy 4-22 Parallel Twy - Alt. 3 (Option 1B-SC2500) Plotted: Sep 25, 2015, 09:30AM

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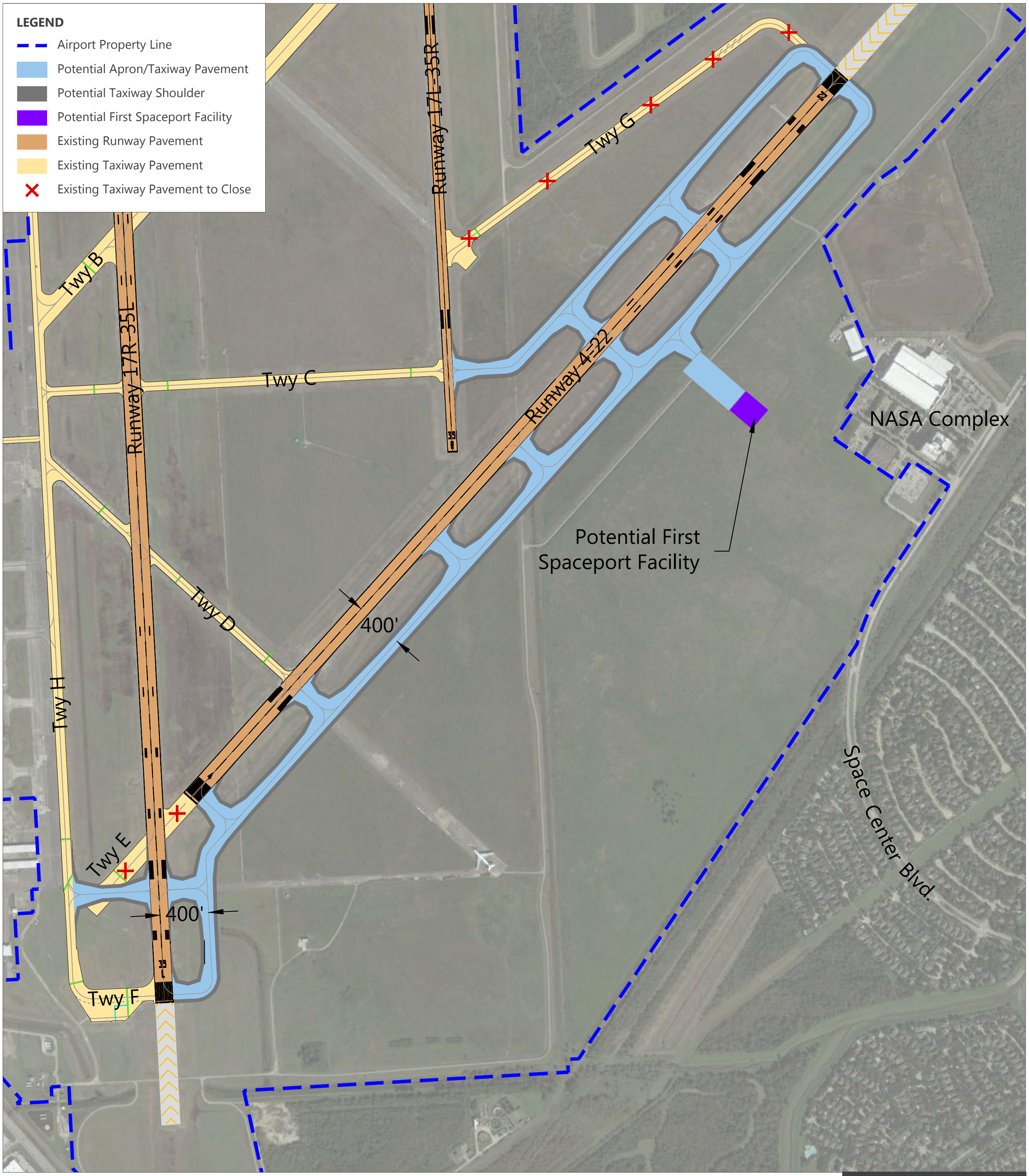

SOURCES: Ricondo and Associates, Inc., Ellington Airport, Draft Future Airport Layout Plan, April 2014; Google Earth Pro 2014; Terra Metrics, October 31, 2013 (aerial photography - for visual reference only, may not be to scale); Ricondo & Associates, Inc., April 2014.
PREPARED BY: Ricondo & Associates, Inc., April 2014.

EXHIBIT 5-11

NORTH 0 1,200 ft.

Runway 4-22 Parallel Taxiways Preferred Alternative

Drawing: Z:\Houston\1-EFD\EFD Master Plan 2012\05_Alternatives Development\3-Airfield\Taxiway Network Alternatives\Exh 5-11_Rwy 4-22 Taxiway Improvements.dwg Layout: 5-11 - Proposed Runway 4-22 Taxiway Improvments Plotted: Oct 6, 2015, 11:09AM

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One important factor to consider when developing spacecraft taxiing routes is the location of the area where spacecraft would load oxidizer shortly before takeoff. Once the oxidizer has been loaded onto the spacecraft, which would then carry fuel and oxidizer, the spacecraft is treated as an explosive hazard and a safe public area around the spacecraft is required. The minimum distance allowed between a spacecraft loaded with both fuel and oxidizer and any occupied facility is 1,250 feet. In the short term, the oxidizer loading area is planned to be located on Taxiway B between the two parallel runways; this area would measure 150 feet by 150 feet. This area meets the public area distance requirements. In the long term, if demand supports development of the northeast quadrant, the oxidizer loading area would be relocated to the south.

The public area distance (the FAA term for the minimum distance required between a public area and an explosive hazard) would dictate the boundaries of the oxidizer loading area. The western and southern boundaries of the area must remain 1,250 feet from the Runway 17R-35L safety area and 1,250 feet from the Taxiway D safety area. The eastern and northern boundaries of the oxidizer loading area would restrict development of the northeast quadrant. Therefore, the optimized location to limit restriction on future development areas and comply with runway and taxiway standards would be 1,250 feet east of the Runway 17R-35L safety area and 1,250 north of the Taxiway D safety area. The original oxidizer loading area would become an auxiliary oxidizer loading area in the long term.

The characteristics of all taxiways intended to accommodate spacecraft must be determined based on the dimensions of the spacecraft. These characteristics include the width of the taxiway and its shoulders, the spacecraft turning radius, and the separation distance between a runway and a parallel taxiway. Based on the requirements determined in Section 4, the taxiways to be developed for spacecraft must meet ADG V and TDG 5 standards if spacecraft do not include the Stratolaunch Carrier Aircraft (which is not planned to be accommodated at Ellington Airport). If the Stratolaunch Carrier Aircraft were to operate at the Airport, the taxiway dimensions would be tailored to its characteristics. The Stratolaunch Carrier Aircraft has a main gear width of approximately 130 feet and a wingspan of 384 feet. The dimension between the two inner engines is approximately 180 feet. To ensure that the inner engines are above a clear surface and the main gear is on pavement, 135-foot-wide taxiways and 22.5-foot-wide paved shoulders would be required to accommodate the aircraft.

Cargo/Manufacturing/Maintenance, Repair, Overhaul

Potential developments at the Airport, such as cargo, manufacturing, or MRO operations, would require improvement of the existing taxiway network or construction of additional taxiways to support large aircraft, such as ADG V aircraft. However, taxiway layouts cannot be developed until a site is selected.

5.3.5.2 Short-Term Development

In the short term, a taxiway is recommended to provide access to/from the first potential spaceport hangar to be located in the southeast quadrant of the Airport adjacent to the existing NASA facilities. To minimize the required capital investment, the taxiway would only extend from the hangar to Runway 4-22, while meeting FAA design criteria that the taxiway should not provide a straight path from the apron to the runway. **Exhibit 5-12** depicts the planned taxiway. The location of the taxiway is based on the Runway 4-22 exit analysis, as this connector taxiway is planned to ultimately be used as a runway exit.

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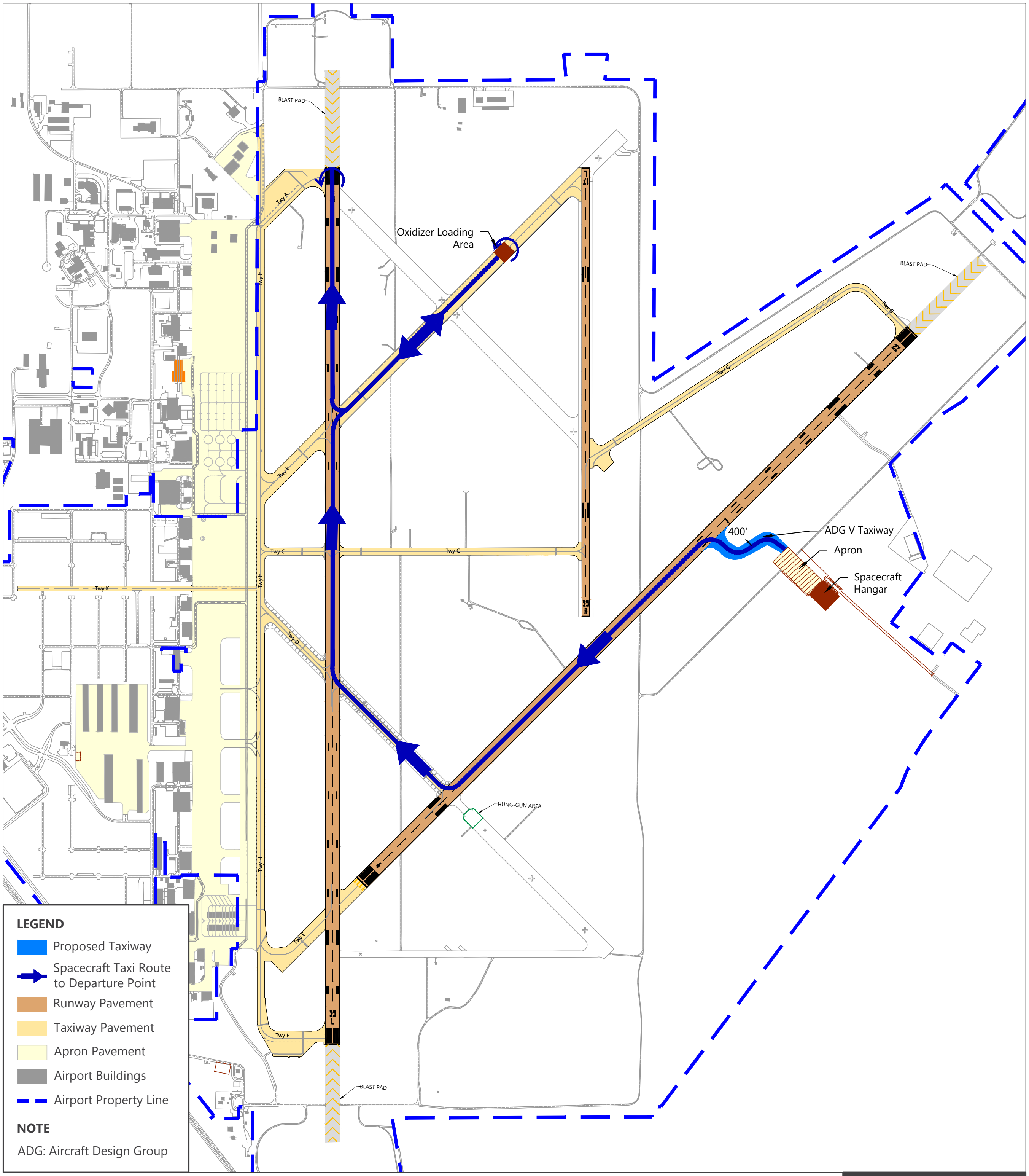

SOURCES: Draft Ellington Airport Layout Plan, Ricondo & Associates, Inc., March 2014; Ricondo & Associates, Inc., February 2015.
PREPARED BY: Ricondo & Associates, Inc., February 2015.

EXHIBIT 5-12

NORTH

0 1,500 ft.

Proposed Taxiway Improvements
Short Term

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Spacecraft would taxi along this new taxiway to Runway 4-22, then onto Runway 4-22 southbound, turning right onto Taxiway D, and taxiing northbound on Runway 17R-35L. Spacecraft would then taxi eastbound on Taxiway B to the oxidizer loading area. Upon being loaded with oxidizer, spacecraft would return to Runway 17R-35L via Taxiway B and taxi to the Runway 17R threshold. Upon landing on Runway 17R, spacecraft would exit either at Taxiway D or E, and taxi back to the hangar via Runway 4-22.

For strategic purposes (specifically, to ensure that all legitimate possibilities for future aeronautical development could be accommodated at the Airport and especially in the southeast quadrant), all proposed taxiway dimensions should be based on the largest possible aircraft that would regularly need access to the site. These aircraft could include widebody all-cargo aircraft, large future spacecraft, and potentially large aircraft associated with manufacturing or MRO facilities. HAS management has decided to accommodate aircraft up to ADG V and TDG 5 (which would not include the Stratolaunch Carrier Aircraft). Therefore, the planned taxiway connecting the spacecraft hangar with Runway 4-22 would be 75 feet wide with 25-foot paved shoulders, and the centerline of the portion of the taxiway parallel to Runway 4-22 would be 400 feet east of the Runway 4-22 centerline. Taxiway D, which is 75 feet wide and has 25-foot-wide shoulders, and Taxiway B (150 feet wide) comply with ADG V and TDG 5 taxiway standards.

5.3.5.3 Medium- and Long-Term Development

The taxiway development for the medium and long terms will depend on several factors:

- The types of aircraft/spacecraft operating at the Airport
- The annual number of spacecraft operations
- The scale and timing for development of the northeast quadrant (potential cargo/manufacturing and MRO operations)

Exhibit 5-13 illustrates recommended taxiway development in the medium term. A partial parallel taxiway to Runway 4-22 would be constructed, extending the taxiway connecting the initial spaceport hangar to Runway 4-22 and Taxiway D. This taxiway would be 75 feet wide with 25-foot paved shoulders and its centerline would be 400 feet from the centerline of Runway 4-22. If the Stratolaunch Carrier Aircraft were to operate at the Airport, the taxiway would have to be 140 feet wide with 20-foot shoulders. The purpose of this taxiway extension is to eliminate the need to use Runway 4-22 as a taxiway to provide access between Runway 17R-35L (or the oxidizer loading area) and the initial spaceport hangar.

When Runway 17L-35R is decommissioned, Taxiway G will also be decommissioned. As previously noted, when these facilities are decommissioned, it is recommended that the pavement be physically removed from the site. If demand materializes to develop the northeast quadrant, the original oxidizer loading area would be relocated approximately 1,500 feet south to maximize the area available for development. To access the relocated oxidizer loading area, a taxiway would be constructed between Taxiway C and the oxidizer loading area. This potential taxiway should meet ADG V and TDG 5 standards. The spacecraft taxiing route would slightly differ from the original route. Instead of taxiing on Taxiway B, spacecraft would use Taxiway C and a new taxiway to reach the oxidizer loading area, then backtrack to return to Runway 17R-35L.

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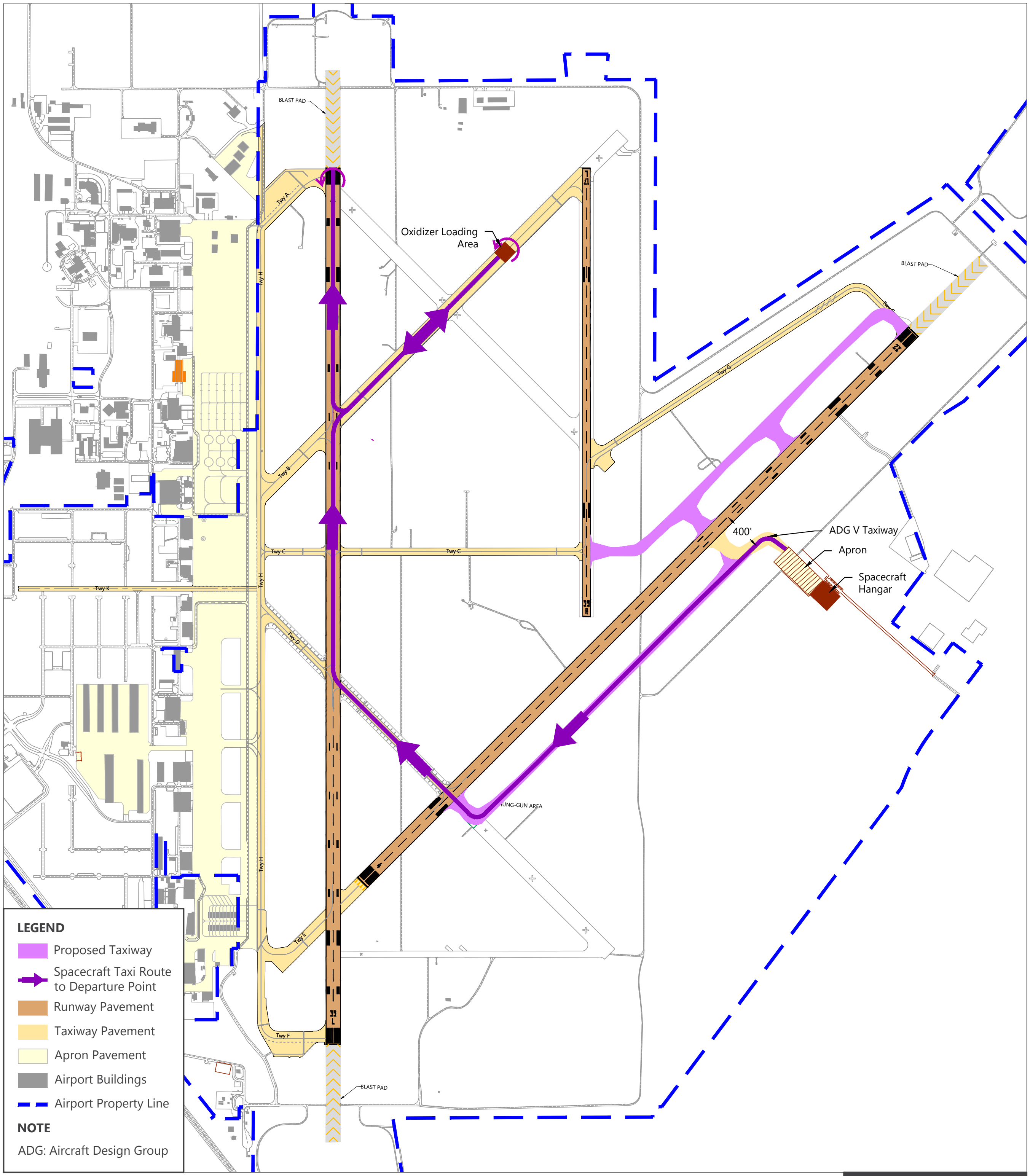

SOURCES: Draft Ellington Airport Layout Plan, Ricondo & Associates, Inc., March 2014; Ricondo & Associates, Inc., February 2015.
PREPARED BY: Ricondo & Associates, Inc., February 2015.

EXHIBIT 5-13

NORTH 0 1,500 ft.

Proposed Taxiway Improvements Medium Term

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Taxiway C would need to be compliant with ADG V and TDG 5 standards; therefore, 25-foot paved shoulders would have to be constructed. This upgrade would only be necessary for the segment of Taxiway C between Runway 17R-35L and the taxiway that would provide access to the relocated oxidizer loading area. If the Stratolaunch Carrier Aircraft were to operate at the Airport, Taxiway C and the new taxiway would both need to be 100 feet wide with 20-foot wide shoulders. As mentioned previously, development of the northeast quadrant may require the decommissioning of Taxiway G. As a result, the partial taxiway parallel to Runway 4-22 would need to be extended to a full length taxiway to provide access to the Runway 22 threshold and the west side of the Airport.

In the long term, if spacecraft operations reach a frequency that adversely affects the capacity of Runway 17R-35L (by taxiing on the runway), a taxiway parallel to and east of Runway 17R-35L is recommended to be constructed between Taxiway D and the Runway 17R end. **Exhibit 5-14** depicts recommended long-term taxiway development.

If spacecraft operating at the Airport do not include the Stratolaunch Carrier Aircraft, this parallel taxiway would be designed to ADG V and TDG 5 standards (i.e., 75 feet wide, 25-foot shoulders, and a centerline located 400 feet from the centerline of Runway 17R-35L). The area located within 1,250 feet of the taxiway centerline would be restricted from development, as all facilities in this area would need to be evacuated during spacecraft operations. If the Stratolaunch Carrier Aircraft were to operate at the Airport, the parallel taxiway would be 140 feet wide and have 20-foot wide shoulders to ensure that the gears of the spacecraft would be on the pavement and its two inner engines would be above the paved shoulders. The separation between the runway and taxiway centerlines would be increased to 550 feet.

5.3.6 RUNWAY AND TAXIWAY SHOULDERS

Runways 4-22 and 17R-35L do not have shoulders; therefore, 25-foot-wide paved shoulders should be constructed along either side of the runways. Currently, Taxiway D is the only taxiway with paved shoulders. All other taxiways and taxilanes at EFD should have 30-foot-wide paved shoulders, except for Taxiway K and Taxilane J, which accommodate smaller aircraft. **Exhibit 5-15** illustrates those portions of airfield pavement that need shoulders to meet ADG IV and ADG V standards. All new airfield pavement recommended as part of this Master Plan Update should be built to ADG V standards.

5.3.7 TAXIWAY FILLETS

Although a thorough taxiway fillets analysis is not included in the scope of this Master Plan Update, it is anticipated that taxiway fillets would need to be improved to comply with the latest FAA standards. All new airfield pavement recommended as part of this Master Plan Update should be built to ADG V standards.

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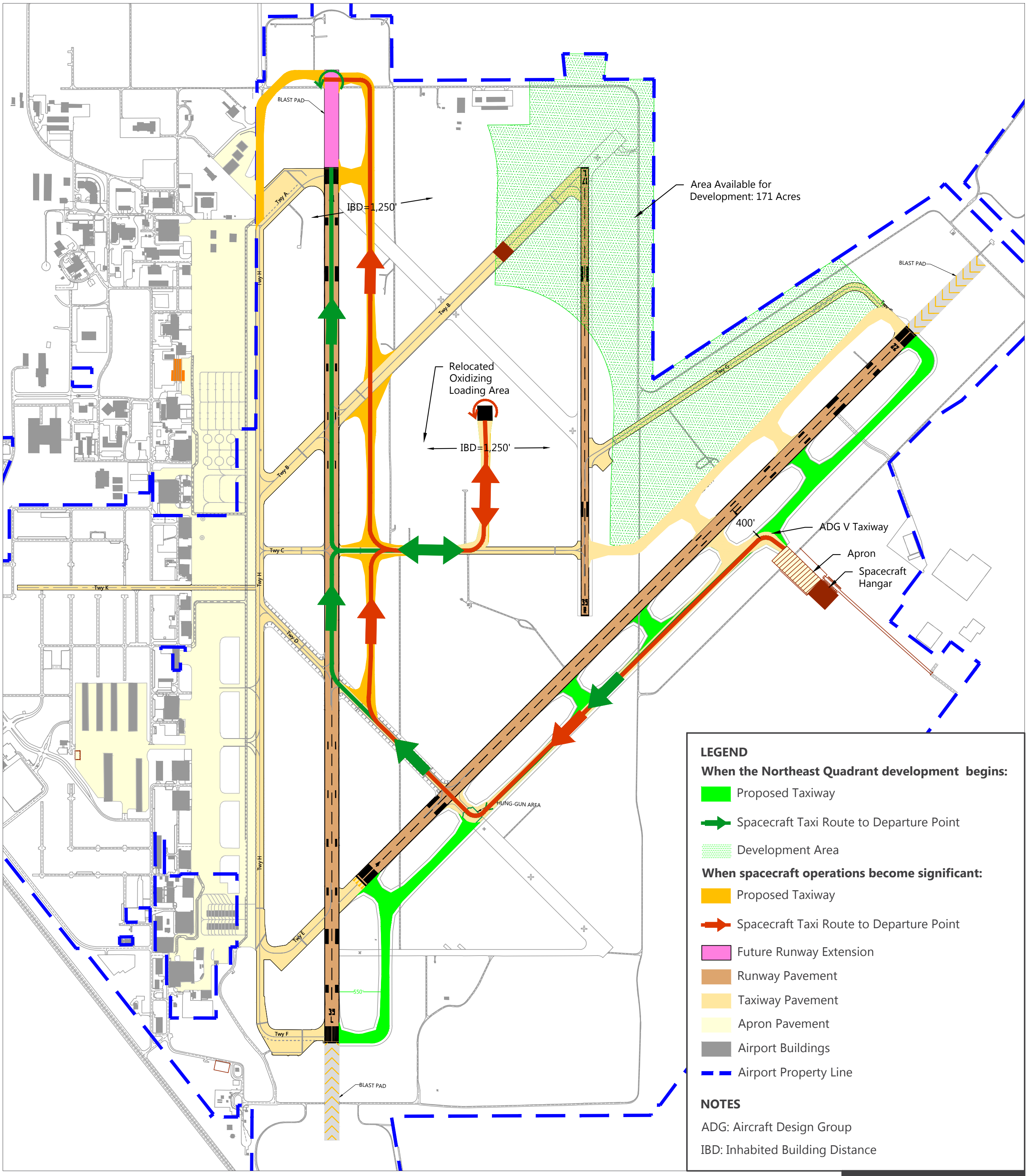

SOURCES: Draft Ellington Airport Layout Plan, Ricondo & Associates, Inc., March 2014; Ricondo & Associates, Inc., February 2015.
PREPARED BY: Ricondo & Associates, Inc., February 2015.

EXHIBIT 5-14

NORTH

0 1,500 ft.

Proposed Taxiway Improvements Long Term

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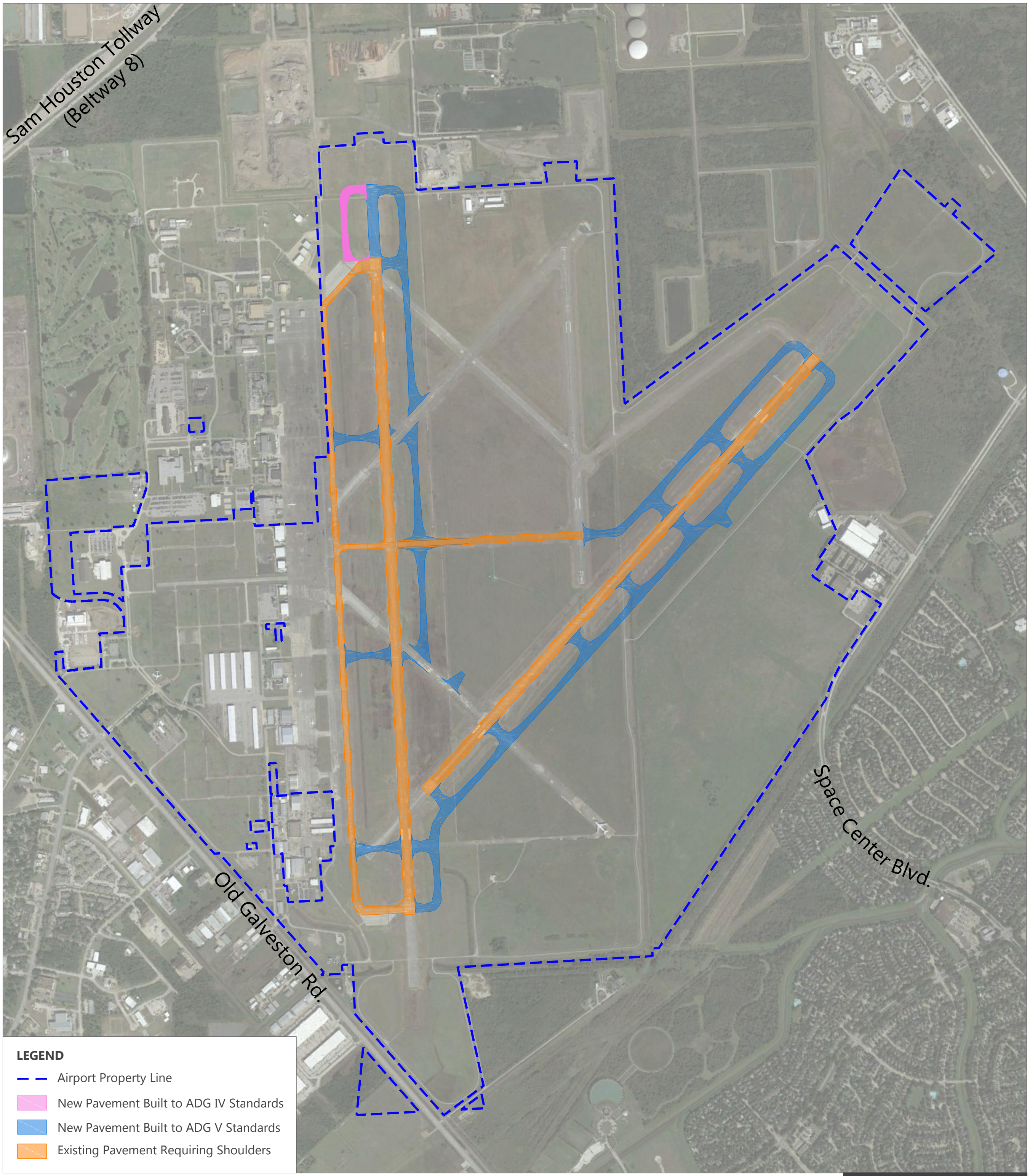

SOURCE: Ricondo and Associates, Inc., Ellington Airport, Draft Future Airport Layout Plan, April 2014; Google Earth Pro 2014; Terra Metrics, October 31, 2013 (aerial photography - for visual reference only, may not be to scale); Ricondo & Associates, Inc., April 2014.
PREPARED BY: Ricondo & Associates, Inc., April 2014.

EXHIBIT 5-15

NORTH

0 2,000 ft.

Required Airfield Pavement Shoulder Upgrades

Drawing: Z:\Houston\1-EFD\EFD Master Plan 2012\05_Alternatives Development\3-Airfield\Taxiway Network Alternatives\Exh 5-15_Required Airfield Pavement Shoulder Upgrades.dwg Layout: 5-15 Required Airfield Pavement Shoulder Upgrades Plotted: Sep 25, 2015, 09:38AM

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5.4 General Aviation Support Facilities

The support facility requirements for general aviation tenants are predicated on the number of based aircraft at EFD throughout the planning period for this Master Plan Update.

5.4.1 GENERAL AVIATION ACTIVITY CENTER

Until 2004, EFD accommodated commercial passenger airline service. Continental Express shuttled passengers from EFD to IAH for connections with mainline service. This service was discontinued, but in recent years (and with diminishing space available at HOU), interest has been expressed in building a basic passenger terminal at EFD that could accommodate a range of services, including renewed shuttle operations, charter activity (domestic and/or international, for aircraft as large as the Boeing 757) or even ultra-low-cost carrier service from Mexico or South America. Although market demand has not materialized for these services (this activity has historically been located at HOU), there has been enough interest by HAS and Landmark Aviation (formerly Southwest Airport Services) to independently consider terminal development alternatives.

A vacant site at the Airport was identified as a potential site for the General Aviation Activity Center, in a desirable location along the West Ramp. It is the site of the old EFD ARFF station. The site is depicted on **Exhibit 5-16**. Vacant land is available with excellent potential for vehicular ingress/egress. Two simple alternatives were considered. The first alternative would involve construction of a new facility, and the second alternative would reuse the recently abandoned ARFF station. No decision has yet been made as to whether or not the old ARFF station would remain and be converted into an General Aviation Activity Center, or if a new facility would be built in its location.

Although the old ARFF station would require significant remodeling to be converted to a passenger processing facility, it is large enough and could accommodate the various functions defined for the facility. Details of the facility conversion are provided in **Appendix I**. The major disadvantage of this alternative would be the cost to convert the facility. Floors are currently sloped for trench drains for the fire equipment previously housed there, and would need to be leveled. Asbestos would have to be removed, and plumbing, heating, ventilation, and air conditioning would have to be added to what would become the primary passenger holding areas (previously the garage bays).

In discussing the Master Plan Update with various EFD tenants, repeated interest was expressed in HAS/Airport management encouraging the development of additional eating establishments on/near EFD. One option, if HAS or Landmark Aviation develops a passenger terminal would be to collocate a restaurant with the General Aviation Activity Center. The restaurant could be a separate facility or integrated within the Activity Center in a single facility. Although it is unlikely that HAS would develop a restaurant, the overall site is large enough for both facilities, and would provide pleasant views for aviation enthusiasts and the wide variety of tenants at EFD.

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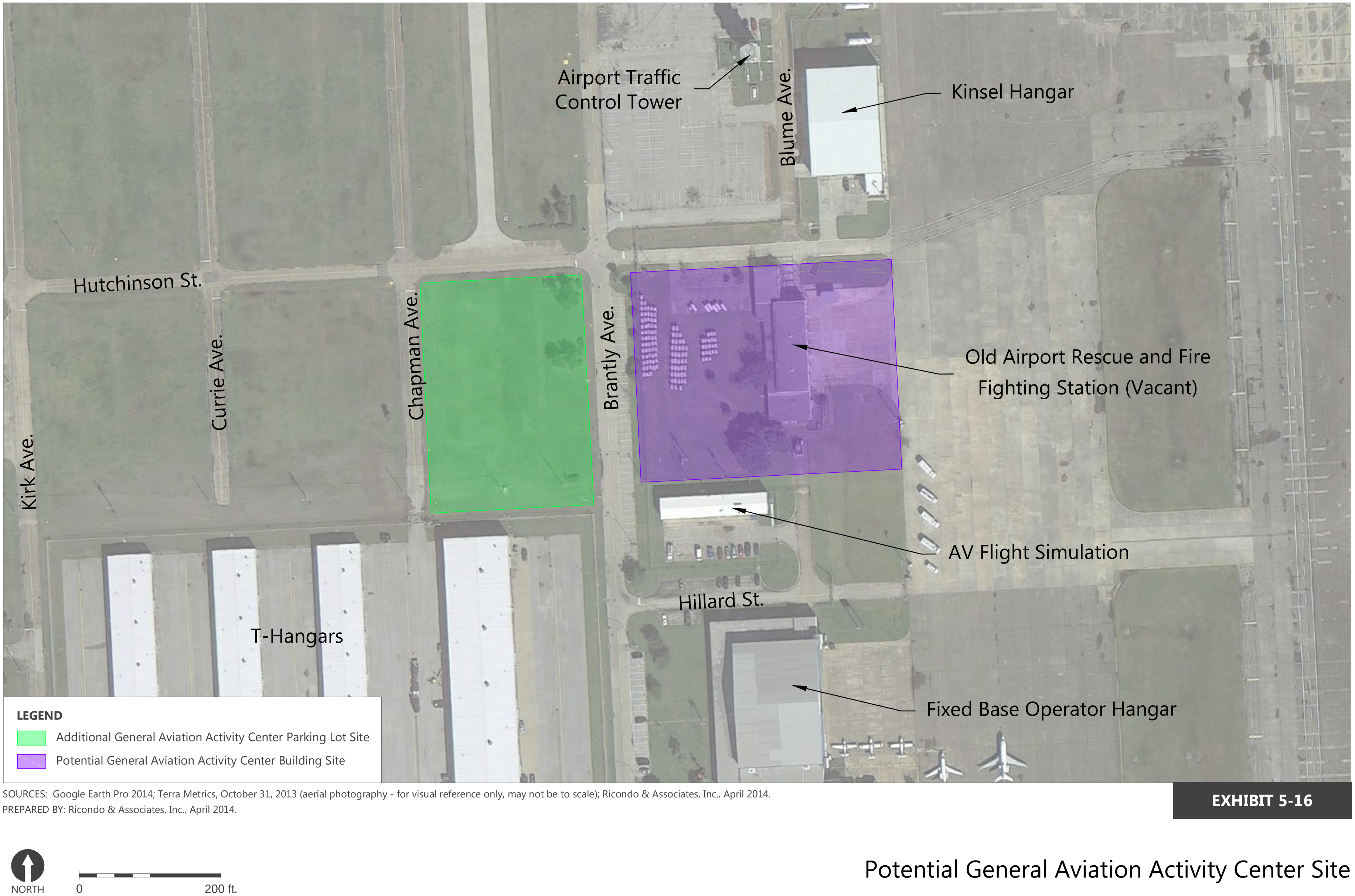

SOURCES: Google Earth Pro 2014; Terra Metrics, October 31, 2013 (aerial photography - for visual reference only, may not be to scale); Ricondo & Associates, Inc., April 2014.
PREPARED BY: Ricondo & Associates, Inc., April 2014.

EXHIBIT 5-16

Potential General Aviation Activity Center Site

Drawing: Z:\Houston\1-EFD\EFD Master Plan 2012\05_Alternatives Development\5-GA Activity Center\Exh 5-16_GAAC Site.dwg Layout: 5-16 GAAC Site Plotted: Sep 29, 2015, 01:49PM

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5.4.2 GENERAL AVIATION AIRCRAFT STORAGE

Table 5-3 summarizes the facility requirements established for based aircraft storage at EFD. The table includes a breakdown of small and large T-hangars, as well as conventional hangars. Associated apron requirements are not included in the table, but were accounted for in the alternatives development.

Table 5-3: Based Aircraft Storage Requirements (in Square Feet)

STORAGE TYPE	2015	2020	2025	2030
Small T-Hangars	3,000	7,500	12,000	18,000
Large T-Hangars	3,200	6,400	9,600	16,000
Conventional Hangars	44,900	126,275	207,325	279,700

SOURCES: Houston Airport System, March 2014; Ricondo & Associates, Inc., March 2014.
PREPARED BY: Ricondo & Associates, Inc. April 2014.

5.4.2.1 Small and Large T-Hangar Development Plans

A third-party developer has expressed interest in developing small and large T-hangars on either side of Taxiway K at EFD, as depicted on **Exhibit 5-17**. Development would be incremental, based on demand. The full buildout layout depicted on Exhibit 5-16 would provide approximately 475,000 square feet of T-hangar space, which exceeds requirements through the planning period. Such a large-scale development may only be needed if Ellington Airport were to attract aircraft owners from other airports, which was not an assumption underlying the forecasts.

A smaller scale T-hangar development could consist of constructing a new T-hangar east of HAS T-hangar A, which would provide approximately 50,000 square feet of aircraft storage space, and/or extending T-hangars A, B, and C to the north, with each extension providing approximately 10,000 square feet of additional aircraft storage space. These hangars are also depicted on Exhibit 5-16.

5.4.2.2 Fixed Base Operator Development Plans

Since the Master Plan Update was initiated in 2011, Landmark Aviation has constructed two new conventional hangars, W-601 and W-602, which provide approximately 15,000 and 30,000 square feet of aircraft storage, respectively, for a total of an additional 45,000 square feet of conventional hangar space. As such, conventional hangar requirements would be satisfied through 2015.

According to Airport staff, Landmark Aviation plans to construct two new hangars adjacent to its existing hangars south of Taxilane J. As shown on **Exhibit 5-18**, one hangar is planned to be located south of Building W-601, and would be similar in size and shape to Building W-601. The second hangar is planned to be located south of Building W-602, and would be similar in size and shape to Building W-602. These planned hangars would provide an additional 45,000 square feet of conventional hangar aircraft storage space in the short term. Construction of the first hangar requires the relocation of Brantly and Robbins Avenues to provide apron access to the hangar.

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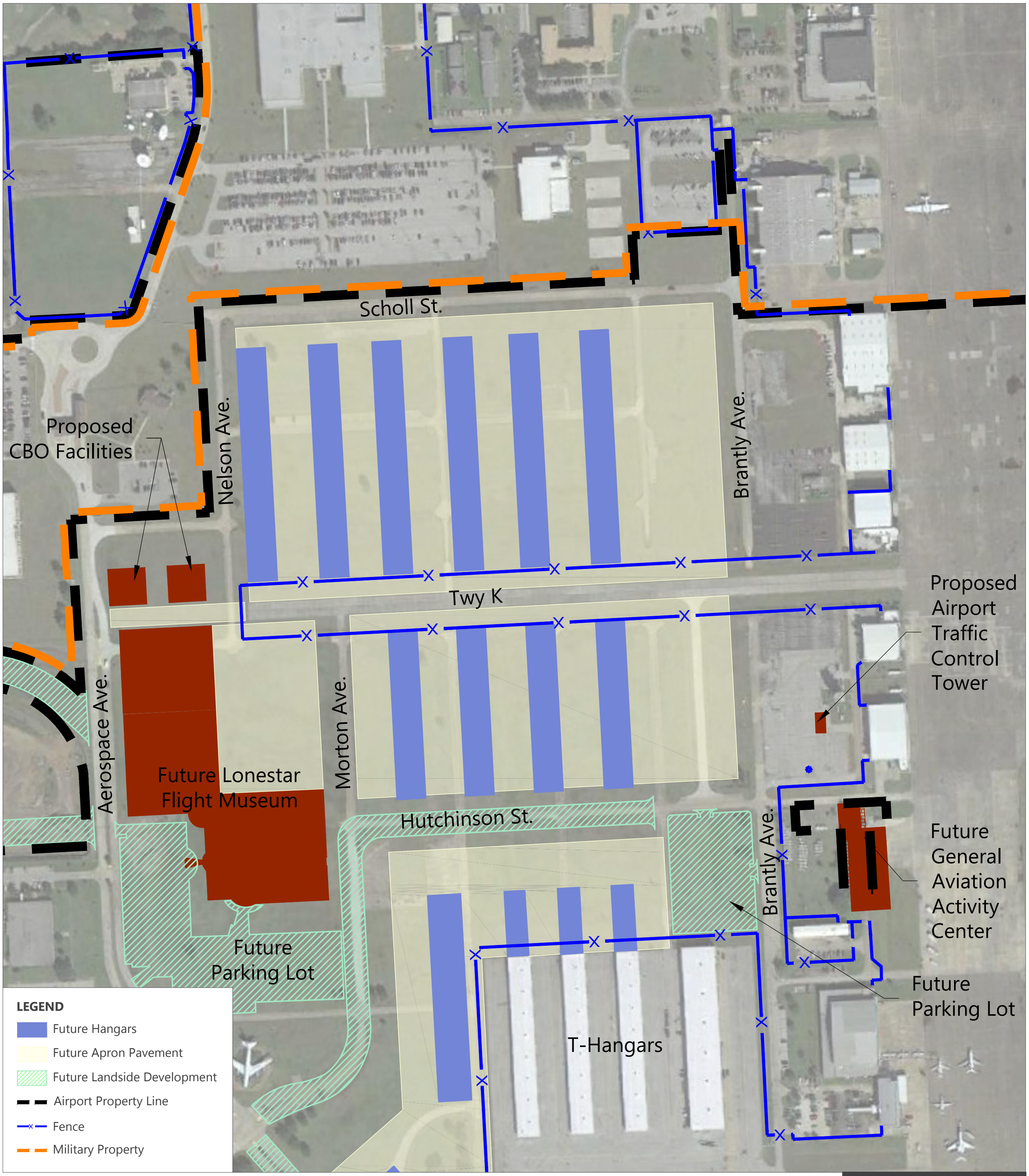

SOURCES: Ricondo and Associates, Inc., Ellington Airport, Draft Future Airport Layout Plan, April 2014; Google Earth Pro 2014; Terra Metrics, October 31, 2013 (aerial photography - for visual reference only, may not be to scale), Ricondo & Associates, Inc., April 2014.
PREPARED BY: Ricondo & Associates, Inc., April 2014.

EXHIBIT 5-17

Potential T-Hangar Development

Drawing: Z:\Houston\1-EFD\EFD Master Plan 2012\05_Alternatives Development\4-West Side Development\Potential T-Hangar Development_20150202.dwg Layout: 5-17 - Potential T-Hangar Development Plotted: Sep 25, 2015, 09:43AM

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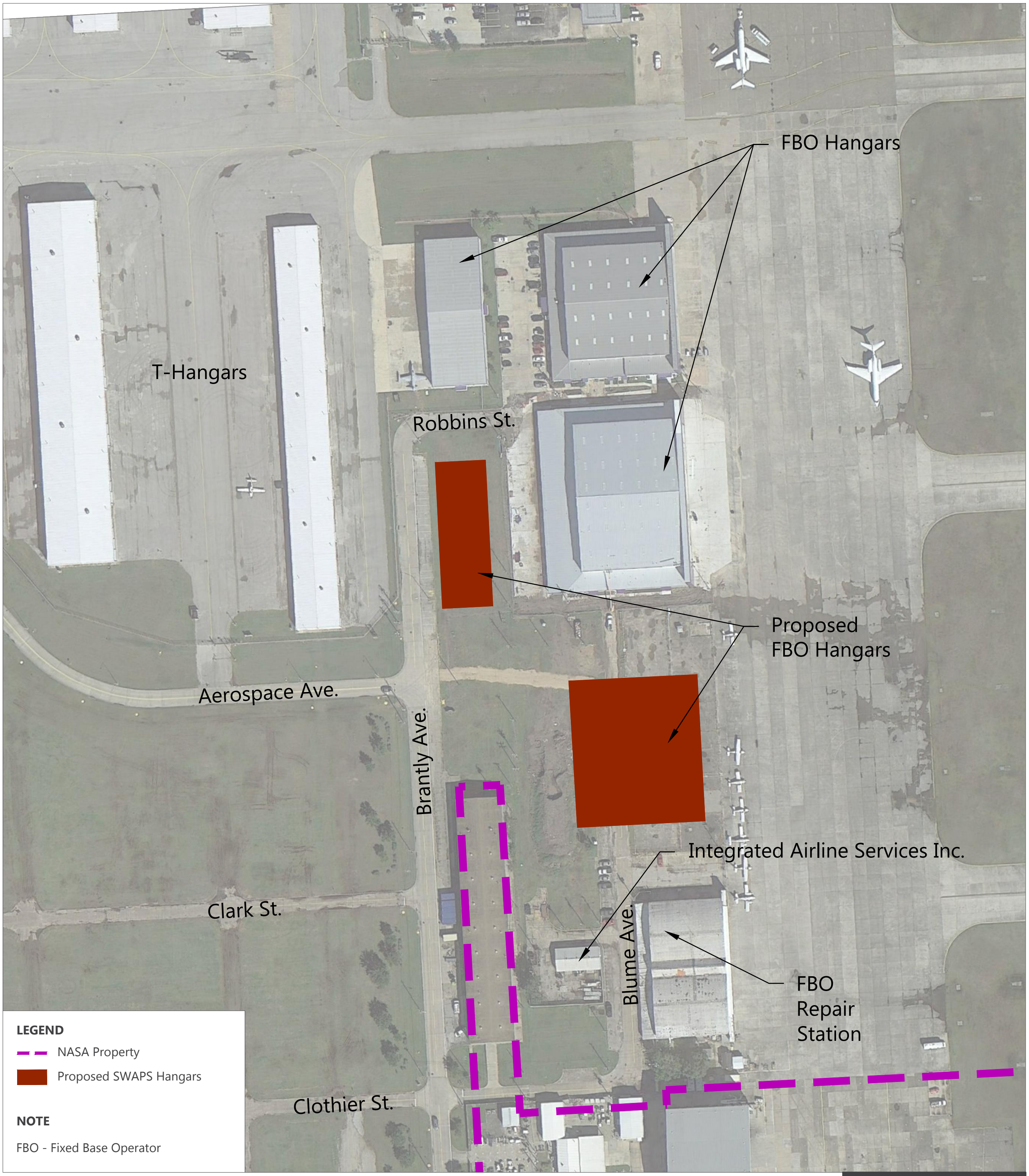

SOURCES: Ricondo and Associates, Inc., Ellington Airport, Draft Future Airport Layout Plan, April 2014; Google Earth Pro 2014; Terra Metrics, October 31, 2013 (aerial photography - for visual reference only, may not be to scale); Ricondo & Associates, Inc., April 2014.
PREPARED BY: Ricondo & Associates, Inc., April 2014.

EXHIBIT 5-18

NORTH 0 200 ft.

Planned Fixed Base Operator Hangar Development

Drawing: Z:\Houston\1-EFD\EFD Master Plan 2012\05_Alternatives Development\4-West Side Development\Exh 5-18_Proposed FBO Hangar Development_20150929.dwg Layout: 5-18 Planned SWAPS Hangars Plotted: Sep 29, 2015, 01:42PM

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The northern portion of Brantly Avenue would be shifted to the east, midway between its current location and Blume Avenue. This relocated roadway would provide access to the four Landmark Aviation hangars. Limited vacant space would then be available for additional expansion of Landmark Aviation facilities along the apron, and further expansion would have to be accommodated south of the existing HAS T-hangars, as discussed in the later Section 5.4.2.3.

5.4.2.3 Conventional Hangar Development Alternatives

Seven conceptual alternatives (A through G) were developed to illustrate potential conventional hangar expansion in the southwest quadrant of the Airport. It is anticipated that these hangars would accommodate mostly CBOs, but they could also include a mix of CBOs, private tenants, and FBOs. These alternatives, which would all allow for incremental expansion based on need, are shown on **Exhibits 5-19** through **5-25**.

Alternative A

Alternative A, depicted on Exhibit 5-19, consists of the addition of four hangars, which would encompass a total area of approximately 142,000 square feet of aircraft storage space. Considering the recently added 45,000 square feet by Landmark Aviation, the total aircraft storage area resulting from Alternative A would consist of approximately 187,000 square feet, which would satisfy forecast requirements at EFD through 2023.

Alternative B

Alternative B, depicted on Exhibit 5-20, consists of the addition of five hangars, which would encompass a total area of approximately 190,000 square feet of aircraft storage space. Considering the recently added 45,000 square feet by Landmark Aviation, the total aircraft storage area resulting from Alternative B would consist of approximately 235,000 square feet, which would satisfy forecast requirements at EFD through 2027.

Alternative C

Alternative C, depicted on Exhibit 5-21, consists of the addition of nine hangars, which would encompass a total area of approximately 250,000 square feet of aircraft storage space. Considering the recently added 45,000 square feet by Landmark Aviation, the total aircraft storage area resulting from Alternative C would consist of approximately 295,000 square feet, which would exceed forecast requirements through the planning period (2030).

Alternative D

Alternative D, depicted on Exhibit 5-22, consists of the addition of six conventional hangars, which would encompass a total area of approximately 235,000 square feet of aircraft storage space. Considering the recently added 45,000 square feet by Landmark Aviation, the total aircraft storage area resulting from Alternative D would consist of 280,000 square feet, which would satisfy forecast requirements through the planning period (2030).

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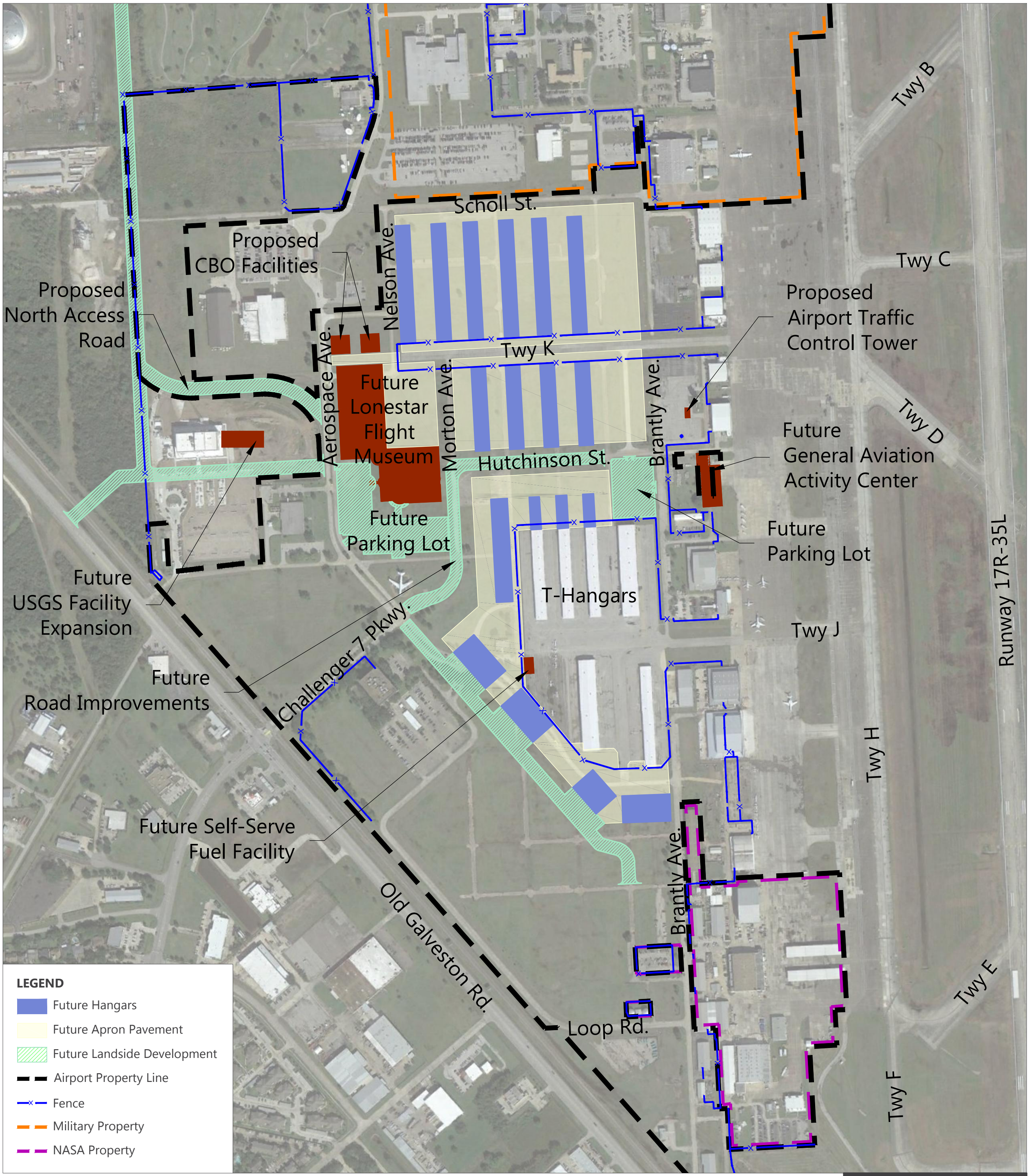

SOURCES: Ricondo and Associates, Inc., Ellington Airport, Draft Future Airport Layout Plan, April 2014; Google Earth Pro 2014; Terra Metrics, October 31, 2013 (aerial photography - for visual reference only, may not be to scale), Ricondo & Associates, Inc., April 2014.
PREPARED BY: Ricondo & Associates, Inc., April 2014.

EXHIBIT 5-19

NORTH 0 800 ft.

Conventional Aircraft Hangar Development Alternative A

Drawing: Z:\Houston\1-EFD\EFD Master Plan 2012\05_Alternatives Development\4-West Side Development\West Side_Hangar Expansion Development (Alt. A)_20150202.dwg_Layout: 5-19 - West Side Hangar Expansion (Alt. A)_Sep 25, 2015, 9:46am

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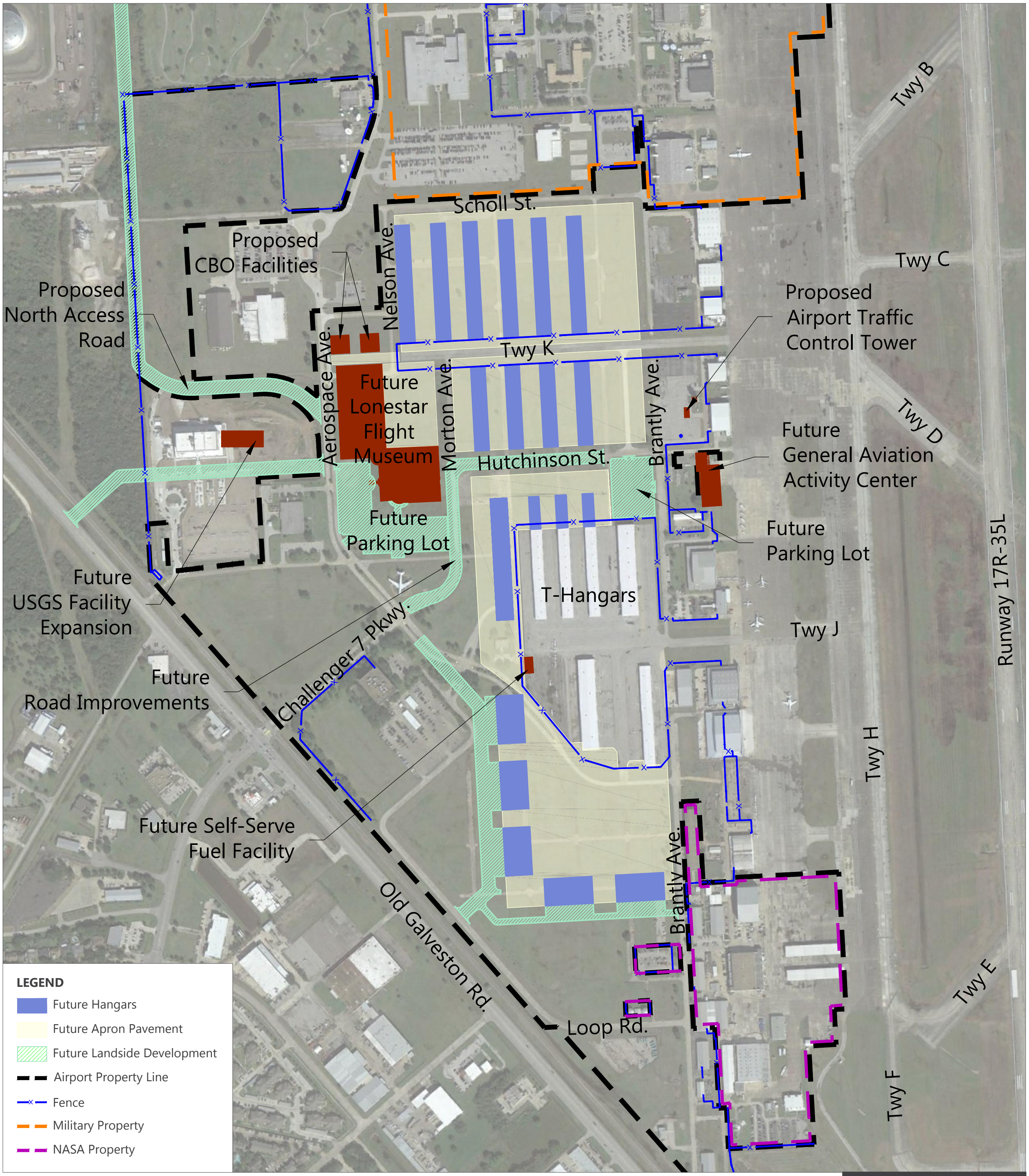

EXHIBIT 5-20

SOURCES: Ricondo and Associates, Inc., Ellington Airport, Draft Future Airport Layout Plan, April 2014; Google Earth Pro 2014; Terra Metrics, October 31, 2013 (aerial photography - for visual reference only, may not be to scale), Ricondo & Associates, Inc., April 2014.
PREPARED BY: Ricondo & Associates, Inc., April 2014.

Conventional Aircraft Hangar Development
Alternative B

Drawing: Z:\Houston\1-EFD\EFD Master Plan 2012\05_Alternatives Development\4-West Side Development\West Side_Hangar Expansion Development (Alt. B)_20150202.dwg_Layout: 5-20 - West Side Hangar Expansion (Alt. B)_Sep 25, 2015, 9:47am

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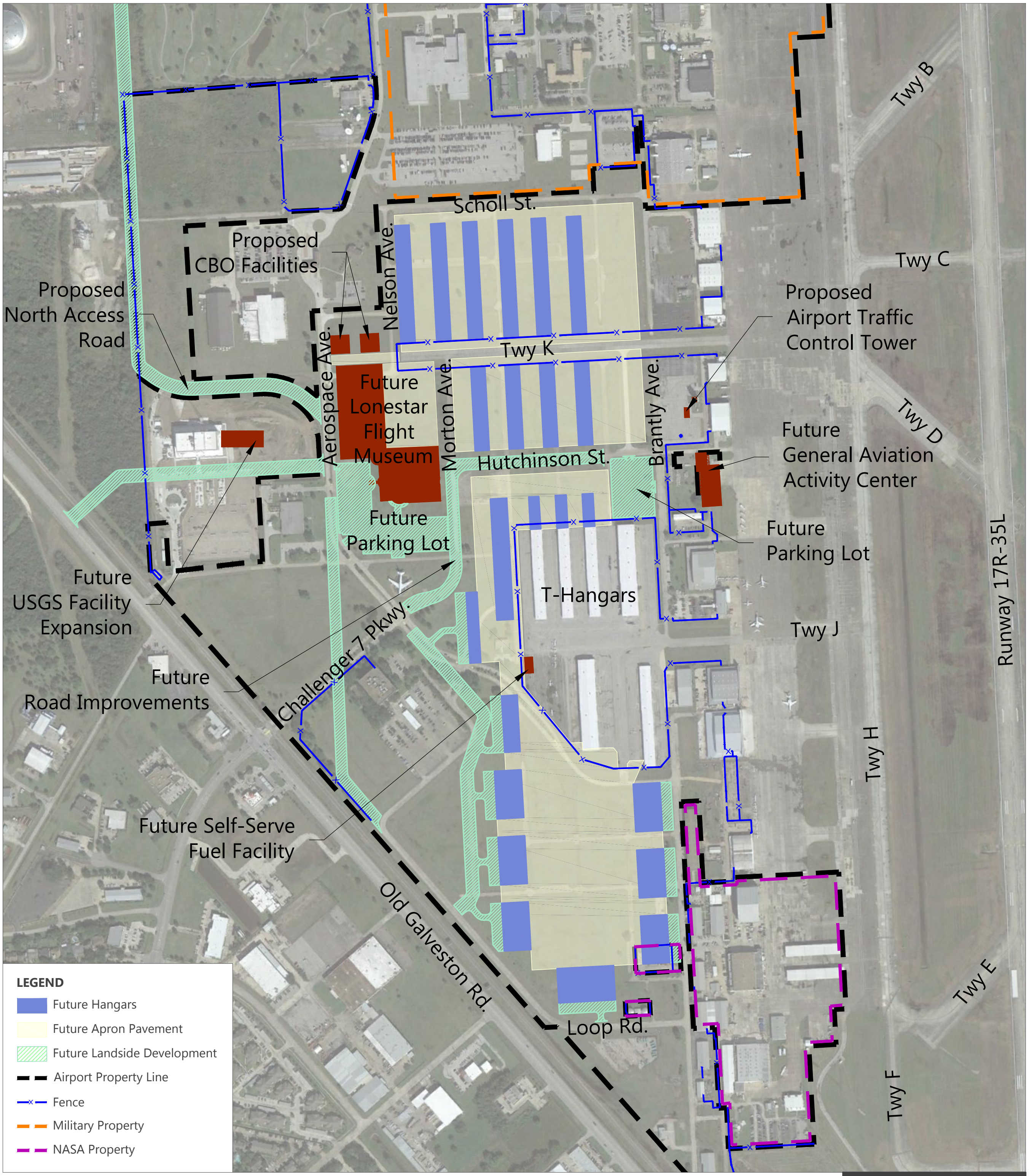

SOURCES: Ricondo and Associates, Inc., Ellington Airport, Draft Future Airport Layout Plan, April 2014; Google Earth Pro 2014; Terra Metrics, October 31, 2013 (aerial photography - for visual reference only, may not be to scale), Ricondo & Associates, Inc., April 2014.
PREPARED BY: Ricondo & Associates, Inc., April 2014.

EXHIBIT 5-21

NORTH

0 800 ft.

Conventional Aircraft Hangar Development Alternative C

Drawing: Z:\Houston\1-EFD\EFD Master Plan 2012\05_Alternatives Development\4-West Side Development\West Side_Hangar Expansion Development (Alt. C)_20150202.dwg Layout: 5-21 - West Side Hangar Expansion (Alt. C) Plotted: Sep 25, 2015, 09:51AM

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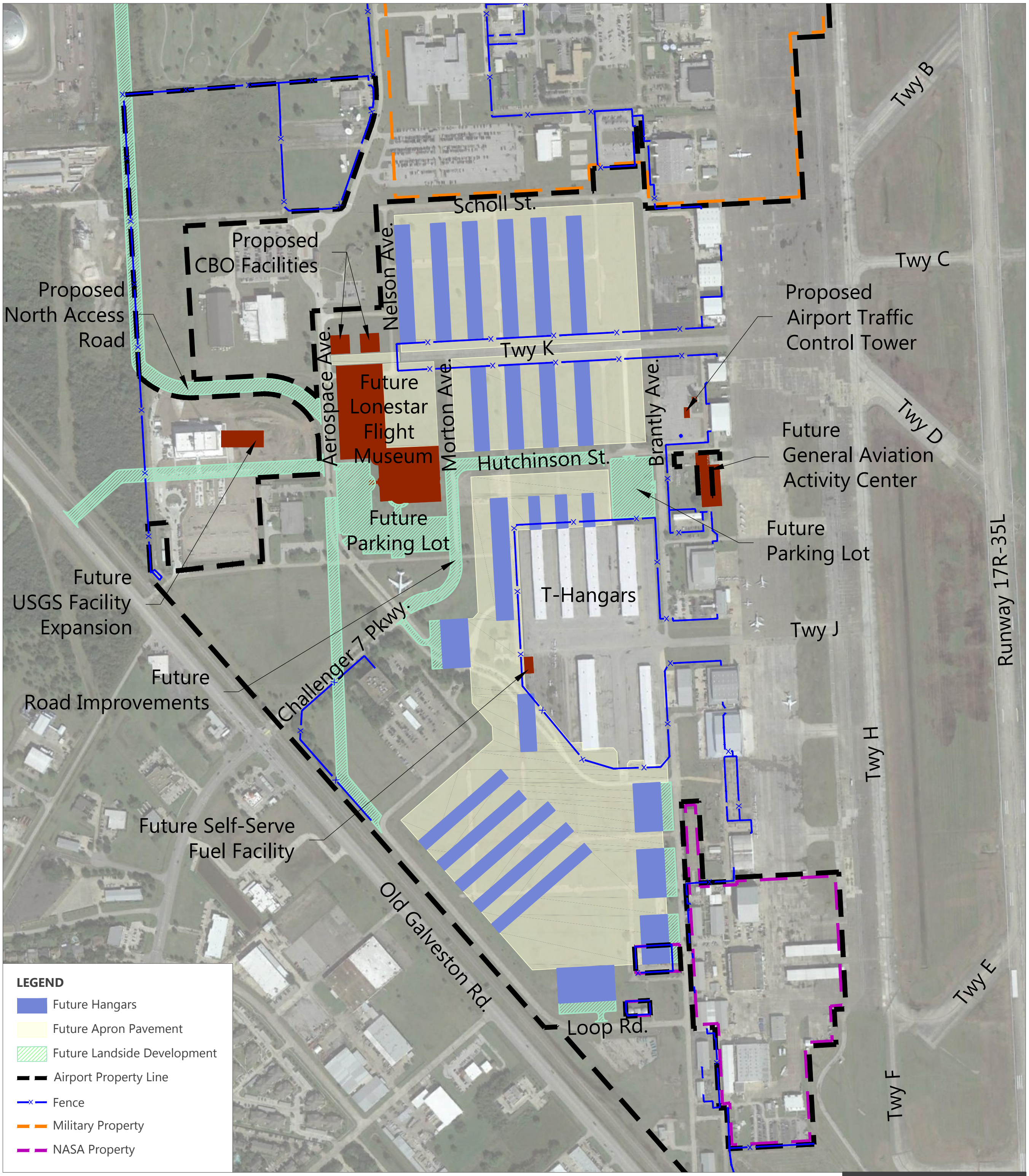

SOURCES: Ricondo and Associates, Inc., Ellington Airport, Draft Future Airport Layout Plan, April 2014; Google Earth Pro 2014; Terra Metrics, October 31, 2013 (aerial photography - for visual reference only, may not be to scale), Ricondo & Associates, Inc., April 2014.
PREPARED BY: Ricondo & Associates, Inc., April 2014.

EXHIBIT 5-22

NORTH

0 800 ft.

Conventional Aircraft Hangar Development Alternative D

Drawing: Z:\Houston\1-EFD\EFD Master Plan 2012\05_Alternatives Development\4-West Side Development\West Side_Hangar Expansion Development (Alt. D)_20150202.dwg Layout: 5-22 - West Side Hangar Expansion (Alt. D) Plotted: Sep 25, 2015, 09:53AM

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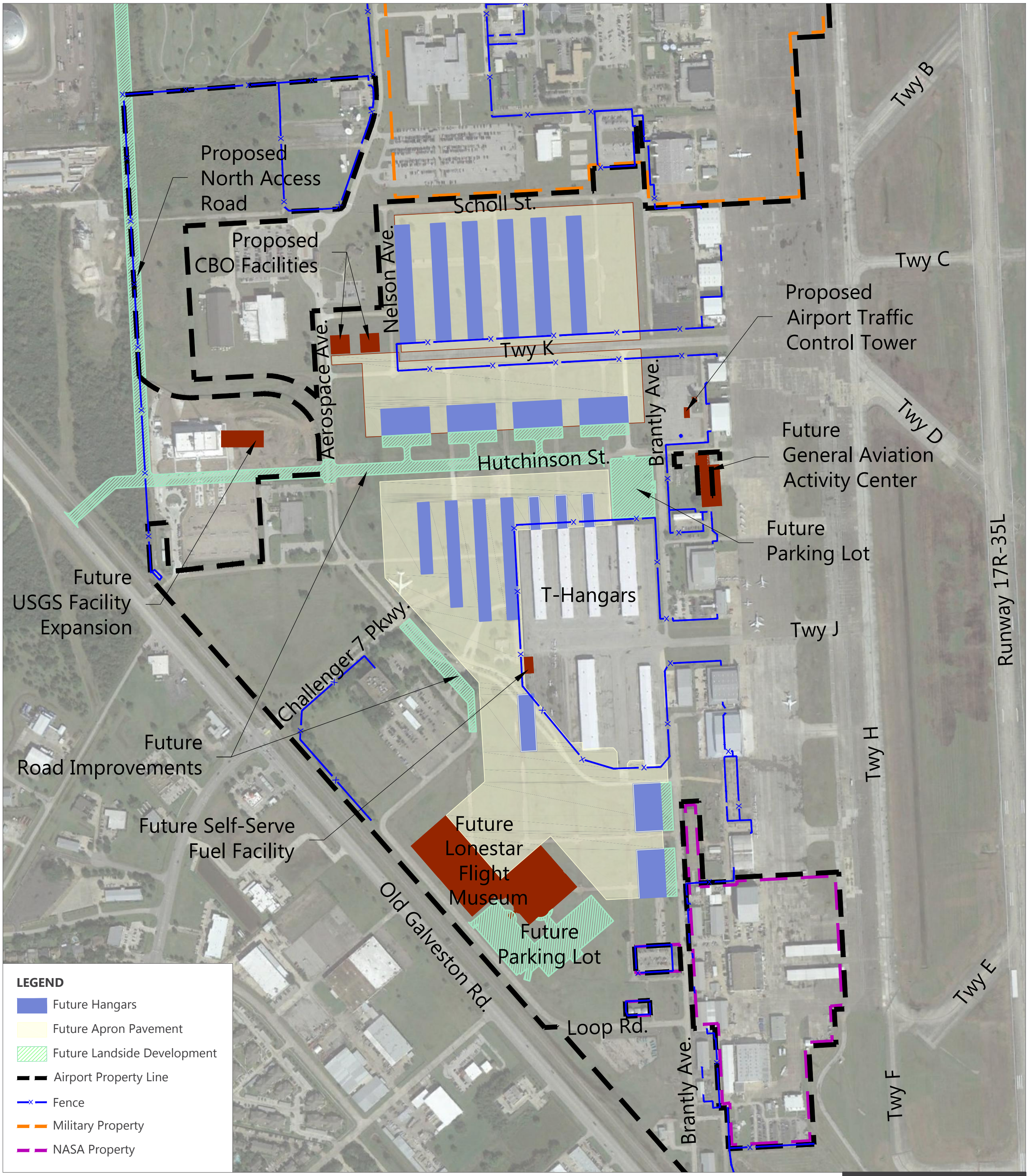

SOURCES: Ricondo and Associates, Inc., Ellington Airport, Draft Future Airport Layout Plan, April 2014; Google Earth Pro 2014; Terra Metrics, October 31, 2013 (aerial photography - for visual reference only, may not be to scale), Ricondo & Associates, Inc., April 2014.
PREPARED BY: Ricondo & Associates, Inc., April 2014.

EXHIBIT 5-23

NORTH

0 800 ft.

Conventional Aircraft Hangar Development Alternative E

Drawing: Z:\Houston\1-EFD\EFD Master Plan 2012\05_Alternatives Development\4-West Side Development\West Side_Hangar Expansion Development (Alt. E)_20150202.dwg Layout: 5-23 - West Side Hangar Expansion (Alt. E) Plotted: Sep 25, 2015, 09:56AM

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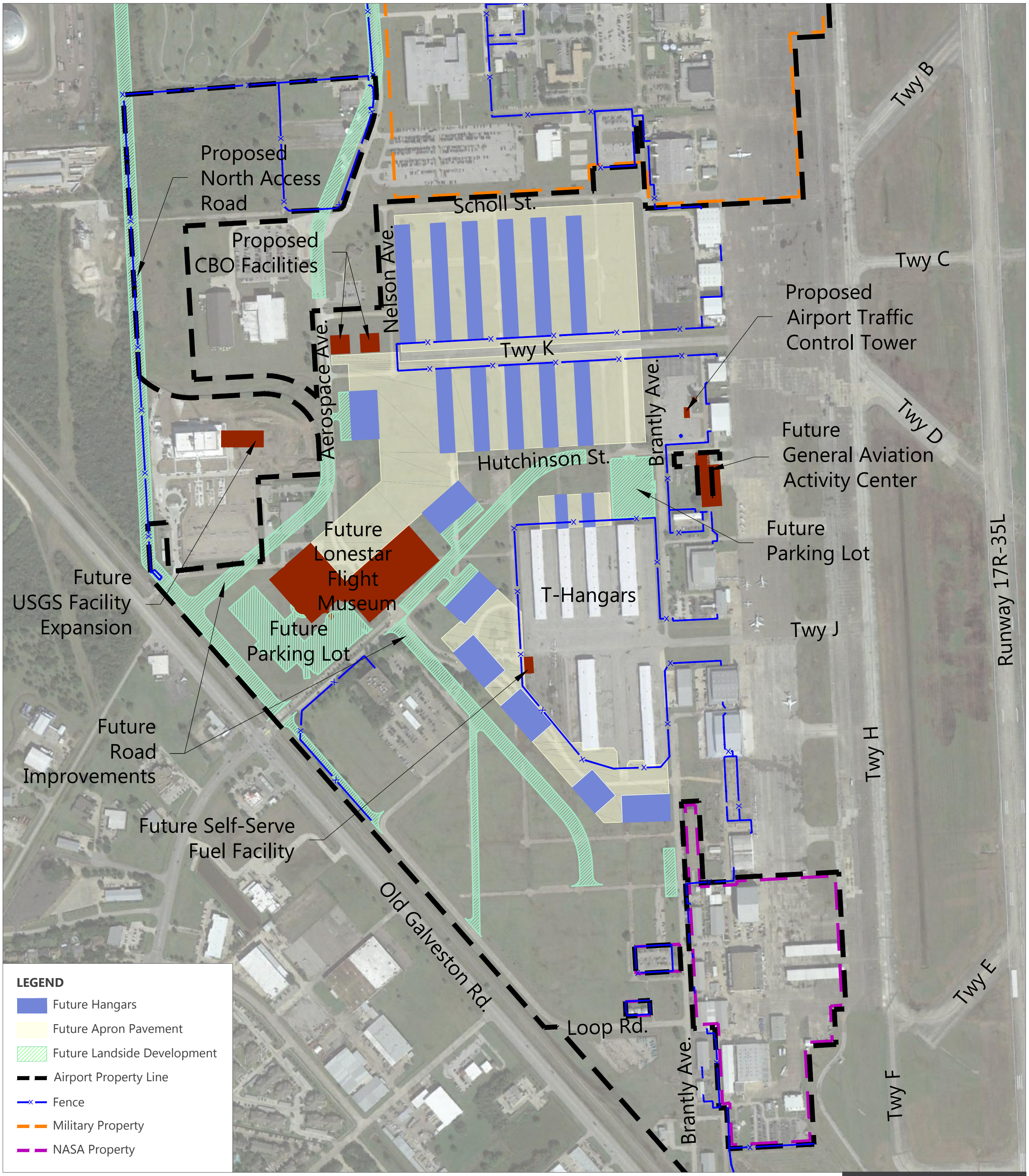

SOURCES: Ricondo and Associates, Inc., Ellington Airport, Draft Future Airport Layout Plan, April 2014; Google Earth Pro 2014; Terra Metrics, October 31, 2013 (aerial photography - for visual reference only, may not be to scale), Ricondo & Associates, Inc., April 2014.
PREPARED BY: Ricondo & Associates, Inc., April 2014.

EXHIBIT 5-24

NORTH

0 800 ft.

Conventional Aircraft Hangar Development Alternative F

Drawing: Z:\Houston\1-EFD\EFD Master Plan 2012\05_Alternatives Development\4-West Side Development\West Side_Hangar Expansion Development (Alt. F)_20150202.dwg Layout: 5-24 - West Side Hangar Expansion (Alt. E) Plotted: Sep 25, 2015, 09:57AM

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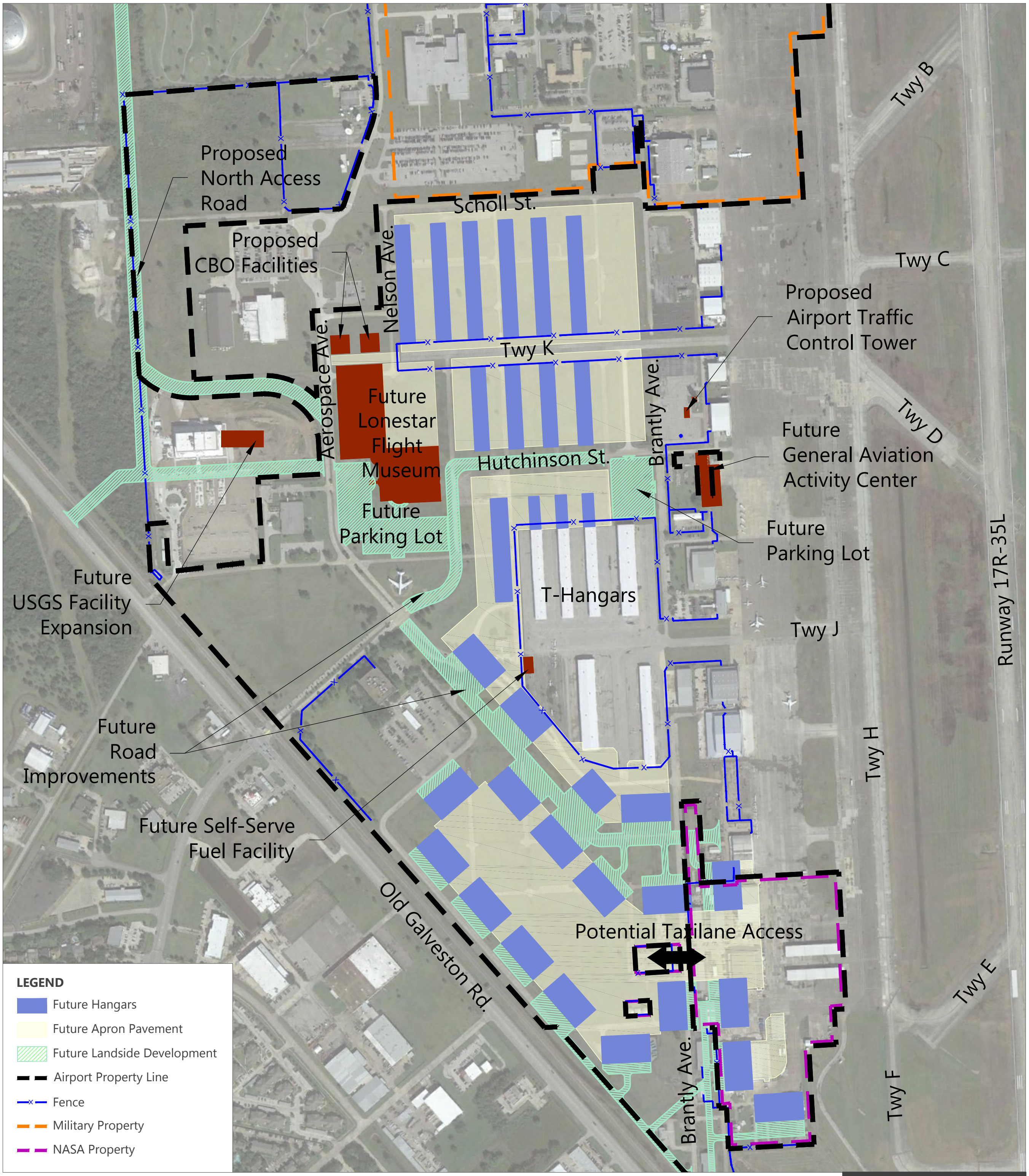

SOURCES: Ricondo and Associates, Inc., Ellington Airport, Draft Future Airport Layout Plan, April 2014; Google Earth Pro 2014; Terra Metrics, October 31, 2013 (aerial photography - for visual reference only, may not be to scale), Ricondo & Associates, Inc., April 2014.
PREPARED BY: Ricondo & Associates, Inc., April 2014.

EXHIBIT 5-25

NORTH 0 800 ft.

Conventional Aircraft Hangar Development Alternative G

Drawing: Z:\Houston\1-EFD\EFD Master Plan 2012\05_Alternatives Development\4-West Side Development\West Side_Hangar Expansion Development (Alt. G)_20150202.dwg Layout: 5-25 - West Side Hangar Expansion (Alt. E) Plotted: Sep 25, 2015, 09:58AM

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Alternative E

Alternative E, depicted on Exhibit 5-23, consists of the addition of seven conventional hangars, which would encompass a total area of approximately 255,000 square feet of conventional hangar aircraft storage space. Considering the recently added 45,000 square feet by Landmark Aviation, the total aircraft storage area resulting from Alternative E would be approximately 290,000 square feet, which would exceed forecast requirements through the planning period (2030).

Alternative F

Alternative F, depicted on Exhibit 5-24, consists of the addition of seven conventional hangars, which would encompass a total area of approximately 255,000 square feet of conventional hangar aircraft storage space. Considering the recently added 45,000 square feet by Landmark Aviation, the total aircraft storage area resulting from Alternative F would consist of approximately 290,000 square feet, which would exceed forecast requirements through the planning period (2030).

Alternative G

Alternative G, depicted on Exhibit 5-25, consists of the addition of four conventional hangars south and west of the existing HAS T-hangars, and approximately 15 conventional hangars in a separate area to the south. This alternative would result in approximately 700,000 square feet of additional conventional hangar aircraft storage space. This alternative would create a separate aircraft hangar area in the southwest quadrant, and would be ideal for the introduction of a second FBO at EFD. This alternative would require the relocation of the NASA facilities in this area. Four hangars are recommended along the apron, on the existing NASA site. A new east-west taxilane would provide access to the remaining hangars. Alternative G would far exceed forecast requirements through the planning period (2030).

Preferred Alternative

At the time this Master Plan Update was being prepared, there was no significant potential for large-scale future hangar development such as that depicted in Alternatives A through G. The purpose of the conceptual alternative layouts shown on Exhibits 5-19 through 5-25 was not to identify a specific concept that would drive future development schedules, but to demonstrate a range of layouts and scales of development that could be possible in the southwest quadrant of the Airport. EFD already offers all amenities in the southwest quadrant that would be of interest to potential developers (utilities, FBO services, airfield access, etc.) with the possible exception that care must be taken to ensure that efficient vehicular access is provided to future development areas from the main Airport entrance, and that efficient vehicular access is maintained throughout the southwest quadrant of the Airport. These alternatives demonstrate that vehicular access can be maintained while allowing for extensive hangar development.

Although the alternatives were developed mostly for conceptual purposes, HAS and EFD management identified Alternatives B and F as the preferred alternatives.

5.4.3 AIRPORT TRAFFIC CONTROL TOWER

A new ATCT is planned to be constructed adjacent to the existing ATCT, which is currently in very poor condition. The existing ATCT was damaged during Hurricane Ike in 2008. The new ATCT is anticipated to meet the needs of the Airport and its users through the planning period. Line-of-sight and depth perception issues should be evaluated for any future runway/taxiway modifications. The site of the new ATCT is depicted on **Exhibit 5-26**.

5.5 Airport Ground Access

5.5.1 ROADWAY IMPROVEMENTS

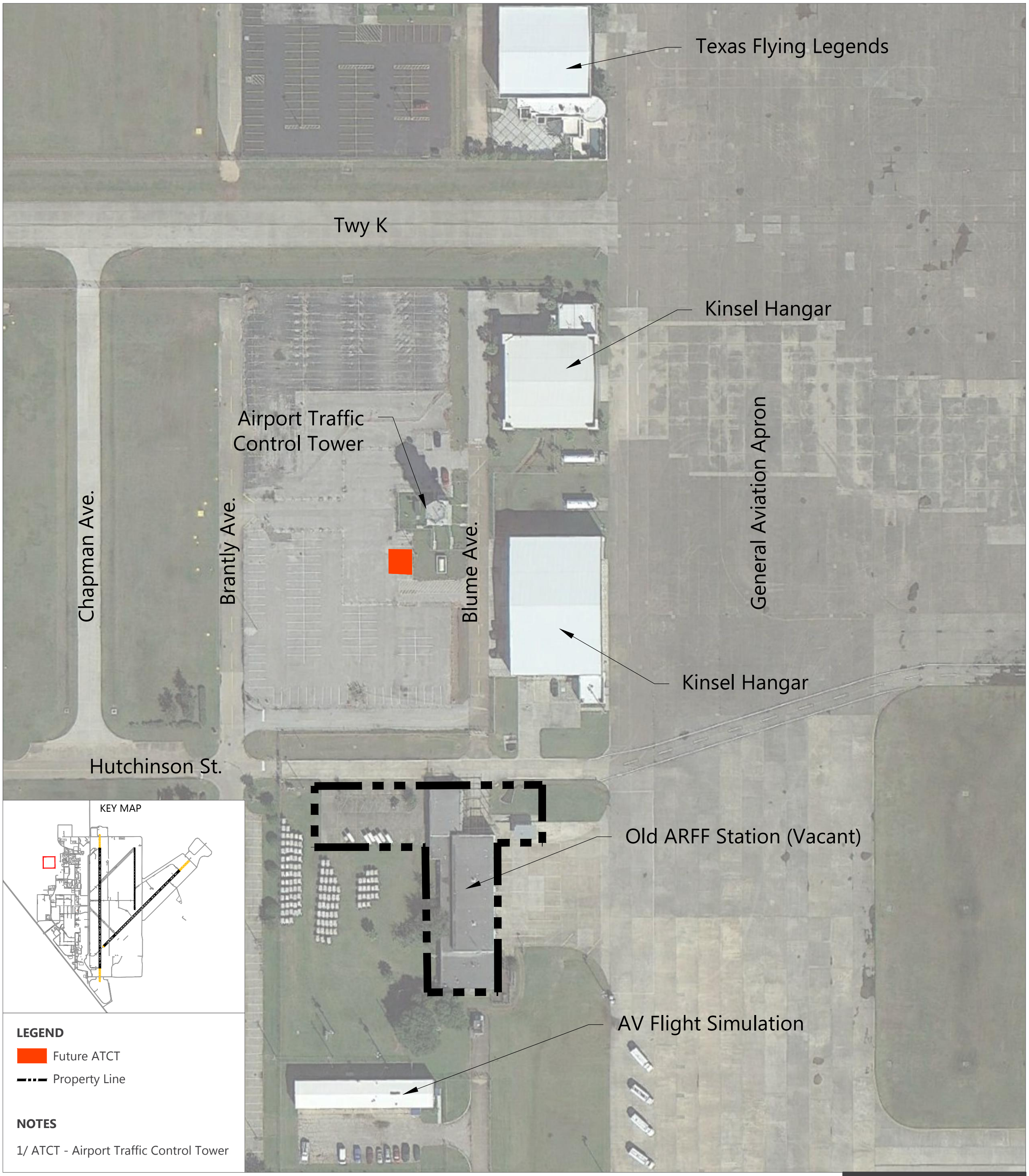
As discussed in Section 4, **Exhibit 5-27** depicts the recommended alignments of a north access roadway connecting the Airport with Beltway 8, as well as the Ellington Bypass (providing access to the southeast quadrant of the Airport). These two access roads were adopted by the Houston City Council in the *2012 Major Thoroughfare and Freeway Plan*.

The north access roadway would provide a direct connection between the Airport and Beltway 8, and would also mitigate delays incurred during railroad blockages along Old Galveston Road. The Ellington Bypass would connect Space Center Boulevard with Old Galveston Road, along the southern edge of the Airport. These roadways would provide additional egress from and ingress to the Airport.

5.5.2 ROADWAY INTERSECTIONS IMPROVEMENTS

Based on the analysis and findings in the *EFD Traffic Analysis Report* (Gunda Corporation, May 2015), the following roadway intersection improvements are recommended to meet LOS D through the planning horizon:

- Old Galveston Road at Challenger 7 Parkway:
    - Add additional south/eastbound right turn bay (200’)
- • Old Galveston Road at Clearlake City Boulevard:
    - Add additional south/eastbound left turn bay (300’)
    - Add additional north/westbound left turn bay (300’)
    - Add additional south/westbound left turn bay (125’)
    - Add additional north/eastbound left turn bay (315’)
    - Add south/eastbound right turn bay (300’)
    - Add north/westbound right turn bay (300’)
    - Add south/westbound right turn bay (250’)



LEGEND

🟥 Future ATCT

-·-· Property Line

NOTES

1/ ATCT - Airport Traffic Control Tower

SOURCES: Ricondo and Associates, Inc., Ellington Airport, Draft Future Airport Layout Plan, March 2014; Google Earth Pro 2014; Terra Metrics, October 31, 2013 (aerial photography - for visual reference only, may not be to scale), Ricondo & Associates, Inc., March 2014.
PREPARED BY: Ricondo & Associates, Inc., March 2014.

EXHIBIT 5-26

NORTH

0 160 ft.

Planned Location of Future Airport Traffic Control Tower

Drawing: Z:\Houston\1-EFD\EFD Master Plan 2012\05_Alternatives Development\4-West Side Development\Exhibit 5-26_Future ATCT-20150202.dwg_Layout: 5-26_Planned Location of Future ATCT_Sep 25, 2015, 10:00am

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SOURCE: 2012 Major Thoroughfare and Freeway Plan, as adopted by Houston City Council in September 2012.
PREPARED BY: Ricondo & Associates, Inc., January 2014.

EXHIBIT 5-27

NORTH 0 Not To Scale

City of Houston Plans for Roadway Improvements
in the Vicinity of the Airport

Drawing: Z:\Houston\1-EFD\EFD Master Plan 2012\05_Alternatives Development\8-Ellington Bypass\Exhibits\CAD\Exh 5-27_Ellington Bypass.dwg_Layout: 05-27-Ellington Bypass_Sep 25, 2015, 10:02am

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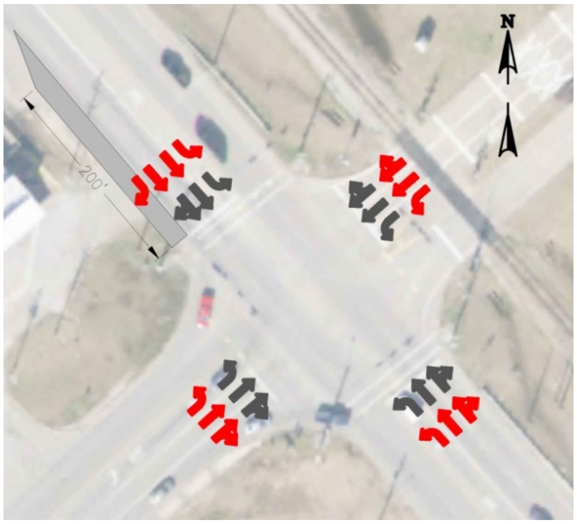
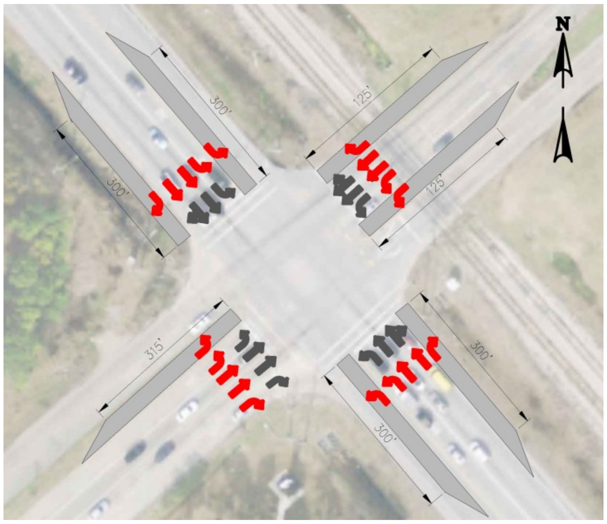
Exhibit 5-28 depicts the improvements proposed at the intersection of Old Galveston Road and Challenger 7 Parkway, while **Exhibit 5-29** depicts the improvements proposed at the intersection of Old Galveston Road and Clearlake City Boulevard.

Exhibit 5-28: Roadway Intersection Improvements at Old Galveston Road and Challenger 7 Parkway



SOURCE: Gunda Corporation, *EFD Traffic Analysis Report*, May 2015.
PREPARED BY: Gunda Corporation, May 2015.

Exhibit 5-29: Roadway Intersection Improvements at Old Galveston Road and Clear Lake City Boulevard



SOURCE: Gunda Corporation, *EFD Traffic Analysis Report*, May 2015.
PREPARED BY: Gunda Corporation, May 2015

Table 5-4 summarizes the level of service anticipated in 2020 and 2030, as a result of these intersection improvements. Although the 2030 LOS at the intersection of Old Galveston Road and Clearlake City Boulevard are less than LOS D, the access and connectivity improvements described in Section 5.5.1 would improve the operation of the intersection and reduce delays: a significant portion of the traffic currently using Clear Lake City Boulevard would be diverted to the Ellington Bypass, connecting to Space Center Boulevard. As a result, it is believed that the implementation of both the intersection improvements and the new access roadways would together alleviate the delays anticipated in 2030.

Table 5-4: Roadway Intersections Level of Service

	2020		2030	
INTERSECTIONS	**AM PEAK HOUR**	**PM PEAK HOUR**	**AM PEAK HOUR**	**PM PEAK HOUR**
Old Galveston Road at Challenger 7 Parkway	C	C	C	D
Old Galveston Road at Clearlake City Blvd.	D	D	**E**	**F**

SOURCE: Gunda Corporation, *EFD Traffic Analysis Report*, May 2015.
PREPARED BY: Ricondo & Associates, Inc., May 2015.

6. Comprehensive Land Use Plan

6.1 Off-Airport Land Use

This section discusses the development of the areas surrounding EFD, which consists of a mixture of agricultural, single-family residential, multifamily residential, industrial, and commercial uses, as well as schools, churches, and vacant/underdeveloped land. There is an interest in revitalizing the land uses adjacent to the major thoroughfares leading to EFD to attract off-Airport development suitable for a potential spaceport.

In support of this interest, land uses in the Airport environs were evaluated. The purpose of this section is to: (a) document existing land uses in the Airport environs and the land use patterns around the Airport and in neighboring communities, (b) identify potential land use development opportunities in the Airport environs, and (c) identify potential incompatible land use areas and recommend specific land use and economic development planning policies that may accelerate revitalization of the region.

6.1.1 AREA OF INFLUENCE

To implement effective land use planning and control measures around airports, it is necessary to identify specific planning boundaries. These boundaries define the Airport environs for land use planning purposes and are referred to herein as the Area of Influence (AOI) related to development in the Airport environs. For purposes of this Master Plan Update, the AOI is defined as property within a 1.0 mile buffer zone of the EFD property boundary.

A land use plan must incorporate federal and state airport design criteria, flight safety requirements, economic development policies, and land use provisions unique to the community. The FAA recommends that safety zones, standard traffic patterns, overflight areas, noise contours, and 14 CFR Part 77 height restriction criteria be considered as “building blocks” by land use planners when developing height hazard and land use zoning ordinances, airport overlay districts, and comprehensive community land use plans.

6.1.2 LAND USES WITHIN THE AREA OF INFLUENCE

The analysis of existing land uses within the AOI boundary and in the surrounding environs was based on a review of existing documents and graphic depiction of how the land and structures are currently used for particular purposes. Land use maps are the most common way of presenting land-based data. The maps show different land uses by rendering them in different colors. Currently, the AOI includes a mixture of land uses that can be grouped into the following categories:

- Residential (Single-family and Multifamily)
- Commercial
- Industrial
- Office
- Agricultural (Agricultural Exempt Land)
- Public/Institutional (City/County/State/Federal Owned Land, Schools, Places of Worship)
- Vacant/Underdeveloped
- Parks/Open Space (Parks, Homeowners Association Parks, Detention/Retention Ponds, Cemeteries)
- Transportation/Utilities (Pipelines, Railways, Utility Easements, Private Streets)

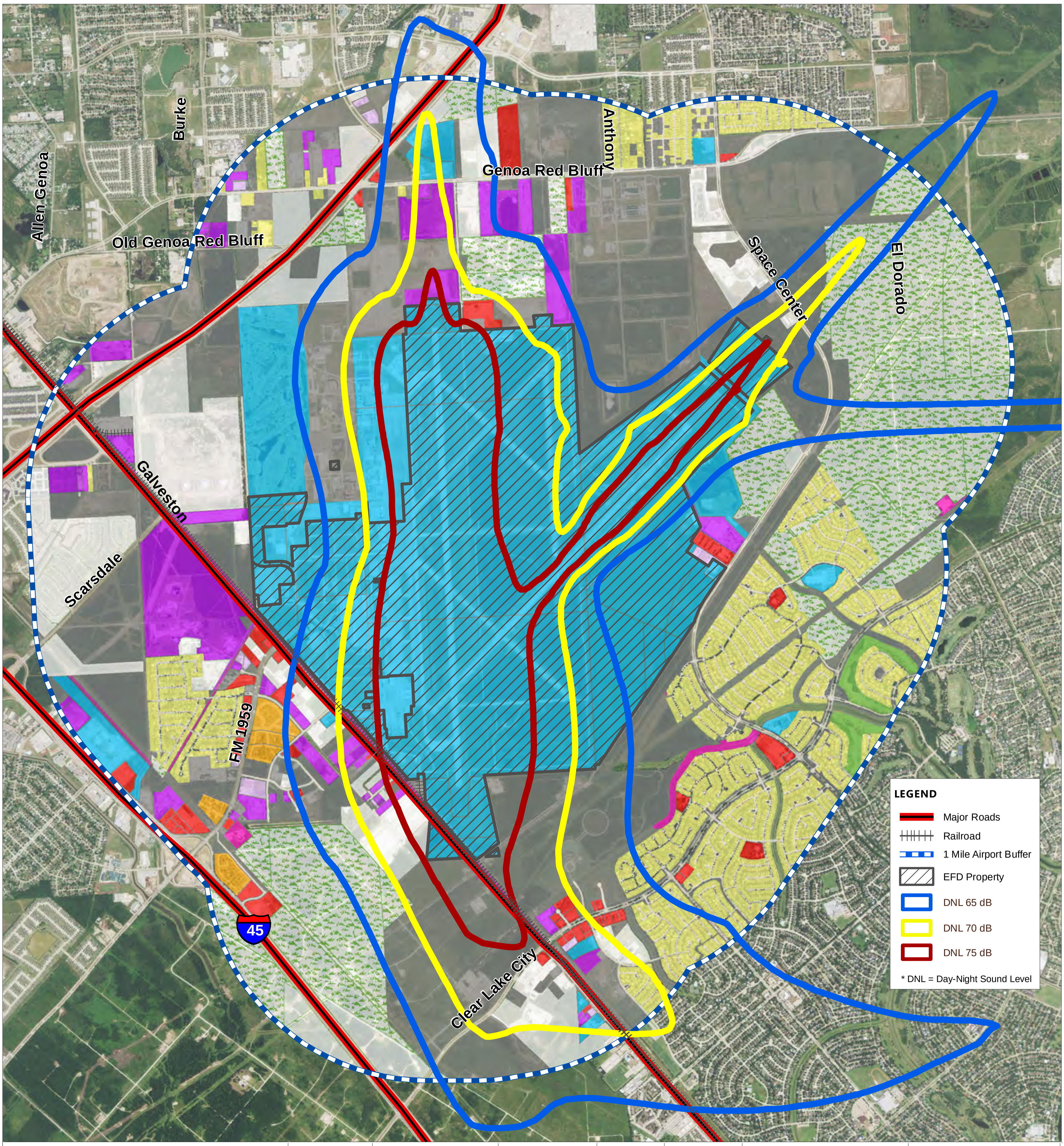
6.1.2.1 2005 Land Use

Exhibit 6-1 shows land uses within the EFD AOI in 2005. The eastern and southwestern portions of the AOI were densely developed. A majority of the vacant/underdeveloped land in the AOI was located in the northeastern, southern, and western portions. Most of the single-family residential parcels were located to the east of EFD. Multifamily residences were clustered along Dixie Farm Road, south of EFD. A majority of the commercial land use bordered Old Galveston Road and Clear Lake City Boulevard. Space Center Boulevard was fully constructed from Clear Lake City Boulevard to Genoa Red Bluff Road at the beginning of 2004, allowing for more commercial land uses to be developed east of EFD. Areas of industrial land uses were located along Old Galveston Road, Dixie Farm Road, and Genoa Red Bluff Road.

Table 6-1 summarizes the land uses in the EFD AOI in 2005, including the number of parcels or units, total market value, average property value, total acreage, and the percentage share of each land use within the AOI. Agricultural was the dominant land use by total area, followed by public/institutional land uses in 2005. EFD accounted for a majority of the public/institutional land, followed by the Pasadena Municipal Golf Course and Grace Church. Harris County Appraisal District (HCAD) records were used to calculate area and values. Several tax identification numbers/parcels had no data (no acreage, no values, etc.). This is not unusual for multiple appraisal districts in Texas, mostly for parcels that are tax exempt.

6.1.2.2 2012 Land Use

Exhibit 6-2 shows the existing land use categories in 2012 within the AOI and specific areas exposed to various levels of aircraft noise. The AOI is densely developed on the northern end and less densely developed on the eastern and western ends. More than 723 acres of land are vacant or underdeveloped. A majority of the vacant/underdeveloped land is located in the western area of the AOI. Most of the single-family residential parcels are located east of EFD.



Land Use	Number of Parcels	Dwelling/Units	% of Total Dwellings	Sq Miles	Acres	Average Property Value	Total Market Value
🟨 Single Family Residential	3,751	3,751	76.41%	1.22	781	$185,054 / dwelling	$694,138,461
🟧 Multi-family Residential	5	1,158	23.59%	0.07	47	$22,944 / unit	$26,569,603
	Total	4,909	100%	0.00	828		
🟥 Commercial	64			0.21	133	$11.21/ sq ft	$64,945,943
🟪 Industrial	67			0.76	487	$2.46 / sq ft	$52,201,111
🟪 Office	13			0.05	30	$9.84/ sq ft	$12,853,929
▨ Agricultural	35			4.29	2,748	$4,656 / per acre	$12,794,750
🟦 Public/Institutional	44			3.59	2,295	$0.01 / sq ft	$759,000
⬛ Vacant/Underdeveloped	1,220			1.12	719	$0.11 / sq ft	$3,461,228
🟩 Parks/Open Space	3			0.09	55	$6,334 / per acre	$348,365
🟪 Transportation/Utilities	17			0.06	37	$1.77 / sq ft	$2,849,788
⬜ No Data/Public Right-of-Way	776			3.49	2,236	$0 / sq ft	$0
			Totals	14.95	9,568		$870,922,178

SOURCES: Houston Airport System, 2008; Harris County Appraisal District, 2005; Houston-Galveston Area Council, 2006; Federal Aviation Administration, 2008

PREPARED BY: Ricondo & Associates, Inc., July 2014.

NORTH 0 0.25 0.5 1 Miles

EXHIBIT 6-1

Land Uses within the Area of Influence, 2005

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Table 6-1: Land Uses within the Area of Influence, 2005

LAND USE TYPE	NUMBER OF PARCELS/ UNITS	TOTAL MARKET VALUE (2005$)	AVERAGE PROPERTY VALUE (2005$)	TOTAL AREA (ACRES)	PERCENT OF TOTAL AREA
Agricultural	35	$12,794,750	$4,656/acre	2,748	28.7%
Commercial	64	$64,945,943	$11.21/square foot	133	1.4%
Industrial	67	$52,201,111	$2.46/square foot	487	5.1%
Multifamily Residential	1,158	$26,569,603	$22,944/unit	47	0.5%
Office	13	$12,853,929	$9.84/square foot	30	0.3%
Parks/Open Space	3	$348,365	$6,334/acre	55	0.6%
Public/Institutional	44	$759,000	$0.01/square foot	2,295	24.0%
Residential Vacant	126	$3,326,990	$26,405/lot	127	1.3%
Single-family Residential	3,751	$694,138,461	$185,054/unit	781	8.1%
Transportation/Utilities	17	$2,849,788	$1.77/square foot	37	0.4%
Vacant/Underdeveloped	1,220	$22,476,270	$0.87/square foot	592	6.2%
No Parcel Data	776	N/A	N/A	2,236	23.4%
Total	**7,274**	**$893,264,210**		**9,568**	**100.0%**

N/A = Not Available

SOURCE: Harris County Appraisal District, hcad.org. Accessed May 2015.
PREPARED BY: UrbanCore Collaborative, Inc., and Knudson, LP, May 2015.

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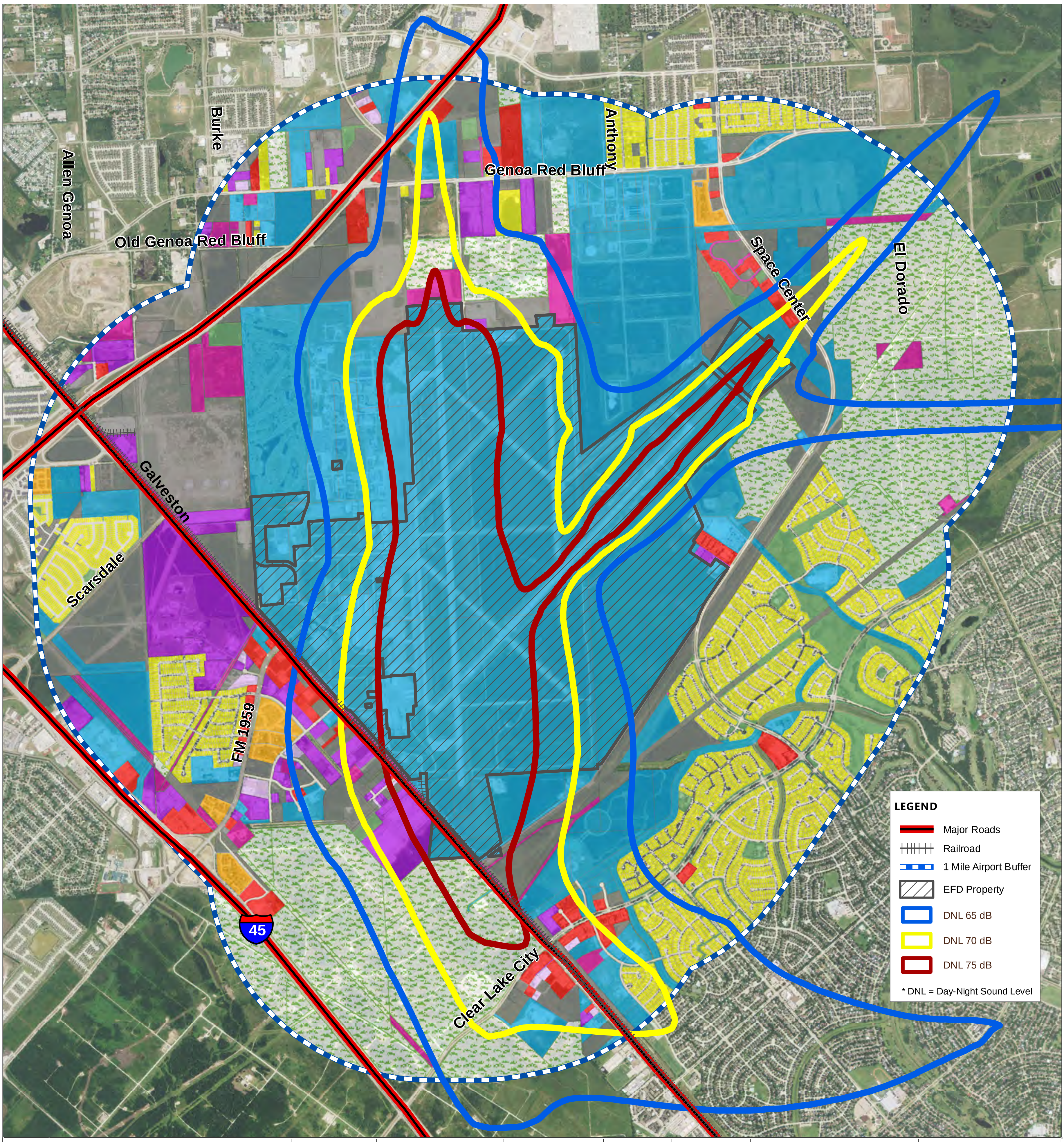

	Land Use	Number of Parcels	Dwelling/Units	% of Total Dwellings	Sq Miles	Acres	Average Property Value	Total Market Value
🟨	Single Family Residential	4,390	4390	72.54%	1.38	885	$186,278 / dwelling	$817,761,623
🟧	Multi-family Residential	7	1662	27.46%	0.11	68	$44,652 / unit	$74,211,183
		Total	6052	100%	0.00	954		
🟥	Commercial	90			0.32	204	$19.67 / sq ft	$175,056,243
🟪	Industrial	72			0.46	292	$6.38 / sq ft	$81,275,806
■	Office	19			0.05	30	$12.635 / sq ft	$16,780,937
▨	Agricultural	35			3.56	2,276	$10,111 / per acre	$23,015,841
🟦	Public/Institutional	136			6.23	3,990	$0 / sq ft	$0
■	Vacant/Underdeveloped	219			1.17	750	$1.97 / sq ft	$64,516,894
🟩	Parks/Open Space	148			0.28	181	$19,720 / per acre	$3,548,898
■	Transportation/Utilities	92			1.39	890	$0.58 / sq ft	$22,649,952
	No Data/Public Right-of-Way	0			0.00	0	$0 / sq ft	$0
				Totals	**14.95**	**9,568**		**$1,278,817,377**

SOURCES: Houston Airport System, 2013; Harris County Appraisal District, 2012; Houston-Galveston Area Council, 2012; Railroad Commission of Texas, 2013; Federal Aviation Administration, 2008

PREPARED BY: Ricondo & Associates, Inc., July 2014.

NORTH

0 0.25 0.5 1 Miles

P:\Dallas\Project\Houston Airport System\Ellington Airport\2014 Master Plan Update\06 - Land Use\3-KLP Exhibits\2015-05 Source File\Exhibit 6-2 Land Uses within the Area of Influence 2012

EXHIBIT 6-2

Land Uses within the Area of Influence, 2012

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Multifamily residences are clustered along Beltway 8, Space Center Boulevard, and Dixie Farm Road northeast, south, and west of EFD. Golf courses, parks, and recreation areas surround EFD, including Pasadena Municipal Golf Course, Bay Oaks Country Club, Bay Pointe Section 7 Park, Standing Stone Solstice Circle, Dad's Club Sports Park, Pine Brook Park, and Pine Brook Wetlands. Industrial land uses are clustered along Old Galveston Road and Genoa Red Bluff Road, and commercial land uses border I-45, Old Galveston Road, Clear Lake City Boulevard, and Space Center Boulevard.

Table 6-2 presents 2012 land uses and market values within the EFD AOI. As shown in Table 6-2, public/institutional uses account for the largest land area, with 41.7 percent (3,990 acres) of the total AOI. Public/institutional land uses encompass properties that are typically not on the tax rolls as they are owned by tax-exempt entities. EFD encompasses 2,362 acres, which accounts for 59 percent of the public/institutional land use. Publicly owned real estate is easier to control for land use purposes, with the exception of schools and places of worship. Five public, private, and early education schools are located within the AOI. They include Lomax Middle School, future Conklin Middle School, Grace Kidz World, Clear Lake Christian School, and North Pointe Elementary School. Since the last Master Plan for EFD was prepared in 2004, EFD has experienced a constant increase in demand related to the research and development sector with the presence of NASA and Boeing, as well as the continuous presence of military facilities.

There were 6,052 total residential dwelling units within the EFD AOI as of 2012, 4,390 single-family residences and 1,662 multifamily residences. In addition, 74 residential parcels are categorized as vacant by the HCAD. The average value of the single-family dwelling units is $186,278 and the average value of the multifamily dwelling units is $44,652. Property values increased overall between 2005 and 2012 as a result of real property value appreciation and not as a result of any significant revitalization of off-Airport properties.

A total of 723 acres of vacant/underdeveloped parcels are available within the AOI. In addition, 2,276 acres are classified as agricultural land use. A majority of the agricultural land use parcels are oil wells and tank farms owned by Exxon Corporation with farming animals.

Between 2005 and 2012, the number of agricultural, industrial, and residential vacant, acreage in the AOI decreased and commercial, multifamily, public/institutional, and single-family acreage increased. **Table 6-3** shows the property value and total land area comparisons between 2005 and 2012 from HCAD data.

Table 6-2: Land Uses within the Area of Influence, 2012

LAND USE TYPE	NUMBER OF PARCELS/ UNITS	TOTAL MARKET VALUE	AVERAGE PROPERTY VALUE	TOTAL AREA (ACRES)	PERCENT OF TOTAL AREA
Agricultural	35	$ 23,015,841	$ 10,111/acre	2,276	23.8%
Commercial	90	$ 175,056,243	$ 19.47/square foot	204	2.1%
Industrial	72	$ 81,275,806	$ 6.38/square foot	292	3.0%
Multifamily Residential	1,662	$ 74,211,183	$ 44,652/unit	68	0.7%
Office	19	$16,780,937	$ 12.63/square foot	30	0.3%
Parks/Open Space	148	$ 3,548,898	$ 19,643/acre	181	1.9%
Public/Institutional	136	$0	$0	3,990	41.7%
Residential Vacant	74	$ 2,336,399	$ 31,573/lot	28	0.3%
Single-family Residential	4,390	$ 817,761,623	$ 186,278/unit	885	9.3%
Transportation/ Utilities	92	$ 22,649,952	$ 0.58/square foot	890	9.3%
Vacant/Underdeveloped	145	$ 62,180,495	$ 1.97/square foot	723	7.6%
No Parcel Data		N/A	N/A	0	0.0%
Total	**6,863**	**$ 1,278,817,377**		**9,567**	**100.0%**

N/A = Not Available

SOURCE: Harris County Appraisal District, hcad.org. Accessed May 2015.
PREPARED BY: UrbanCore Collaborative, Inc., and Knudson, LP, May 2015.

Table 6-3: Comparison of Land Uses within the Area of Influence, 2005 and 2012

LAND USE TYPE	CHANGE FROM 2005 TO 2012 IN TOTAL MARKET VALUE	CHANGE FROM 2005 TO 2012 IN VALUE PER UNIT	CHANGE FROM 2005 TO 2012 IN TOTAL AREA (ACRES)	CHANGE FROM 2005 TO 2012 IN PERCENT OF TOTAL AREA
Agricultural	$ 10,221,091	$ 5,455/acre	(472)	(4.9%)
Commercial	$ 110,110,300	$ 8.46/square foot	71	0.7%
Industrial	$ 29,074,695	$ 3.92/square foot	(195)	(2.0 %)
Multifamily Residential	$ 47,641,580	$ 21,707/unit	21	0.2%
Office	$ 3,927,008	$ 2.80/square foot	0	(0.1%)
Parks/Open Space	$ 3,200,533	$ 13,309/acre	126	1.3%
Public/Institutional	($759,000)	($0.01/square foot)	1,695	17.7%
Residential Vacant	($ 990,591)	$ 5,168/lot	(99)	(1.0 %)
Single-family Residential	$ 123,623,162	$ 1,224/unit	104	1.1%
Transportation/Utilities	$ 19,800,164	($ 1.18/square foot)	853	8.9%
Vacant/Underdeveloped	$ 39,704,225	$ 0.56/square foot	131	1.4%
No Parcel Data	N/A	N/A	(2,236)	(23.4%)
Total	**$ 404,568,209**			

N/A = Not Available

SOURCE: Harris County Appraisal District, hcad.org. Accessed May 2015.
PREPARED BY: UrbanCore Collaborative, Inc., and Knudson, LP, May 2015.

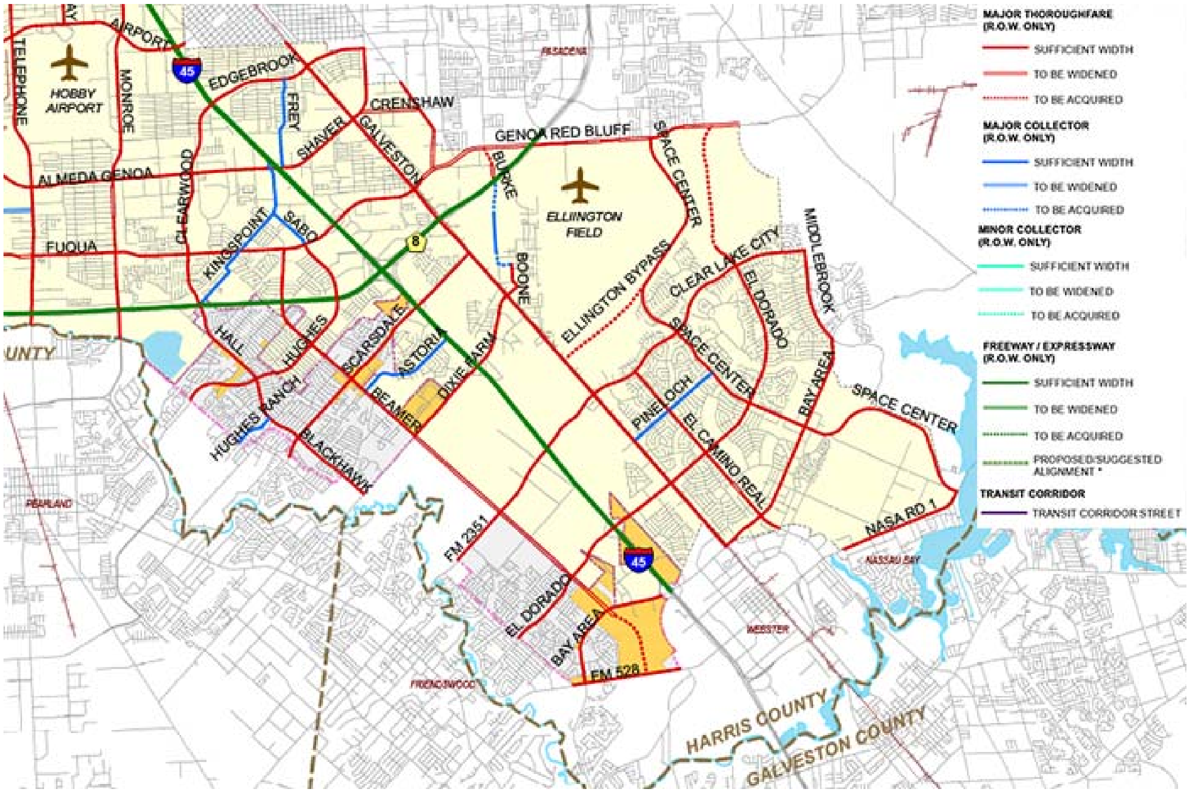
The change in land uses between 2005 and 2012 was not significant enough to suggest a particular trend in future development within the AOI. However, single-family and multifamily residential development grew. Table 6-3 shows the changes in market value, cost per unit, acreage, and percent of AOI from 2005 to 2012. The most significant value change was within the residential land uses. The number of single-family units increased by 639 units and the average market value for a single-family residential unit increased $1,224 per unit between 2005 and 2012 from $185,054 to $186,278. The number of multifamily units increased by 503 units and the average market value for multifamily residential land use increased $21,707 per unit between 2005 and 2012 from $22,944 to $31,573. Real property redevelopment or revitalization is not occurring in a meaningful focused manner; therefore, land use patterns are scattered and, absent a City of Houston economic development strategy or zoning to influence land use patterns, it can be assumed that the land uses in 2005 and 2012 will continue through 2030. Using economic tools to strategically realize a vision for off-Airport land uses and influence land use patterns could yield significant results in 5 to 10 years.

6.1.3 VEHICULAR ACCESS TO THE AIRPORT

EFD is accessible by five major thoroughfares from various directions: Old Galveston Road, Clear Lake City Boulevard, Dixie Farm Road, Scarsdale Boulevard, and Space Center Boulevard. All roadways within the AOI are maintained by the City of Houston with the exception of Old Galveston Road, which is maintained by the Texas Department of Transportation, and Beltway 8, which is maintained by the Harris County Tollroad Authority.

Exhibit 6-3 shows a portion of the 2014 Major Thoroughfare and Freeway Plan (MTFP) for the City of Houston, including the types of streets and connectivity surrounding EFD. Old Galveston Road, Clear Lake City Boulevard, Dixie Farm Road, Scarsdale Boulevard, and Space Center Boulevard are classified as major thoroughfares, and Astoria Boulevard and Boone Street are classified as major collectors.[1] Portions of Boone Street will need to be acquired from private landowners for vehicular connection to Beltway 8.

Exhibit 6-3: City of Houston Major Thoroughfare and Freeway Plan, 2014



SOURCE: City of Houston, *2014 Major Thoroughfare and Freeway Plan*.
PREPARED BY: City of Houston, 2014.

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[1] City of Houston, http://www.houstontx.gov/planning/mobility/MTFP.html (accessed March 2015).

6.1.3.1 Old Galveston Road Corridor

Old Galveston Road is the primary north/south corridor used to access EFD. It is a Texas state highway and is maintained by the Texas Department of Transportation. Old Galveston Road consists of five lanes, with two lanes in each direction and a continuous left turn lane in the center of the highway. It is located approximately 1 mile east of and parallel to I-45. Old Galveston Road serves as an alternate connector from Houston to Galveston and is heavily traveled during peak hours and on the weekends, especially during the summer. Old Galveston Road also serves as an evacuation route for Galveston County residents during a major catastrophe or storm evacuation. As a rail line runs parallel to and east of Old Galveston Road, a majority of the development is along the western side of the road. The major land uses along Old Galveston Road are commercial and industrial. Improvements recommended to beautify the roadway include access management tools, such as raised landscaped medians, sidewalks, better street lighting, and reduced commercial signage.

6.1.3.2 Clear Lake City Boulevard Corridor

Farm to Market Road 2351 is known locally as Clear Lake City Boulevard. The major land uses along Clear Lake City Boulevard are commercial and single-family residential, along with some agricultural land owned by Exxon Mobile. Clear Lake City Boulevard is a four-lane divided boulevard with a grassy median east and west of Old Galveston Road. A majority of the commercial land use is located at the intersection of Old Galveston Road and Space Center Boulevard. Commercial development will continue west along the corridor as I-45 roadway improvements between Beltway 8 and Bay Area Boulevard are completed. Clear Lake City Boulevard serves as an east-west connector to I-45 for many residents of Clear Lake and Friendswood.

6.1.3.3 Dixie Farm Road Corridor

Farm to Market Road 1959, known locally as Dixie Farm Road, is 1.3 miles (2.1 km) long. It passes from I-45 to the EFD entrance on Old Galveston Road just to the northeast. The land uses surrounding the Dixie Farm Road corridor are mixed with commercial, industrial, multifamily residential, public/ institutional, and office. Dixie Farm Road was built and is maintained by the Texas Department of Transportation. Dixie Farm Road is a five-lane highway with two lanes in each direction and a continuous left turn lane in the center of the roadway. Recommendations to beautify the roadway include access management tools, such as raised landscaped medians, sidewalks, better street lighting, and reduced commercial signage.

6.1.3.4 Scarsdale Boulevard Corridor

A majority of the property along Scarsdale Boulevard consists of single-family residential and vacant or underdeveloped land. The single-family residential development was initiated in 2006. Scarsdale Boulevard is a two-lane, open-ditch road that connects Old Galveston Road to I-45. No further development is anticipated because of constraints within properties along the southern portion of the roadway.

6.1.3.5 Space Center Boulevard Corridor

Space Center Boulevard is a four-lane, median-divided thoroughfare of steel-reinforced concrete with signal controlled traffic that traverses 7 miles northwest from NASA Road 1 on Clear Lake's northern shore. The road structure is curbs with gutters that drain to underground storm sewers funneling to outfalls at flood-control channels. Space Center Boulevard serves as another route to help Galveston Bay and Clear Lake area residents leave the area during hurricane evacuations. Some commercial and multifamily land uses are located along the northern portion of EFD. A majority of the adjacent land remains vacant and is not developable because of the presence of pipelines.

6.1.4 LINKAGES TO POTENTIAL COMMUTER RAIL

The Metropolitan Transit Authority of Harris County (METRO) serves the EFD area with regular bus service connecting downtown and many other parts of the City. **Exhibit 6-4** depicts *METRO's Re-Imagined Bus Network*. This new bus network is an innovative system of routes designed on the basis of where people want to go today and tomorrow. The routes work together to create a network, with better connections, weekend service, and much more.[2]

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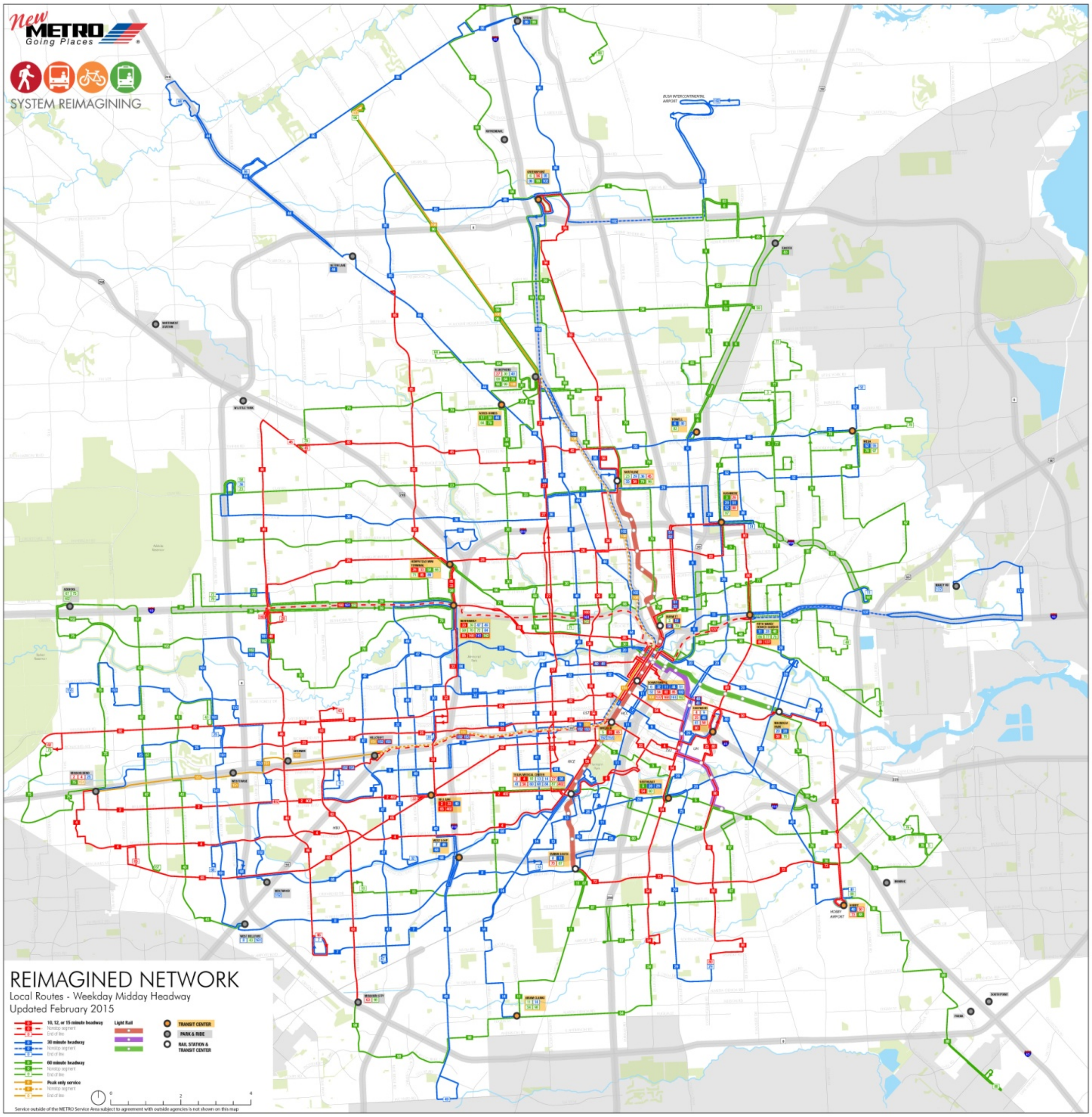
[2] METRO's New Bus Network www.ridemetro.org (accessed May 2015).

Exhibit 6-4: METRO's Re-Imagined Bus Network



SOURCE: www.ridemetro.org

PREPARED BY: The Metropolitan Transit Authority of Harris County, February 11, 2015.

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6.2 Constraints and Opportunities

Off-Airport private properties present an opportunity for compatible redevelopment. The AOI includes the five principal and major thoroughfares that provide primary vehicular access to EFD and has the potential to be redeveloped over time, including the future commuter rail corridor along Old Galveston Road. Currently, the land uses in the AOI are mixed, providing a variety of services and everyday shopping needs. Opportunities to improve the current land uses over the next 5 to 10 years are evident, but the thoroughfare corridors cannot be redeveloped with predictable land use outcomes without an area-wide City initiative of incentives that trigger revitalization and, in turn, add value to the Airport environment. **Exhibit 6-5** identifies current vacant tracts in red with no known improvements for development in the AOI.

6.2.1 INCOMPATIBLE AIRPORT LAND USE

The development of land uses that are not compatible with Airport operations and aircraft noise is a growing concern across the country. In addition to aircraft noise, other issues, such as safety and other environmental impacts on sensitive land uses around airports, need to be considered when addressing the overall issue of land use compatibility. Although several federal programs include noise standards or guidelines as part of their funding eligibility and performance criteria, the primary responsibility for integrating airport considerations into the local land use planning process rests with local governments. The objectives of compatible land use planning are to encourage the development of land uses that are generally considered to be incompatible with airports (such as residences, schools, and places of worship) to locate away from airports and to encourage the development of land uses that are more compatible with airport operations (such as industrial and commercial uses) to locate around airports. Incompatible land uses around an airport can affect the safe and efficient operation of aircraft. Incompatible land uses can include wildlife-attracting land uses, such as wetlands and landfills, cell towers, and antennae transmitting signals that interfere with radio transmissions or navigational aids; lights that may be disorienting to a pilot; and tall structures, including towers and construction cranes that may affect an airport's airspace.[3]

The first step in examining land use compatibility surrounding an airport is to identify whether incompatibilities currently exist and whether or not adequate measures are in place to prevent future incompatibility. The FAA has established safety criteria related to the height of objects in proximity to airports, and in the approaches to airports, that affect operations on the ground and in the air. Some areas on the ground around an airport are more prone to high noise levels and should be protected from incompatible uses. Additionally, the City of Houston has established a Height Hazard Ordinance in the vicinity of the three HAS airports, which specifies allowable heights for specific parcels based on the controlling airspace surface.

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[3] Federal Interagency Committee on Aviation Noise. http://www.fican.org (accessed March 2015).

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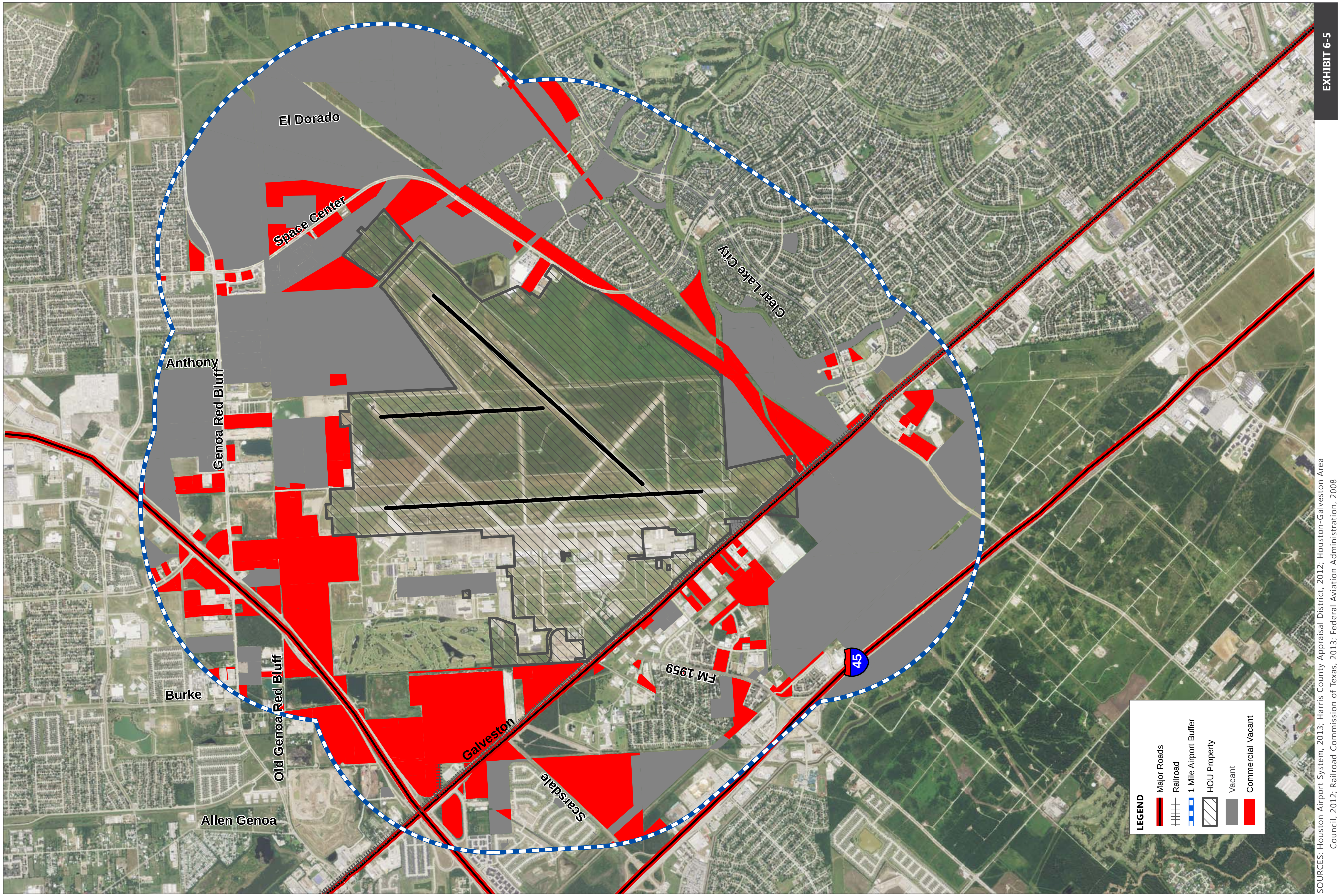
EXHIBIT 6-5

Development Opportunities in the Area of Influence



SOURCES: Houston Airport System, 2013; Harris County Appraisal District, 2012; Houston-Galveston Area Council, 2012; Railroad Commission of Texas, 2013; Federal Aviation Administration, 2008

PREPARED BY: Ricondo & Associates, Inc., July 2014.

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The day-night average sound level (DNL) is the standard federal metric used to determine cumulative exposure of individuals to noise. DNL is based on sound levels measuring the relative intensity of sound, or decibels (dB), on the "A" weighted scale (dBA). In 1981, the FAA formally adopted DNL as its primary metric to evaluate cumulative noise effects on people caused by aviation-related activities. This scale most closely approximates the response characteristics of the human ear to sound; the higher the number on the scale, the louder the sound. DNL represents noise exposure events over a 24-hour period. To account for human sensitivity to noise during nighttime hours, 10 p.m. to 7 a.m., noise events occurring during these hours receive a "penalty" when DNL is calculated. Each nighttime noise event is measured as if 10 daytime noise events occurred.

To more consistently and easily describe and compare the noise environment consisting of numerous single events that vary in duration and magnitude over long periods of time, the U.S. EPA developed a single number descriptor (DNL). The DNL metric is used by the FAA to quantify aircraft noise exposure in the vicinity of an airport. Noise contours of specific DNLs are developed using the FAA's Integrated Noise Model (INM). Airport-specific data (i.e., average daily operations, aircraft fleet mix, runway use, flight corridors and use, departure destinations and day/night use) are used in the INM to develop the contours depicting noise exposure in the vicinity of an airport.

Noise contours are a series of lines superimposed on a map of the airport environs. These lines represent various DNLs (typically DNL 65, 70, and 75). DNL noise contours are used for several purposes:

- Noise contours highlight existing or potential areas of significant aircraft noise exposure (as defined by the FAA).
- Noise contours are used to assess the relative aircraft noise exposure of different runway or flight corridor alternatives.
- Noise contours provide guidance to political jurisdictions in developing land use control measures. These measures include zoning ordinances, subdivision regulations, building codes, and airport overlay zones.[4]

The FAA considers the areas exposed to DNL 65, 70, and 75 to be the most affected by aircraft-generated noise. Beyond the DNL 65 noise exposure area, noise is most noticeable in areas below established flight corridors.

According to the FAA, DNL 65 and above are incompatible with residential communities. Communities in affected areas may be eligible for mitigation programs, such as soundproofing.

Table 6-4 presents a land use compatibility matrix that shows the types of land uses allowed within areas exposed to DNL 65, DNL 70, and DNL 75.

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[4] Federal Aviation Administration, Part 150, "Land Use Compatibility," http://www.faa.gov/airports/environmental/airport_noise (accessed August 2014).

Table 6-4 (1 of 2): Land Use Compatibility

	YEARLY DAY-NIGHT AVERAGE SOUND LEVEL (L_{DN}) IN DECIBELS					
	BELOW 65	**65-70**	**70-75**	**75-80**	**80-85**	**OVER 85**
RESIDENTIAL						
Residential, other than mobile homes and transient lodgings	Y	N(1)	N(1)	N	N	N
Mobile home parks	Y	N	N	N	N	N
Transient lodgings	Y	N(1)	N(1)	N(1)	N	N
PUBLIC USE						
Schools	Y	N(1)	N(1)	N	N	N
Hospitals and nursing homes	Y	25	30	N	N	N
Churches, auditoriums, and concert halls	Y	25	30	N	N	N
Governmental services	Y	Y	25	30	N	N
Transportation	Y	Y	Y(2)	Y(3)	Y(4)	Y(4)
Parking	Y	Y	Y(2)	Y(3)	Y(4)	N
COMMERCIAL USE						
Offices, business and professional	Y	Y	25	30	N	N
Wholesale and retail—building materials, hardware and farm equipment	Y	Y	Y(2)	Y(3)	Y(4)	N
Retail trade—general	Y	Y	25	30	N	N
Utilities	Y	Y	Y(2)	Y(3)	Y(4)	N
Communication	Y	Y	25	30	N	N
MANUFACTURING AND PRODUCTION						
Manufacturing, general	Y	Y	Y(2)	Y(3)	Y(4)	N
Photographic and optical	Y	Y	25	30	N	N
Agriculture (except livestock) and forestry	Y	Y(6)	Y(7)	Y(8)	Y(8)	Y(8)
Livestock farming and breeding	Y	Y(6)	Y(7)	N	N	N
Mining and fishing, resource production and extraction	Y	Y	Y	Y	Y	Y

Table 6-4 (1 of 2): Land Use Compatibility

YEARLY DAY-NIGHT AVERAGE SOUND LEVEL (L_{DN}) IN DECIBELS

	BELOW 65	65-70	70-75	75-80	80-85	OVER 85
RECREATIONAL						
Outdoor sports arenas and spectator sports	Y	Y(5)	Y(5)	N	N	N
Outdoor music shells, amphitheaters	Y	N	N	N	N	N
Nature exhibits and zoos	Y	Y	N	N	N	N
Amusements, parks, resorts and camps	Y	Y	Y	N	N	N
Golf courses, riding stables and water recreation	Y	Y	25	30	N	N

Numbers in parentheses refer to notes.

* The designations contained in this table do not constitute a Federal determination that any use of land covered by the program is acceptable or unacceptable under Federal, State, or local law. The responsibility for determining the acceptable and permissible land uses and the relationship between specific properties and specific noise contours rests with the local authorities. FAA determinations under part 150 are not intended to substitute federally determined land uses for those determined to be appropriate by local authorities in response to locally determined needs and values in achieving noise compatible land uses.

Key to Table 6-4:

SLUCM = Standard Land Use Coding Manual.

Y (Yes) = Land Use and related structures compatible without restrictions.

N (No) = Land Use and related structures are not compatible and should be prohibited.

NLR = Noise Level Reduction (outdoor to indoor) to be achieved through incorporation of noise attenuation into the design and construction of the structure.

25, 30, or 35=Land use and related structures generally compatible; measures to achieve NLR of 25, 30, or 35 dB must be incorporated into design and construction of structure.

Notes for Table 6-4:

Where the community determines that residential or school uses must be allowed, measures to achieve outdoor to indoor Noise Level Reduction (NLR) of at least 25 dB and 30 dB should be incorporated into building codes and be considered in individual approvals. Normal residential construction can be expected to provide a NLR of 20 dB, thus, the reduction requirements are often stated as 5, 10 or 15 dB over standard construction and normally assume mechanical ventilation and closed windows year round. However, the use of NLR criteria will not eliminate outdoor noise problems.

Measures to achieve NLR 25 dB must be incorporated into the design and construction of portions of these buildings where the public is received, office areas, noise sensitive areas or where the normal noise level is low.

Measures to achieve NLR of 30 dB must be incorporated into the design and construction of portions of these buildings where the public is received, office areas, noise sensitive areas or where the normal noise level is low.

Measures to achieve NLR 35 dB must be incorporated into the design and construction of portions of these buildings where the public is received, office areas, noise sensitive areas or where the normal level is low.

Land use compatible provided special sound reinforcement systems are installed.

Residential buildings require an NLR of 25.

Residential buildings require an NLR of 30.

Residential buildings not permitted.

SOURCE: e-CFR Part 150 – Airport Noise Compatibility Planning, May 22, 2015

PREPARED BY: Knudson, LP, May 27, 2015

6.2.2 ISSUES AFFECTING OFF-AIRPORT DEVELOPMENT

With the development opportunities in the EFD AOI, several impediments may restrict or alter the development pattern. **Exhibit 6-6** identifies the multiple gas transmission and hazardous liquid pipelines located around EFD and physical constraints for future development in the EFD AOI. No evidence of hazardous material locations or sexually oriented businesses was found that could impede development. Floodplain issues should be considered around the approaches from Space Center Boulevard and Clear Lake City Boulevard. HAS should consider conducting a wetlands assessment on and around EFD to document the wetlands and plan for remediation. Land located within the 100-year floodplain, as shown on Exhibit 6-6, could be acquired by the Harris County Flood Control District or the City to create park and open space compatible with Airport development within the AOI. In addition to pipelines, a high transmission Houston Lighting & Power Corporation parcel runs parallel to I-45. A majority of the agricultural land consists of oil fields owned by Clear Dorado Land, Enterprise Crude Pipeline, Exxon Corporation, and Kinder Morgan.

6.2.3 OPPORTUNITIES FOR DEVELOPMENT

6.2.3.1 Aerospace Park

EFD is situated in the center of one of the top aerospace parks in the United States, consisting of more than 50 aerospace contractors and companies, such as The Boeing Company and Lockheed Martin. EFD is strategically positioned to help make Houston a leader in space commerce. HAS has already gained FAA certification for the Houston Spaceport at EFD and is recruiting potential commercial aerospace companies to establish operations onsite.

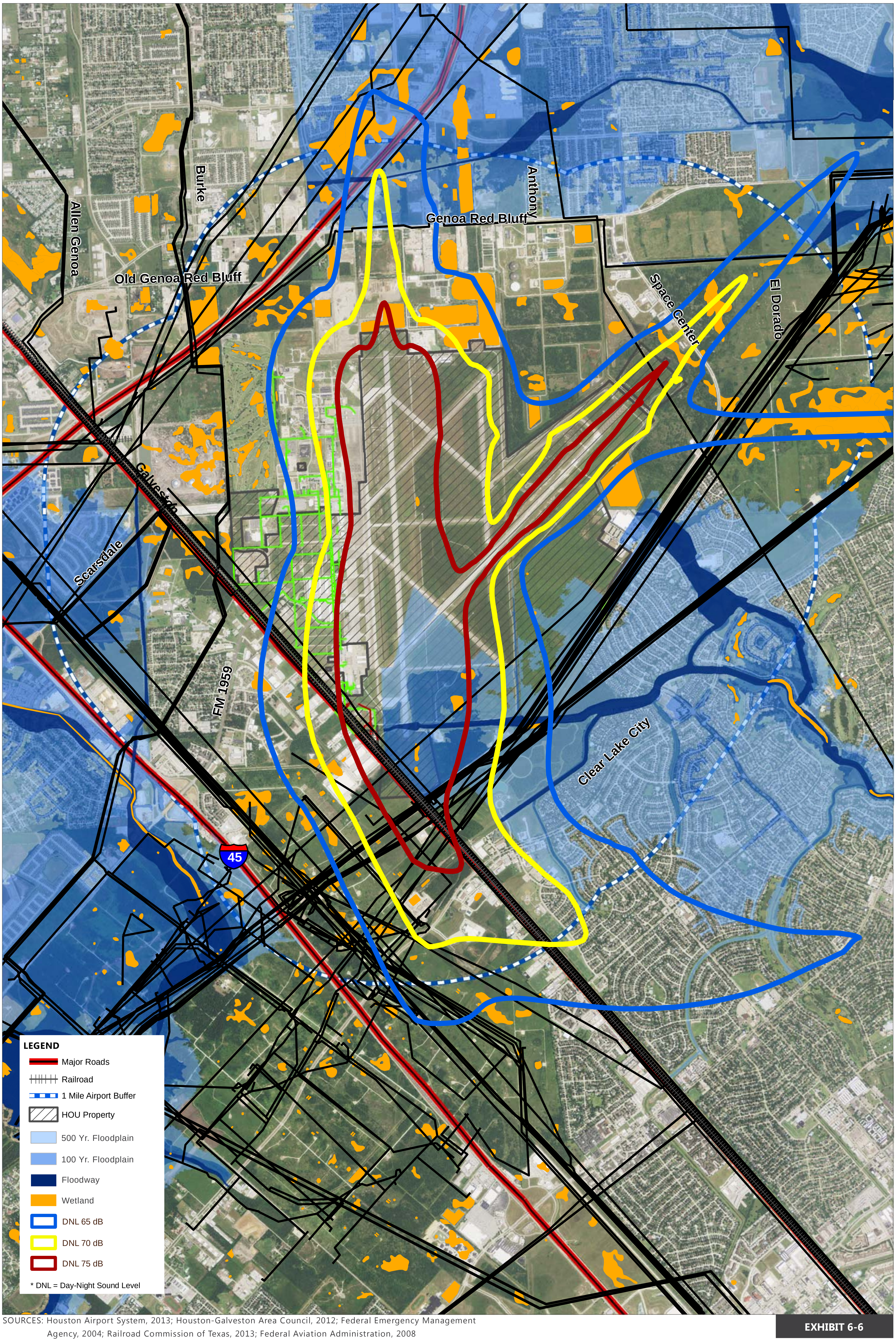
6.2.3.2 Transportation Accessibility

As described in previous chapters of this master plan update, EFD is readily accessible. Three (3) major highways are within 1 mile of EFD, while a joint-use rail line, accommodating both the Union Pacific Railroad and the Burlington Northern Railroad operations, borders the west side of the Airport. Additionally, just a few miles away are the deep-water container and bulk liquid terminals of the ports of Houston, Texas City, and Galveston, as well as Barbours Cut and Bayport container terminals. The ports of Houston and Galveston also accommodate a growing cruise industry.

6.2.3.3 On- and Off-Airport Land

EFD has more than 600 acres of airfield-accessible land that could be developed. Under the Home Rule Charter, the City has the ability to incentivize development in these areas.

Both on-Airport and off-Airport commercial development should be explored. More than 723 acres of vacant or underdeveloped land uses are available for development within the AOI. With the changing opportunities at EFD, such as the proposed spaceport, NASA research, relocation of the Flight Museum from Galveston to EFD, the presence of research institutions such as the University of Texas Medical Branch (UTMB), and many parallel aviation-related commercial needs, there is a potential need for small, medium, and large commercial developments on and off Airport locations.



SOURCES: Houston Airport System, 2013; Houston-Galveston Area Council, 2012; Federal Emergency Management Agency, 2004; Railroad Commission of Texas, 2013; Federal Aviation Administration, 2008

PREPARED BY: Ricondo & Associates, Inc., July 2014.

EXHIBIT 6-6

Development Constraints

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Off-Airport private properties are good candidates for redevelopment. The current land uses of these properties are mixed, but are dominated by agricultural and public/institutional uses. The available vacant land can directly be incentivized by the City of Houston for future expansion and commercial development around the Airport. A majority of the vacant land is along Scarsdale Boulevard, Space Center Boulevard, Old Galveston Road, and Beltway 8. The Space Center Boulevard corridor is a prime area for commercial, industrial, and office development. The vacant parcels along Beltway 8 have good access to IH-45 as the last free exit ramp is located just north of Old Galveston Road.

A relatively high percentage of vacant land and low real property values surrounds EFD, indicating that ample redevelopment opportunities exist that could align with the integration of spaceport operations at EFD. The targeted approach of City incentives and CIP improvements would be instrumental in driving the revitalization of off-Airport properties.

The majority of vacant land is located on the west and northwest sides of the Airport property along Beltway 8. This vacant lands offer the opportunity for commercial and office development on large parcels. The large amount of undeveloped land, combined with the proximity to major highways; a rail line; the Ports of Houston, Texas City, and Galveston; EFD; and major residential and commercial areas, positions the AOI ideally for future commercial and office development. Economic incentives should be strategically applied to encourage Airport compatible land uses and spaceport-related development.

There are too many small properties and too many multiple property owners for revitalization to occur one property at a time. Seeking public-to-public partnerships across political jurisdictions is as important as public-to-private partnerships for off-Airport redevelopment and is critical to the success of such redevelopment.

6.2.3.4 Local Gateway

EFD is a gateway to the Clear Lake area, and should not only create a good first impression on travelers arriving at EFD, but also provide a positive image of the region as a whole. Landscaping and building materials should reflect EFD’s local and regional setting and should introduce travelers to regional amenities, such as access to the Texas Gulf Coast, the cruise industry at the Ports of Houston and Galveston, NASA facilities, the oil and gas hub, and the bayous and native sanctuaries in the area. Major Airport signage and area-wide designed landscape monumentation features should be created at each major thoroughfare corridor, announcing arrival at EFD. This family of landscape architecture monumentation could be in the form of signage as well as public art, similar to that being installed at HOU and IAH. The dual design opportunity would be conducive to the nearby residential community. Residential neighborhoods surrounding EFD should also be incorporated in the overall Master Plan to promote the compatible residential development characteristics of streets entering the adjacent neighborhoods, and to promote the sustainable protection of those areas.

Understanding the existing land uses around each thoroughfare is valuable in identifying opportunities for redevelopment. The creation of new arrival gateways from each major thoroughfare to EFD will require the various stakeholders, including multiple property owners, to participate in an area-wide economic development initiative along each thoroughfare to facilitate the renaissance of the area.

Exhibit 6-7 identifies three intersections recommended for gateways, wayfinding, streetscaping, and/or public art.

A variety of opportunities and constraints that affect development at EFD and in the immediate environs have been discussed in this section. It is apparent that a number of constraints exist, including pipeline and utility corridors, and location in the 100-year floodplain. However, the opportunities presented outweigh the constraints. The AOI has excellent transportation connectivity essential for commercial, industrial, and office land uses. The topography is flat, which translates to low site development costs. Given the opportunities and constraints discussed in this section, an overall land use plan would be an effective tool to help stimulate and encourage development within the AOI.

6.2.4 ECONOMIC DEVELOPMENT INCENTIVES AVAILABLE UNDER STATE OR LOCAL LAW

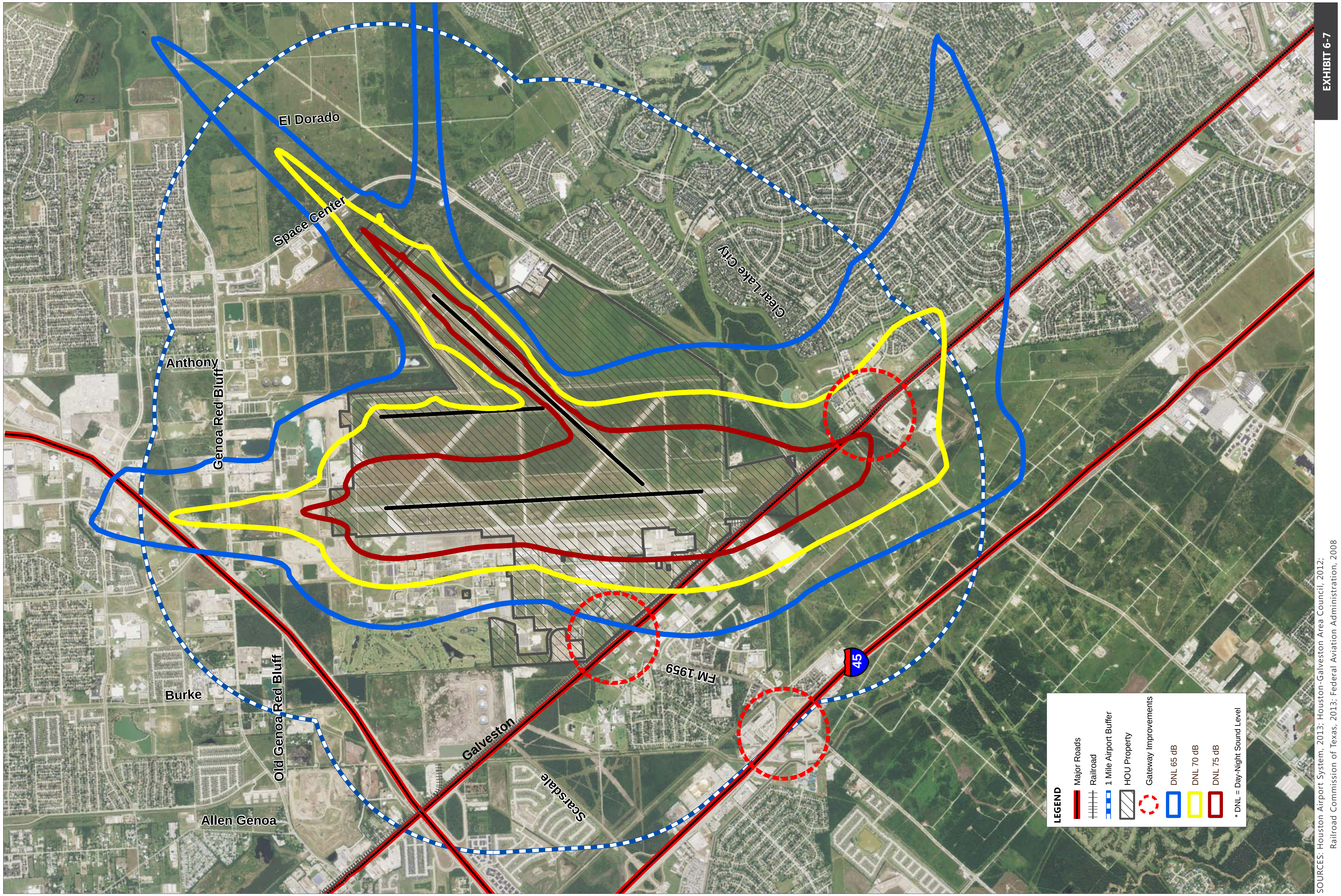
After a review of current conditions at EFD and the opportunities for spaceport development, specific economic development strategies should be pursued to facilitate and guide off-Airport revitalization. The proposed strategies include an area-wide approach to creating sustainable development that supports the new spaceport businesses and also benefits the surrounding community. The ability to incentivize redevelopment that is compatible with EFD is a powerful tool to achieve the goals of the Master Plan Update, since the City of Houston does not have a zoning ordinance. The tools should also be used to guide the renaissance of EFD and its environs.

Special incentives, such as a Tax Increment Reinvestment Zone (TIRZ) or an area Chapter 380 creation (see description in section 6.2.4.1), should be specifically drafted to facilitate revitalization of the available EFD properties and the corridors providing access to EFD, as well as provide buffering and beautification for the existing neighborhoods. Various economic development incentives are available to encourage compatible development and redevelopment of private property within the AOI. These incentives should only be used when the proposed land use is compatible with and complementary to EFD and incentives should be strategically applied to encourage appropriate land uses, such as offering incentives with greater returns to encourage compatible land uses versus incompatible land uses, including the ability to implement the spaceport vision. The economic development strategies should include onsite and offsite beautification elements as a component of the public-private partnerships between the private sector and the City of Houston. If a developer is offered incentives, the incentives should include extending improvements beyond the project site boundaries. Infrastructure should be required offsite and onsite to ensure that the City of Houston’s overall vision can be implemented strategically, providing catalytic revitalization opportunities for other City projects.

The economic incentives that may be used at EFD are discussed in the following subsections.

EXHIBIT 6-7

Proposed Gateway Locations



SOURCES: Houston Airport System, 2013; Houston-Galveston Area Council, 2012; Railroad Commission of Texas, 2013; Federal Aviation Administration, 2008

PREPARED BY: Ricondo & Associates, Inc., July 2014.

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6.2.4.1 Chapter 380/381 Texas Local Government Code

Chapter 380 agreements are an economic development tool for cities allowed under Chapter 380 of the Texas Local Government Code. Chapter 381 of the Texas Local Government Code extends the same powers to counties. The City of Houston has extensively used Chapter 380 agreements over the last 4 years. Harris County has also initiated a Chapter 381 program. These two sections of the State law grant authority to allow cities and counties to provide contractual economic incentives, consisting of loans and public grant funds, for development and redevelopment of facilities and services. Developers receive cash reimbursement or other considerations based on the newly created increment generated by sales or real property values.

Under Mayor Annise Parker, the City has pioneered the use of Chapter 380 agreements to incentivize over $2 billion in new real property values since 2010, generating over $13 million annually in new City tax revenue. These agreements can be used for public or private improvements, but the City has elected to only allow Chapter 380 agreements for public improvements. The City has used Chapter 380 agreements for asbestos abatement and demolition, which will be needed for the multifamily dwelling units constructed in this immediate area in the 1970s. These agreements can be used for remediation, water, sewer, drainage, paving, parks, and streetscapes in support of private development. These agreements also can be established for 10- to 40-year terms or longer, as determined by the City Council. The terms of a Chapter 380 Agreements are driven by the City Council that outline the eligible projects and total value of the proposed projects outlined in the developer agreement. These agreements are very flexible and would be ideal for appropriate redevelopment along the major thoroughfare corridors to support the revitalization of off-Airport land uses. These City-approved agreements can be used to incentivize hotel/convention facilities, housing, and commercial, retail, and industrial properties around EFD. In October 2013, the City created its first area Chapter 380 Program to mitigate blight in the Westchase District from declining multifamily developments and aging retail establishments. The Houston City Council adopts ordinances creating the Chapter 380 agreements, which can be adopted for an area or a single property or development.

The City Council determines terms and levels of funding up to 100 percent of the funds available. The City can use this incentive to drive the vision for off-Airport development that would complement EFD.

6.2.4.2 Municipal Management Districts

Municipal Management Districts (MMDs), under Texas Local Government Code Section 375.001, are created by the Texas State legislature by special legislation. An MMD is a geographic area defined in the creation documents at the time the MMD is created. The documents creating the MMDs outline the project plan, the eligible project improvements, and the proposed tax or assessment, as applicable. The MMD provides for an overlapping tax or assessment on the commercial real property located within the MMD. This overlapping tax/assessment is used to finance facilities, infrastructure, and services beyond those already provided by the county or municipality. The improvements may be paid for by a combination of self-imposed property taxes, special assessments and impact fees, or by other charges against property owners within the MMD.

6.2.4.3 Neighborhood Empowerment Zones

Texas Local Government Code, Section 378.002, allows creation of a Neighborhood Empowerment Zone (NEZ) as a designated area where municipalities can offer economic incentives that promote investment and redevelopment. According to Chapter 378 of the Texas Local Government Code, an NEZ is created for at least one of the following purposes: the creation and rehabilitation of affordable housing (including manufactured housing), economic development opportunities, or an increase in the quality of social services, education, or public safety.

An NEZ is beneficial in revitalizing areas within a municipality that are in need of physical, economic, and social rehabilitation. An NEZ provides greater flexibility and power to remove unwanted elements from the area and promote new housing, business, and social services than a local government has in and of itself.

Specifically, within an NEZ, a municipality may:

- Waive or adopt fees for construction of new buildings, including inspection and impact fees.
- Enter into agreements, not to exceed 10 years, for refunds of municipal sales tax for sales made within the NEZ.
- Abate municipal property taxes, subject to a time limit; and set performance standards to encourage the use of alternative building materials that will benefit the environment through reduced maintenance needs and/or energy consumption.

To form an NEZ within Texas, a municipality must adopt a resolution stating the proposed purpose of the NEZ, a description of its boundaries, and a finding by the governing city that the NEZ will benefit the public health, safety, and welfare of the community.

Any tax abatements in the NEZ must conform to the guidelines of Title 2, Subtitle B, Chapter 312 of the Texas Tax Code, the Property Redevelopment and Tax Abatement Act. Individual municipalities may have additional eligibility requirements to establish NEZs or additional requirements for NEZs to qualify for particular incentives.

These incentives should be explored for the areas around EFD, specifically those with declining surrounding property values and opportunities for Airport-related compatible land uses.

Through the NEZ program, building permit fee waivers, release of city liens, municipal property tax abatements, and sales tax refunds can be granted to homeowners, investor-owners, and developers proposing new construction projects or rehabilitation projects within the NEZ.

6.2.4.4 Public Improvement Districts

Establishment of a Public Improvement District (PID), under Texas Local Government Code Section 372.001, provides for the cost of improvements benefiting a commercial area to be spread equally among all properties through the use of an overlapping assessment. City Council action is required to establish a PID.

PIDs offer cities and counties a means for improving their infrastructure to promote economic growth in an area. The Public Improvement District Assessment Act allows cities and counties to levy and collect special assessments on properties that are within the city or its extraterritorial jurisdiction. Additional financing options are available to certain large counties.

PIDs may be formed to develop, rehabilitate or expand affordable housing; create water, wastewater, health and sanitation, or drainage improvements; street and sidewalk improvements; mass transit improvements; parking improvements; library improvements; park, recreation and cultural improvements; landscaping and other aesthetic improvements; art installation; creation of pedestrian malls or similar improvements; supplemental safety services for the improvement of the district, including public safety and security services; or supplemental business-related services for the improvement of the district, including advertising and business recruitment and development.[5] The terms of a PID can be for a defined period of time or the PID can be terminated early upon satisfactorily paying off any obligations, including debt service or direct pay to a developer. The PID Plan can be amended as deemed necessary by the City Council.

6.2.4.5 Tax Abatements

A project may be eligible for tax abatement, under Texas Tax Code Section 312.002, if it relates to a business or manufacturing facility, research facility, distribution center, regional service facility, basic industry, or other facility “deemed essential to the City’s growth.” A project may be eligible for the abatement of up to 100 percent of taxes for as long as 10 years, depending upon the amount of expenditure and/or the number of employees affected. Reinvestment in an existing project or expansion of existing facilities may also be eligible for tax abatement.

6.2.4.6 Tax Increment Reinvestment Zones

A TIRZ is allowed under Section 311.002 of the Texas Tax Code. The City of Houston has created 25 TIRZs since 1990. A TIRZ is ideal for geographically large economic development districts with multiple property owners and where public improvements are the primary improvement need. The TIRZ is created by the City Council and enables the City to offer incentives to redevelop an area in a manner conducive to the vision of the City improving the overall area, creating higher property values, and increasing sales tax collection. A TIRZ can be used for onsite and offsite public improvements and the term of the TIRZ can be as long as the City deems reasonable to revitalize a geographic area. These zones have been incredibly successful in transforming certain neighborhoods and communities in the Houston region. The newly created tax increment from the TIRZ is used to reimburse the developer. The developer advances all funds and reimbursement is based on performance. The eligible costs of the improvements within the TIRZ are repaid by the contributions of future tax revenues of the participating entities that levy taxes on affected properties. Once the City initiates tax increment financing, counties and junior colleges may also participate in the tax increment

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[5] TexasAhead, http://texasahead.org (accessed May 2015).

financing program. The TIRZ is not a tool for providing incentives for private development improvements, but can be leveraged with the Chapter 380/381 programs that can provide incentives for private improvements.

6.2.4.7 Texas Enterprise Zone Program

The Texas Enterprise Zone Program (TEZ), under Texas Local Government Code Section 2303.002, is an economic development tool for local communities to partner with the State of Texas to promote job creation and capital investment in economically distressed areas of the State. Companies may qualify for refunds of State sales tax paid on eligible items used at the qualified business site. The total amount of any refund is predicated on the investment amount and the number of jobs created/retained at the qualified business site. To qualify, companies must commit that at least 25 percent of their new employees will meet economically disadvantaged or enterprise zone residence requirements if the company is locating or expanding into one of the State's enterprise zones. If the company is not locating in one of the State’s enterprise zones, then it must commit that at least 35 percent of its new employees will meet economically disadvantaged or enterprise zone residence requirements.[6]

6.2.4.8 Texas Product Development/Small Business Fund

The Texas Product Development/Small Business Fund is a State sponsored fund that provides financing to aid in the development, production, and commercialization of new or improved products within the State and provides financing to foster and stimulate the development of small and medium-sized businesses in Texas. Special funding preference is given to emerging technologies, including semiconductors, nanotechnology, biotechnology and biomedicine, renewable energy, and aerospace. Additional preference is given to applicants who have acquired other sources of financing, have formed companies in Texas, and who are receiving assistance from designated State small business development centers or through the Small Business Innovation Research Program. Products appropriate for the fund are inventions, devices, techniques, or processes that have advanced beyond the theoretical stage and are ready for immediate commercial application. The fund is self-supporting, paid for by the program loan participants’ repayments. Thus, the loan repayments are to be structured to fully pay the costs of issuance and program administration. Pursuant to Government Code 489.213 (c), loan participants must provide appropriate security or collateral, equity interest, and the rights and remedies of the Product Development and Small Business Incubator Board and bank in the event of a default on the loan.[7]

6.3 Recommended Off-Airport Development Strategy

The recommended strategies are intended to create an overall sustainable Airport-related development strategy using the most recent environmental technologies and to establish an international identity for EFD

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[6] TexasAhead, http://texasahead.org (accessed March 2015).

[7] Texas Coalition for Capital, http://www.texascapital.org (accessed March 2015).

and the surrounding areas. The following strategies could be implemented to encourage revitalization of the area:

- Conduct multidepartment/agency meetings on HAS plans to educate and brainstorm on the needed improvements to support the region's three airports.
- Coordinate CIP improvements to enhance public infrastructure, including intersection improvements, flood abatement, beautification, and wayfinding.
- Develop a multijurisdictional strategy with Harris County, as well as private developers, to leverage public and private economic development participation to accelerate redevelopment on and off Airport properties to directly benefit the investment in EFD and further the vision of HAS for the region.
- Establish incentives to encourage the development of hotels and other airport-compatible commercial development along all thoroughfares serving EFD.
- Provide developer incentives and economic development tools, such as a TIRZ, area Chapter 380 agreement, NEZ, or other tools, to promote and preserve compatible development in the areas surrounding EFD.
- Preserve the ability to provide commuter rail transit access to the Airport as part of METRO expansion and encourage compatible development and transit service.

Economic development is not just a real estate marketing activity to entice businesses to relocate into a community or to EFD. Today, economic development is truly about enhancing quality of life. Such enhancements include increasing per capita wages, training a workforce, and enhancing infrastructure that, in turn, protects and enhances the area's natural resources. Economic development encompasses not only business expansion and retention, but also addresses tourism, community development, quality of life, workforce development, and environmental protection. Off-airport compatible land uses include hotels, offices, retail, and restaurants. The estimated increases in passenger miles traveled and growth of the proposed spaceport would generate the need for additional services, such as hotels, restaurants, and other related Airport compatible land uses.

Measuring progress is an important element of a successful revitalization strategy. Creating a scoreboard that measures the City's programs (including measuring property value increases, the benefits of sales tax growth, and increased occupancy for area hotels) results in a tool that would enable the City to quantify success and demonstrate that public policies have been effective or would enable the City to create modifications to the incentives to create a more lucrative program. Some incentives will be better than others, depending on the proposals received, and many incentives can be used in combination. They should be designed to help achieve the vision for redevelopment of the corridors used to access EFD and should be implemented efficiently and effectively. The private sector can be a true partner in both off-Airport and on-Airport improvements. Some City incentives relate to private improvements, such as gap financing for a hotel or building. This type of incentive has not typically been used in Houston, but is allowed under State law.

The AOI could be designated a special district and multiple economic incentives could directly assist private developers in creating compatible and desirable land uses in support of the proposed spaceport. A special district could also be used to preserve and protect the residential communities, improving the safety of the area for visitors.

7. Airport Development Plan

The Airport Development Plan (ADP) is a composite of the preferred alternatives described in Section 5. These alternatives not only include specific projects related to airfield development and improvements, roadway improvements and general aviation facility development, but also broad land use recommendations. In the process of consolidating the preferred alternatives for inclusion in the Master Plan Update, some of the recommended development projects were refined to ensure that they form a compatible development plan, while still allowing for a wide range of potential on-Airport land uses in the future.

7.1 Overview

The ADP consists of a summary of Airport development projects recommended for implementation during the planning period and the benefits these projects are expected to generate for the Airport and its tenants and users. The projects include capacity enhancements for the airfield, tenant facilities, and access roadways, as well as development of new activity sectors in the form of a spaceport.

Airfield improvements will provide adequate capacity enhancements to accommodate forecast activity and long-term growth, in addition to several projects that will increase the safety and operational efficiency of the airfield in the short term. These improvements include an extension of Runway 17R-35L to the north, construction of a full-length parallel taxiway to Runway 4-22, and reconfiguration of certain areas of the airfield to enhance safety and efficiency. Land acquisition north of Runway 17R-35L will accommodate the runway extension and protect the area within the RPZs.

In the southwest quadrant of the Airport, the ADP includes expansion of aircraft storage hangars (T-hangars and conventional hangars) and the surrounding apron areas, as well as construction of a General Aviation Activity Center that would provide passenger processing facilities. Development of spaceport support facilities is planned in the southeast quadrant of the Airport.

7.2 Airport Development Plan Projects

The ADP incorporates a number of major development initiatives. Each initiative will be realized through a variety of specific projects that must be carefully coordinated and planned to ensure that operational impacts are minimized throughout implementation. The ADP is divided into four categories: airfield, general aviation area, ground access, based aircraft storage, new activity and land use, and off-Airport impacts. The major initiatives were grouped into the corresponding categories generally in chronological order, with a description of each initiative. In addition, a land acquisition program would be needed to support the individual facility development initiatives, as described in Section 7.2.6.2. The following subsections describe the projects recommended as a result of the analyses conducted for this Master Plan Update.

7.2.1 AIRFIELD

The overall purpose of the recommended airfield development program is to accommodate potential spaceport activities or other potential development opportunities, while also improving safety and meet design standards. These projects include:

- Extension of Runway 17R-35L to the north, for a total runway length of 10,000 feet to accommodate a diversification of aircraft activity at the Airport. Generally, project elements include:
    - Extend the runway by 1,000 feet
    - Add/modify lighting and markings on the existing runway and its extension
    - Acquire parcels of land inside the future RPZ
- Relocation/installation of navigational aids associated with the extension of Runway 17L-35R. This project would include:
    - Relocate the Runway 35L localizer antenna
    - Relocate the Runway 17R glide slope antenna
    - Relocate and upgrade the Runway 17R approach lighting system to a MALSR
    - Relocate the Runway 17R PAPI
    - Relocate/install windsocks
- Extension of Taxiway H to provide access to the extended Runway 17R end.
- Construction of shoulders along Runways 17R-35L and 4-22, as well as along Taxiways A, H, F, and C, to comply with FAA standards.
- Decommissioning of Runway 17L-35R (when pavement conditions become unsafe, requiring major maintenance or when land is required for new development), which would open the northeast quadrant of the Airport for development.
- Realignment of the perimeter road and fence in the northeast quadrant of the Airport to provide continuous access to the interior perimeter of the airfield for ARFF, Airport Operations, and other vehicles.
- Realignment of Taxiway G to a parallel taxiway to Runway 4-22 on the north side; the new Taxiway G would tie in with Taxiway C and existing Taxiway G would be decommissioned.
- Construction of a parallel taxiway to Runway 4-22 on the south side, as well as several runway exits. This project would also include a taxiway tying in the new Runway 4-22 parallel taxiway with the Runway 35L end. Once this tie-in is operational, the portion of Taxiway E east of Runway 17R-35L could be decommissioned to remove an unsafe taxiway/runway alignment.

- Realignment of Taxiway E to provide a 90-degree angled runway crossing.
- Realignment of Taxiway B to provide a 90-degree angled runway crossing. The portion of Taxiway B west of Runway 17R-35L would be decommissioned.
- Realignment of Taxiway D to provide a 90-degree angled runway crossing. The portion of Taxiway D west of Runway 17R-35L would be decommissioned.
- Construction of a parallel taxiway on the east side of Runway 17R-35L to accommodate increased spaceport operations and reduce runway crossings.
- Construction of a taxiway connector between the first spaceport hangar and Runway 4-22.
- Prior to extending Runway 17R-35L, an Environmental Assessment (EA) of the potential effects of all near-term projects would need to be prepared.

7.2.2 GENERAL AVIATION AREA

A General Aviation Activity Center is planned at the Airport to accommodate general aviation aircraft arriving from international destinations and large groups of passengers flying on charter aircraft. A facility to process passengers would be required, as well as automobile parking facilities, office space, and employee areas. Customs services would also be offered in the activity center.

7.2.3 GROUND ACCESS

Roadway improvements are recommended to support planned development and ease traffic congestion:

- A north access road to connect the Airport to Beltway 8 would provide an additional access point and mitigate the access blockage resulting from trains stalled in front of the Airport.
- The Ellington Bypass would provide direct access to the southeast quadrant of the Airport from Old Galveston Road and prevent Airport traffic from using neighborhood roads.
- The addition of several traffic turn lanes is recommended to reduce delays at the intersections of Old Galveston Road and Challenger 7 Parkway, and Old Galveston Road and Clear Lake City Boulevard.

7.2.4 BASED AIRCRAFT STORAGE

Additional based aircraft storage is recommended in two forms:

- T-hangars are planned in the southwest quadrant of the Airport at the expense of a third-party developer. T-hangars would be located along Taxiway K, and could accommodate up to ADG II aircraft. Incremental development would be based on demand, and could encompass up to 35 acres.
- Conventional hangars are also planned in the southwest quadrant of the Airport at the expense of a third-party developer. CBO and FBO hangars would be located south of the existing HAS T-hangars, and would accommodate up to ADG III aircraft. Incremental development would be based on demand, and could encompass up to 20 acres. Realignment of Aerospace Avenue would be required.

7.2.5 NEW ACTIVITY/LAND USE

To initiate spaceport activities, the following projects are recommended:

- Construct the first spaceport facility, a spacecraft hangar, adjacent to existing NASA facilities in the southeast quadrant of the Airport, at the expense of a third-party developer.
- Construct spaceport support facilities, such as fuel/oxidizer storage areas and loading areas.
- Market the Airport to attract new activity, such as educational and space incubator facilities.

7.2.6 OFF-AIRPORT IMPACTS

Minimal off-Airport impacts are expected as a result of the recommended Airport development projects.

7.2.6.1 Obstruction Removal

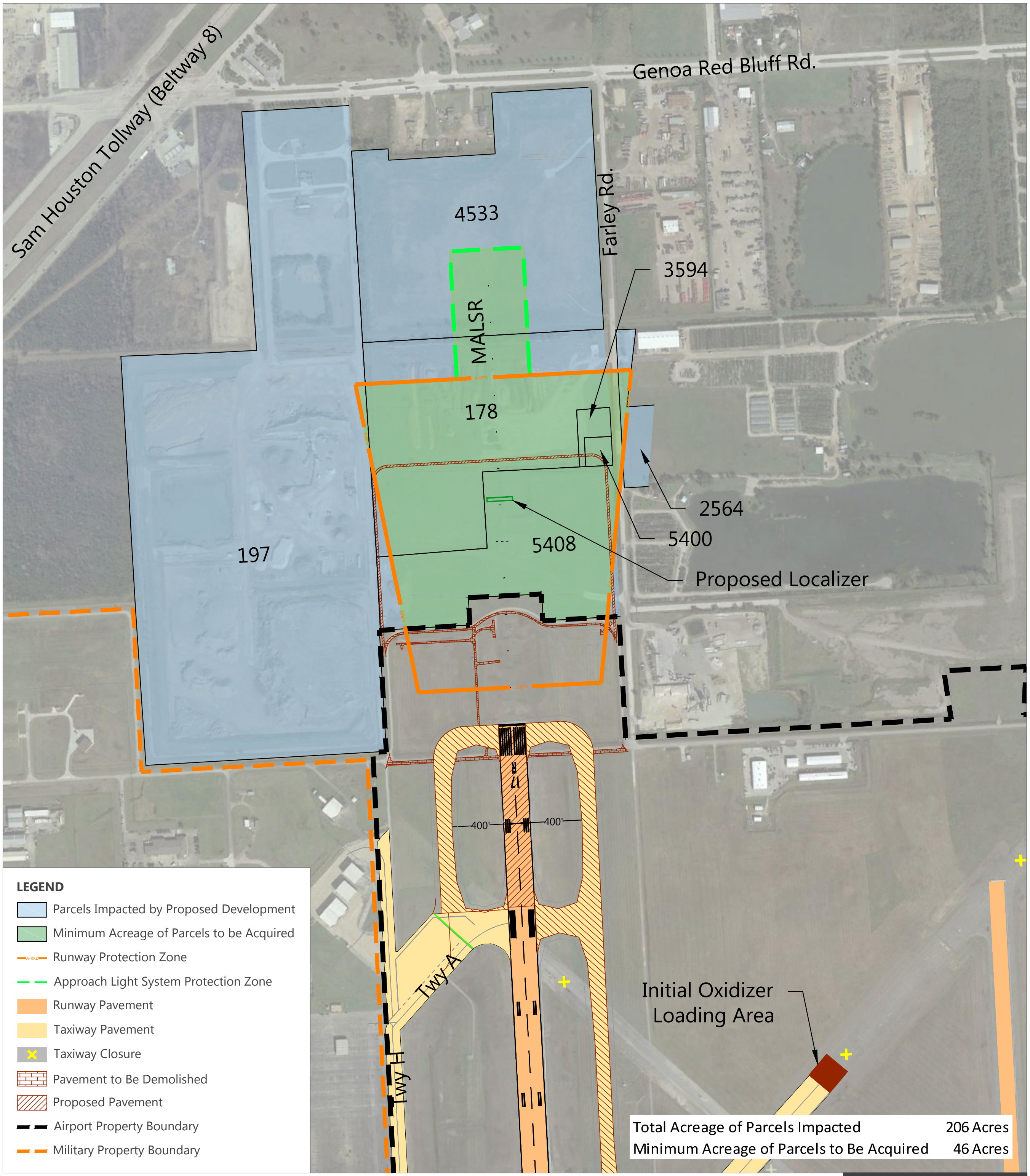
The removal of obstructions to the extended Runway 17R-35L ground and airspace surfaces will be required before the runway extension becomes operational. Existing structures may require demolition and poles that presently obstruct the approach surfaces to the north end of existing Runway 17R-35L may require removal.

7.2.6.2 Land Acquisition

Parcels anticipated to be affected by Airport development projects encompass an area totaling approximately 205 acres north of the Airport. **Exhibit 7-1** shows these parcels, by parcel number. In some instances, it may not be necessary to acquire the entire parcel, and only the portion required for Airport development would be acquired. Approximately 46 acres are within the RPZ and MALSR critical area and are needed to support the ADP. Therefore, it was estimated that the overall land acquisition area associated with recommended Master Plan Update projects would be between 46 acres and 205 acres.

7.2.6.3 Road Realignment

Farley Road, which is located north of the Runway 17R end, would be inside the proposed RPZ of the extended runway. FAA guidance on existing roads inside a proposed RPZ is still outstanding. Coordination with the FAA on this issue will be conducted when the runway extension is approved for construction.



Total Acreage of Parcels Impacted	206 Acres
Minimum Acreage of Parcels to Be Acquired	46 Acres

SOURCES: Ricondo & Associates, Inc., Ellington Airport, Draft Future Airport Layout Plan, May 2014; Google Earth Pro 2014; Terra Metrics, October 31, 2013 (aerial photography - for visual reference only, may not be to scale); Geographic Information System Data, Jacobs Engineering, May 2013; Ricondo & Associates, Inc., May 2014.
PREPARED BY: Ricondo & Associates, Inc., April 2015.

EXHIBIT 7-1

NORTH

0 800 ft.

Off-Airport Parcels Impacted by Proposed Airport Development

Drawing: Z:\Houston\1-EFD\EFD Master Plan 2012\11-ADP\CAD\Exh 7-1_Parcels Impacted by Apt Dvlpt.dwg Layout: Parcels Impacted by Airport Development Plotted: Sep 29, 2015, 12:43PM

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Preliminary recommendations are provided by parcel based on the implementation timing presented in this Master Plan Update:

- Parcel 5408, located north of the Runway 17R end, should be acquired to protect the RPZ for extended Runway 17R. This parcel is currently undeveloped and should remain that way.
- Parcel 178, located north of the Runway 17R end, should be acquired to protect the RPZ for extended Runway 17R. This parcel is currently undeveloped and should remain that way. Several earth berms are located on this parcel.
- Parcel 5400, located north of the Runway 17R end, should be acquired to protect the RPZ for extended Runway 17R. This parcel is currently undeveloped and should remain that way.
- Parcel 3594, located north of the Runway 17R end, should be acquired to protect the RPZ for extended Runway 17R. This parcel is currently undeveloped and should remain that way.
- Parcel 4533, located north of the Runway 17R end, should be acquired to protect the Runway 17R MALSR critical area. This parcel is currently undeveloped and should remain that way.
- A small portion of Parcel 197, located northwest of the Runway 17R end, may be acquired to protect the RPZ for extended Runway 17R. The affected portion of this parcel consists of a dirt road and ditch.
- Parcel 2564, located northeast of the Runway 17R end, should be acquired to protect the RPZ for extended Runway 17R. This parcel is currently undeveloped and should remain that way.

Exhibit 7-2 presents a composite view of the Airport after completion of the projects included in the ADP.

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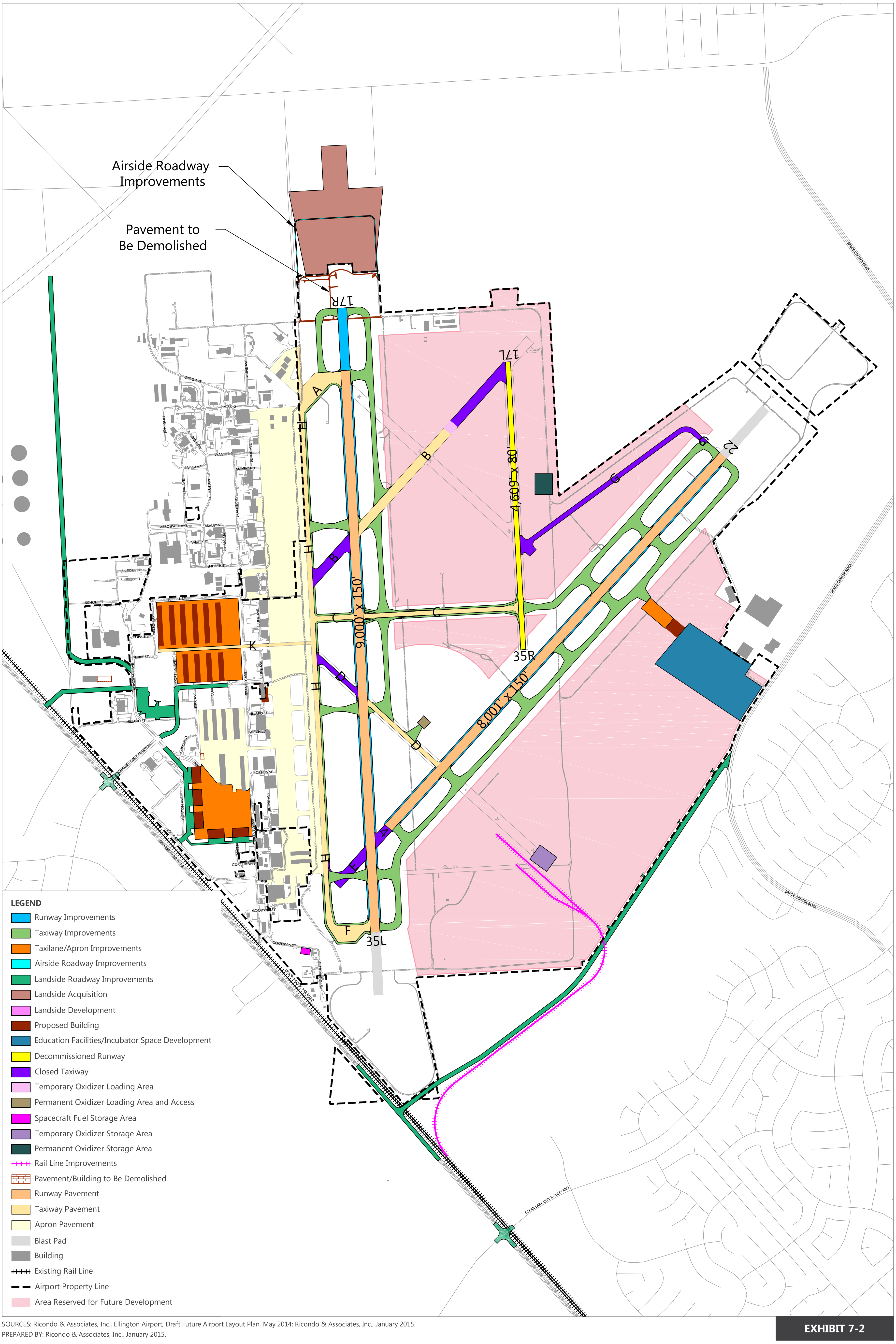

SOURCES: Ricondo & Associates, Inc., Ellington Airport, Draft Future Airport Layout Plan, May 2014; Ricondo & Associates, Inc., January 2015.
PREPARED BY: Ricondo & Associates, Inc., January 2015.

EXHIBIT 7-2

Airport Development Plan 2016-2030

Drawing: Z:\Houston\1-EFD\EFD Master Plan 2012\11-ADP\CAD\Exh 7-2_Airport Development Plan.dwg Layout: Airport Development Plan Plotted: Sep 29, 2015, 12:45PM

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8. Implementation Plan

This Master Plan Update is unusual because its recommendations are driven not only by the facility requirements identified in Section 4, but also by potentially new activity sectors that HAS and EFD management are pursuing for the Airport. Therefore, this Implementation Plan sets forth a possible development sequence and schedule based on the types and rates of growth anticipated through the planning period (2030) and the introduction/maturation of potentially new activity sectors. The development initiatives shown on the ALP and described in previous sections were categorized into distinct projects with budgeted costs, durations, and sequencing, which formed the basis for the Implementation Plan discussed in this section. The Funding Plan for the recommended projects is provided in Section 9.

The timing of project implementation will be based on demand and HAS' desire to introduce new activity sectors at the Airport. Because the timing of growth and development will be tied more to the ability to attract new services (such as spaceport operations) to EFD rather than purely to forecast growth, the Implementation Plan includes an overview of factors that are anticipated to prompt a development action. This approach offers HAS the ability to assess actual demand and the flexibility to respond effectively. Through regular monitoring and data analysis and an understanding of the effects of various trends, HAS can respond strategically to meet tenant and user needs by developing demand-driven facilities in a timely manner.

This section addresses the following:

- **Factors Affecting Implementation and Development Phasing.** These factors include general criteria upon which decisions regarding facility development should be based and identify specific implementation indicators.
- **Phased Implementation Plan.** The plan includes phased project development, identifies individual projects in the ADP, and illustrates the logical progression of those projects from existing conditions at the Airport to future development, as dictated by demand.

Implementation of the ADP projects should be phased so that development corresponds with anticipated demand. Preferably, projects should be implemented in sufficient time to accommodate growing demand, but not so early that facilities are underutilized. Thus, the ability to phase implementation correctly requires an understanding of the factors that prompt development, as well as ongoing data monitoring and analysis to identify when actions should be taken. Typically, master plan projects are implemented as aviation activity materializes. Although this may still be the case for some of the recommended projects, the majority of projects recommended in this Master Plan Update are driven by HAS development initiatives rather than aviation activity. In such a scenario, it is believed that the construction of facilities will generate demand, rather than the other way around.

8.1 Introduction of New Activity Sectors

HAS is aggressively pursuing the development of vacant land on Airport property. The development projects that would be suited to the northeast and southeast quadrants would introduce new activity at Ellington Airport and, as such, the introduction and growth of these sectors cannot be forecast. Implementation of the improvements required to enable these new activities would be tied to actual start dates determined by HAS.

8.2 Volume and Character of Activity Growth

The volume and character of forecast activity (factors addressed in Section 3) determine when development should occur throughout the planning period. Recognizing that activity may not increase as forecast, it is crucial to continuously monitor overall activity and assess the individual characteristics of that activity. The use patterns and facility needs to accommodate the type of demand on individual Airport facilities may be more important than overall activity statistics.

Factors that could influence the volume and character of activity growth at the Airport are changes in the fleet mix, the introduction of new activity (such as air cargo, aircraft maintenance or manufacturing, or spaceport operations), and fluctuations in the type and amount of general aviation operations.

Significant changes in general aviation activity could greatly affect the airfield. For example, the future decommissioning of Runway 17L-35R may result in a decrease in itinerant general aviation operations, as this runway is mostly used by itinerant aircraft practicing touch-and-go operations at the Airport. The in-trail separation between certain general aviation and military aircraft is greater than the separation required between military aircraft because of the effects of wake turbulence and speed differential. As the in-trail separation requirements increase, the amount of time between aircraft operations increases, which reduces airfield capacity.

The Airport Development Plan and the Implementation Plan were developed based on the forecasts presented in Section 3 and the demand/capacity analysis discussed in Section 4, which describes how these factors affect aviation activity

Historically, the Airport has accommodated a mix of military and general aviation aircraft, both fast and slow. As indicated in Section 3, forecast growth at the Airport is based on general aviation growth only; military and NASA activity is anticipated to remain constant. These forecasts are based on historical data, but do not account for the potential effects of decommissioning Runway 17L-35R.

Throughout the planning period, the growth and type of general aviation operations should be carefully monitored. Also, the introduction of new activity at the Airport, such as cargo or spaceport operations, may require the Implementation Plan to be revised.

As the Airport and aviation services offered continue to grow and expand, the ADP and Implementation Plan should be periodically reviewed to ensure that actual trends are similar to those forecast.

8.3 General Criteria for Implementation

The primary criteria used to phase implementation of the ADP projects include:

- Initiate detailed project planning and design so that improvements can be in place when needed. For runways and airfield expansion, environmental analyses and preliminary design should precede design and construction. These steps may take several years before the improvement can be in place and operational.
- Minimize operational impacts on the airfield, tenants, and ground access routes. Minimize closures of runways and taxiways to minimize interim airfield capacity reductions and pilot and user inconvenience and confusion, and maintain access roadways and parking facilities for user vehicles.
- Maintain a logical sequence of development, building individual projects toward the ultimate Airport Development Plan. Near-term development projects should be phased to support long-term development and protect future options. Project sequencing must also be based on airfield access and utility infrastructure considerations.
- Meet HAS goals and objectives. HAS plans and goals were considered during development of the ADP. Optimum development strategies and tenant impacts were coordinated with the HAS Planning Department.

8.4 Implementation Indicators

Two types of indicators, or activity levels, that will trigger development were identified as useful to activity monitoring and implementation: primary and secondary. Primary indicators are considered “triggers” for implementation when a specific level of activity is reached. Secondary indicators do not trigger implementation actions, but provide more insight into the type of demand that is occurring. Secondary indicators may provide another way to measure activity or guide how the project is implemented once the trigger is reached.

Indicators for airfield and general aviation development are discussed below. These indicators are intended to identify an impending need (i.e., a trigger) for additional facilities given existing demand/capacity relationships. Once these triggers are reached, in-depth analyses should be undertaken to confirm the continued validity of the triggers and the facility concepts.

- **Airfield indicators**. Planning for additional airfield capacity should begin when demand exceeds 60 percent of the ASV. By initiating planning at that point, additional capacity could be expected to become operational as demand begins to reach 100 percent of the ASV. The current and forecast airfield demand at the Airport does not indicate a need for additional capacity during the planning period (through 2030). However, airfield improvements will be based on the introduction of operations by aircraft that require a longer runway than is available today.
- **General aviation indicators**. Two principal types of general aviation tenants have facilities at the Airport: corporate tenants and an FBO. The development of new or improved general aviation facilities is typically driven by tenant initiatives rather than by the airport owner. However, activity indicators may provide insight into overall general aviation demand. The based aircraft fleet and the annual number of general aviation aircraft operations indicate the overall demand for general aviation facilities and services at the Airport. Growth in the based aircraft fleet by Airport tenants (corporate or FBO) can indicate a demand for hangar, terminal, or apron expansion.

8.5 Phased Implementation Plan

8.5.1 PHASE DURATION

Phasing of the ADP is based, in part, on specific demand and the timing of introduction of new activity at the Airport. These indicators will trigger the need for implementation of individual projects and a logical progression of development will allow critical projects to be in place to accommodate that demand. **Table 8-1** presents the phases that were identified for this Implementation Plan.

Table 8-1: Correlation between Phases and Activity

PHASE	YEARS	AIRCRAFT OPERATIONS AT END OF PHASE	ANTICIPATED NEW ACTIVITY BY END OF PHASE
1	2016-2020	110,841	General Aviation Activity Center; New T-Hangars, CBO Hangars; First Spaceport Hangar; Education/Incubator Space Facilities
2	2021-2025	114,057	Additional Spaceport Hangars
3	2026-2030	117,455	

NOTE: 2025 aircraft operation number is an average between 2020 and 2030.

SOURCE: Ricondo & Associates, Inc., January 2015.
PREPARED BY: Ricondo & Associates, Inc., January 2015.

Exhibit 8-1 presents a bar chart schedule for the recommended implementation of each Master Plan Update project included in Phases 1 through 3 of the Implementation Plan.

8.5.2 PHASE 1 PROJECTS (2016 – 2020)

8.5.2.1 On-Airport Projects

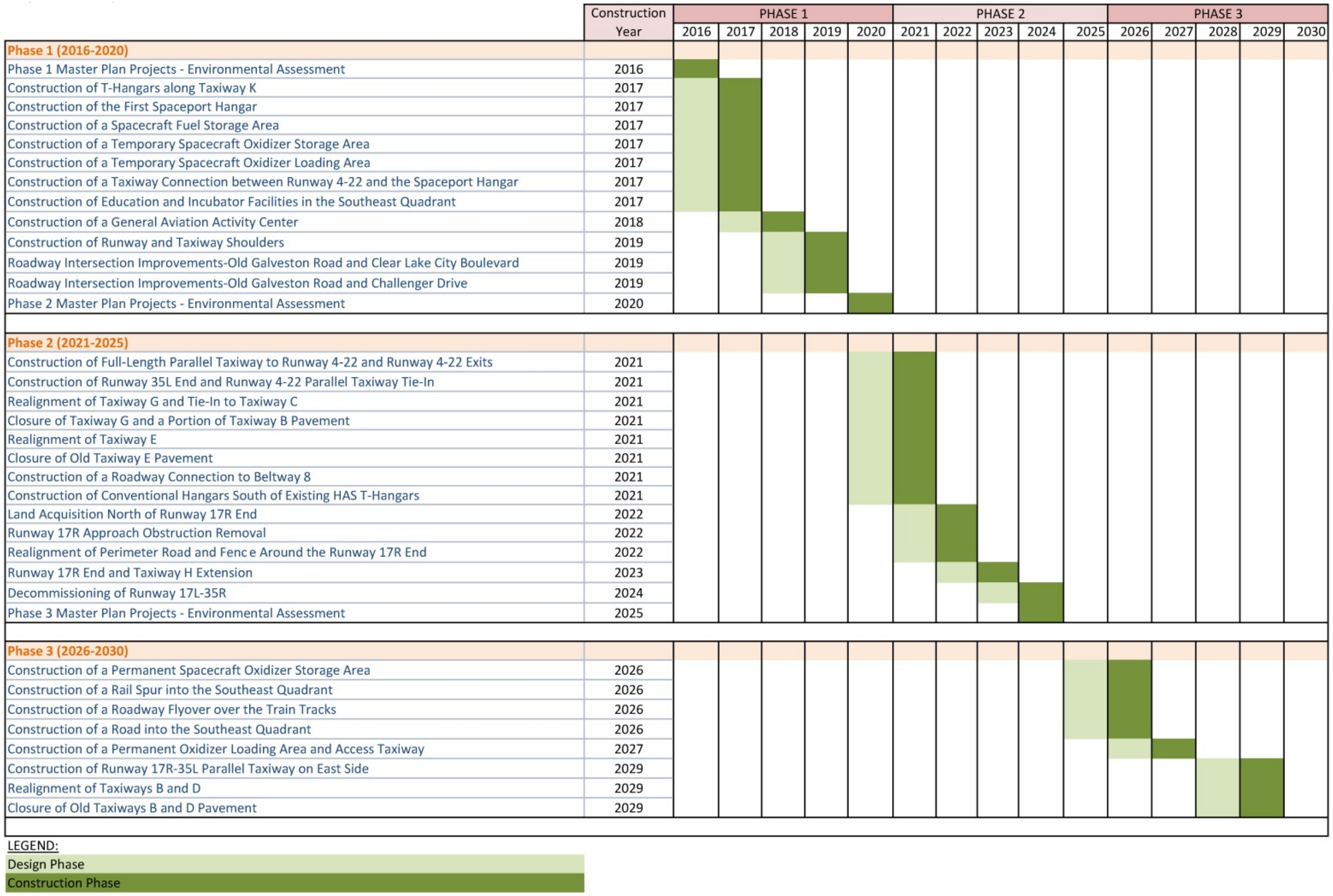
Phase 1 includes Airport facilities and infrastructure to be developed between 2016 and 2020. **Exhibit 8-2** graphically depicts the Phase 1 project areas:

- Completion of an EA for Phase 1 projects before any construction is initiated.
- Construction of general aviation T-hangars along Taxiway K. Construction would be incremental based on demand.
- Construction of the first spaceport-related hangar in the southeast quadrant, along with a taxiway connecting it to Runway 4-22.
- Construction of a spacecraft fuel storage area in the vicinity of the existing fuel farm.
- Construction of a temporary oxidizer storage area on a closed portion of Taxiway D.
- Construction of a temporary spacecraft oxidizer loading area on Taxiway B.
- Decommissioning of Runway 17L-35R, along with Taxiway G and portions of Taxiways B and C.
- Development of education facilities and incubator space in the southeast quadrant, adjacent to the NASA facilities and proposed spaceport hangar.
- Construction of the General Aviation Activity Center on the site of the former ARFF station in the southwest quadrant. The activity center would also require expansion of the existing parking lot.
- Construction of runway and taxiway shoulders for pavement designed to accommodate ADG IV aircraft or larger.
- Initiation of an EA for Phase 2 projects.

8.5.2.2 Off-Airport Projects

Phase 1 off-Airport improvements include the construction of additional traffic lanes at the intersection of Old Galveston Road and Clear Lake City Boulevard, and the intersection of Old Galveston Road and Challenger 7 Parkway.

Exhibit 8-1: Recommended Implementation Schedule



	Construction Year	PHASE 1					PHASE 2					PHASE 3				
		2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Phase 1 (2016-2020)																
Phase 1 Master Plan Projects - Environmental Assessment	2016	🟩														
Construction of T-Hangars along Taxiway K	2017	▨	🟩													
Construction of the First Spaceport Hangar	2017	▨	🟩													
Construction of a Spacecraft Fuel Storage Area	2017	▨	🟩													
Construction of a Temporary Spacecraft Oxidizer Storage Area	2017	▨	🟩													
Construction of a Temporary Spacecraft Oxidizer Loading Area	2017	▨	🟩													
Construction of a Taxiway Connection between Runway 4-22 and the Spaceport Hangar	2017	▨	🟩													
Construction of Education and Incubator Facilities in the Southeast Quadrant	2017	▨	🟩													
Construction of a General Aviation Activity Center	2018		▨	🟩												
Construction of Runway and Taxiway Shoulders	2019			▨	🟩											
Roadway Intersection Improvements-Old Galveston Road and Clear Lake City Boulevard	2019			▨	🟩											
Roadway Intersection Improvements-Old Galveston Road and Challenger Drive	2019			▨	🟩											
Phase 2 Master Plan Projects - Environmental Assessment	2020					🟩										
Phase 2 (2021-2025)																
Construction of Full-Length Parallel Taxiway to Runway 4-22 and Runway 4-22 Exits	2021					▨	🟩									
Construction of Runway 35L End and Runway 4-22 Parallel Taxiway Tie-In	2021					▨	🟩									
Realignment of Taxiway G and Tie-In to Taxiway C	2021					▨	🟩									
Closure of Taxiway G and a Portion of Taxiway B Pavement	2021					▨	🟩									
Realignment of Taxiway E	2021					▨	🟩									
Closure of Old Taxiway E Pavement	2021					▨	🟩									
Construction of a Roadway Connection to Beltway 8	2021					▨	🟩									
Construction of Conventional Hangars South of Existing HAS T-Hangars	2021					▨	🟩									
Land Acquisition North of Runway 17R End	2022						▨	🟩								
Runway 17R Approach Obstruction Removal	2022						▨	🟩								
Realignment of Perimeter Road and Fenc e Around the Runway 17R End	2022						▨	🟩								
Runway 17R End and Taxiway H Extension	2023							▨	🟩							
Decommissioning of Runway 17L-35R	2024								▨	🟩						
Phase 3 Master Plan Projects - Environmental Assessment	2025									🟩						
Phase 3 (2026-2030)																
Construction of a Permanent Spacecraft Oxidizer Storage Area	2026										▨	🟩				
Construction of a Rail Spur into the Southeast Quadrant	2026										▨	🟩				
Construction of a Roadway Flyover over the Train Tracks	2026										▨	🟩				
Construction of a Road into the Southeast Quadrant	2026										▨	🟩				
Construction of a Permanent Oxidizer Loading Area and Access Taxiway	2027											▨	🟩			
Construction of Runway 17R-35L Parallel Taxiway on East Side	2029													▨	🟩	
Realignment of Taxiways B and D	2029													▨	🟩	
Closure of Old Taxiways B and D Pavement	2029													▨	🟩	

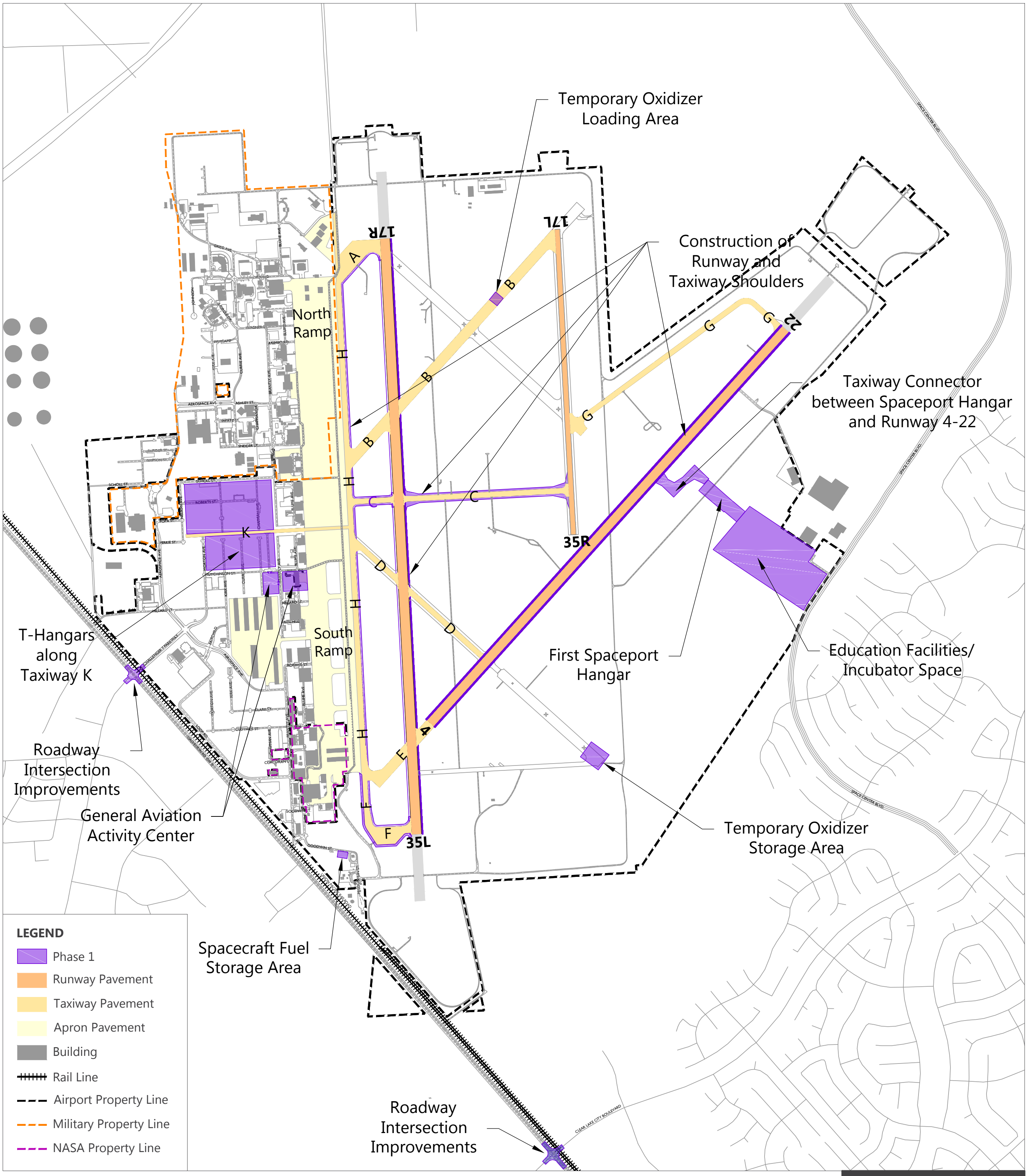
LEGEND:

▨ Design Phase

🟩 Construction Phase

SOURCES: Houston Airport System, 2014; Ricondo & Associates, Inc., March

PREPARED BY: Ricondo & Associates, Inc., March 2015.



SOURCES: Ricondo & Associates, Inc., Ellington Airport, Draft Future Airport Layout Plan, May 2014; Ricondo & Associates, Inc., May 2014.
PREPARED BY: Ricondo & Associates, Inc., May 2014.

EXHIBIT 8-2

NORTH 0 2,200 ft.

Project Areas
Phase 1 (2016-2020)

Drawing: Z:\Houston\1-EFD\EFD Master Plan 2012\11-ADP\CAD\Exh 8-2 through 8-4_Airfield Implementation Plan.dwg Layout: Phase 1 Plotted: Oct 6, 2015, 11:19AM

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8.5.3 PHASE 2 PROJECTS (2021 – 2025)

8.5.3.1 On-Airport Projects

Phase 2 includes Airport facilities and infrastructure to be developed between 2021 and 2025. **Exhibit 8-3** depicts the Phase 2 project areas:

- Construction of a full-length taxiway parallel to Runway 4-22, along with Runway 4-22 runway exits. Construction of certain portions could be incremental based on demand.
- Construction of the taxiway tie-in between the recommended Runway 4-22 parallel taxiway and the Runway 17R-35L end.
- Realignment of existing Taxiway E to provide a 90-degree runway crossing. Upon completion, existing Taxiway E would be closed, eliminating the aligned taxiway geometry.
- Realignment of Taxiway G into a partial parallel taxiway to Runway 4-22, on the north side. The new Taxiway G would tie in with Taxiway C. The existing Taxiway G would be decommissioned.
- Closure of a portion of Taxiway B.
- Construction of conventional hangars in the southwest quadrant of the Airport. Incremental development would be based on demand. The total area to be developed consists of approximately 25 acres. Realignment of Aerospace Avenue would be required.
- Realignment of the perimeter road and fence around the Runway 17R end.
- Extension of the Runway 17R end and Taxiway H.
- Decommissioning of Runway 17L-35R.
- Initiation of an EA for Phase 3 projects.

8.5.3.2 Off-Airport Projects

Phase 2 off-Airport projects include:

- Construction of a roadway connection to Beltway 8.
- Land acquisition in preparation for the extension of the Runway 17R end includes parcels located north of the Airport boundary.
- Removal of obstructions for the extension of the Runway 17R end.

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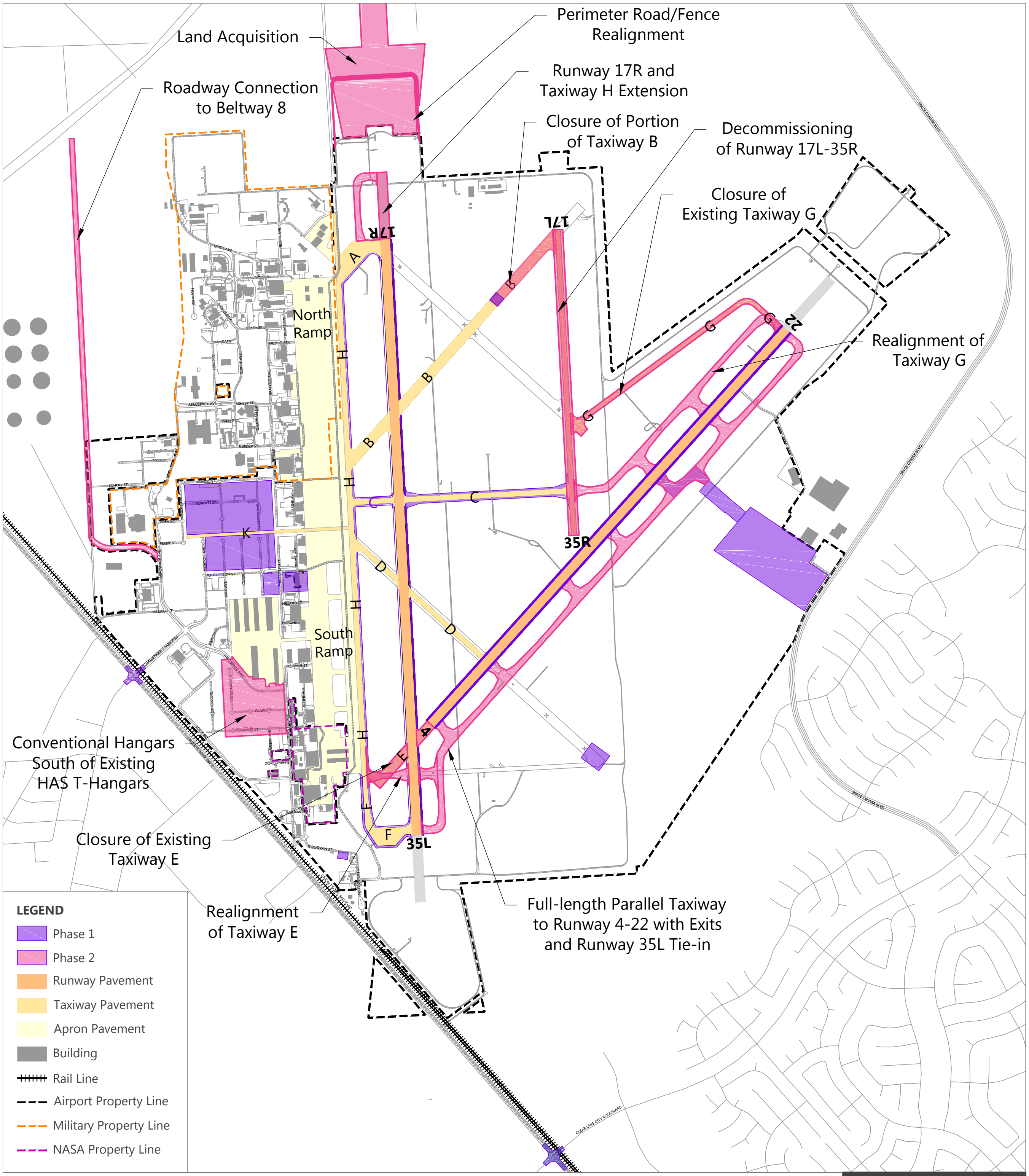

SOURCES: Ricondo & Associates, Inc., Ellington Airport, Draft Future Airport Layout Plan, May 2014; Ricondo & Associates, Inc., May 2014.
PREPARED BY: Ricondo & Associates, Inc., May 2014.

EXHIBIT 8-3

Project Areas
Phase 2 (2021-2025)

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8.5.4 PHASE 3 PROJECTS (2026 – 2030)

8.5.4.1 On-Airport Projects

Phase 3 includes Airport facilities and infrastructure to be developed between 2026 and 2030. **Exhibit 8-4** depicts the Phase 3 project areas, which include:

- Construction of a permanent spacecraft oxidizer storage area.
- Relocation of the oxidizer loading area to a permanent location and construction of associated taxiway access.
- Construction of a parallel taxiway on the east side of Runway 17R-35L.
- Realignment of Taxiway B to provide a 90-degree runway crossing. The existing portion of Taxiway B west of Runway 17R-35L would be decommissioned.
- Realignment of Taxiway D to provide a 90-degree runway crossing. The existing portion of Taxiway D west of Runway 17R-35L would be decommissioned.

8.5.4.2 Off-Airport Projects

Phase 3 off-Airport projects include:

- Construction of a railroad spur into the southeast quadrant of the Airport.
- Construction of roadway access to the southeast quadrant of the Airport from Old Galveston Road.
- Construction of a roadway flyover over the Union Pacific Railroad tracks to access the southeast quadrant of the Airport.

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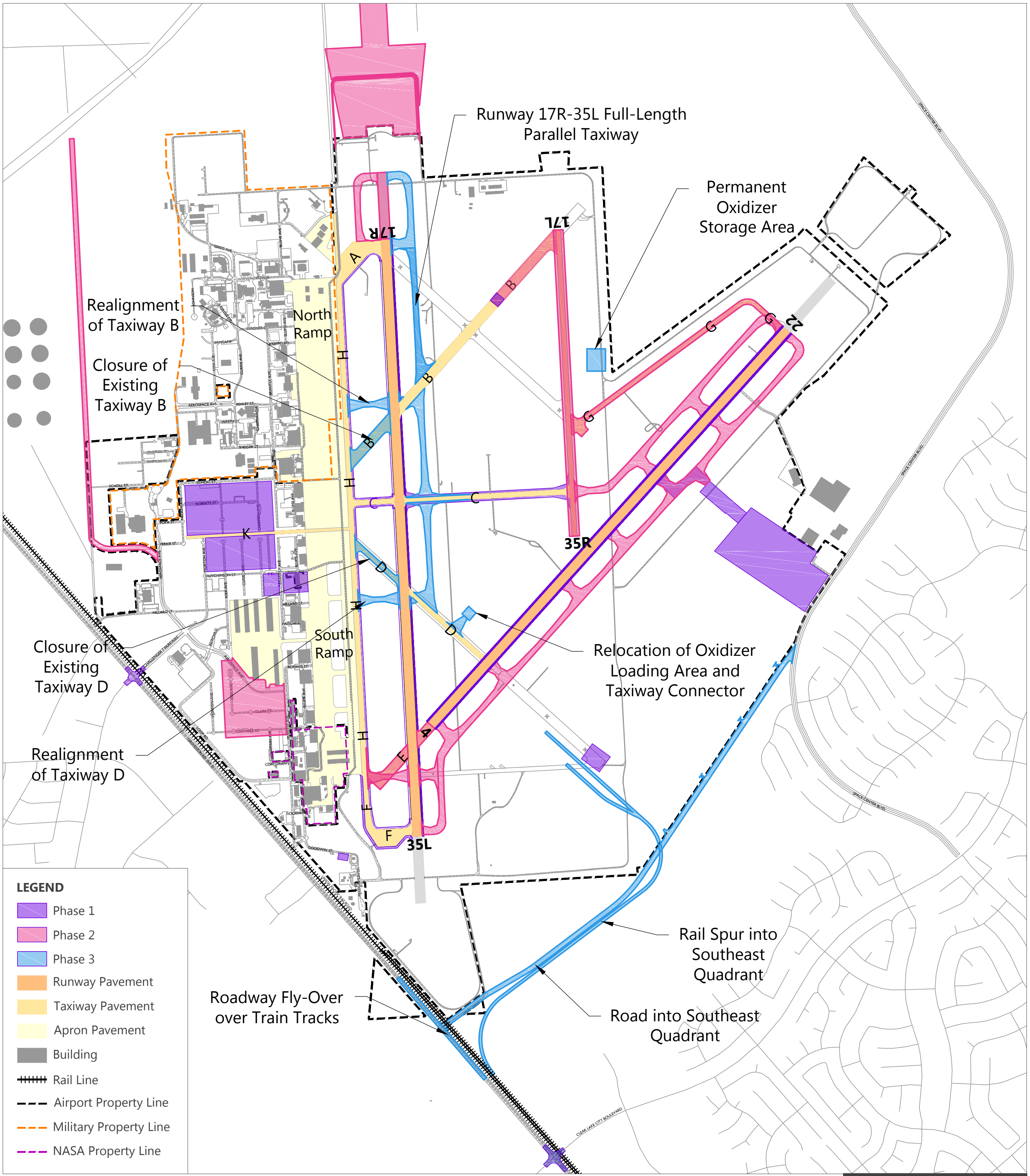

SOURCES: Ricondo & Associates, Inc., Ellington Airport, Draft Future Airport Layout Plan, May 2014; Ricondo & Associates, Inc., May 2014.
PREPARED BY: Ricondo & Associates, Inc., May 2014.

EXHIBIT 8-4

NORTH 0 2,200 ft.

Project Areas
Phase 3 (2026-2030)

Drawing: Z:\Houston\1-EFD\EFD Master Plan 2012\11-ADP\CAD\Exh 8-2 through 8-4_Airfield Implementation Plan.dwg Layout: Phase 3 Plotted: Oct 6, 2015, 11:19AM

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9. Funding Plan

This section provides a three-phase funding plan for implementing the recommended Capital Improvement Program associated with the EFD Master Plan Update: Phase 1 (2016-2020), Phase 2 (2021-2025), and Phase 3 (2026-2030). The actual implementation schedule for the capital projects identified in the CIP will be defined by development triggers and demand growth rather than by specific years. For illustrative purposes, however, a specific implementation schedule is presented in this section. The actual funding strategies to be used will be determined at the time of implementation, reflecting HAS philosophy and expansion strategies for development, HAS financial health, and overall economic conditions nationwide.

This section is organized as follows:

- HAS Financial Structure
- Master Plan CIP Projects and Capital Costs
- Funding Sources
- CIP Limitations

It should be noted that the financial analysis presented in this section differs from the typical master plan financial analysis. With a one-airport system, a typical financial analysis includes the recommended capital program, funding sources for the capital program, operating expenses and revenue projections, future debt service requirements, airline rates and charges, and overall cash flow. The financial feasibility of undertaking the recommended capital program for a single airport is typically measured by: (1) the reasonableness of airline rates and charges (as determined by airline cost per enplaned passenger) and (2) whether or not airport net revenues are adequate to meet debt service coverage requirements of the issuer’s bond enabling legislation.

HAS, however, consists of three airports: EFD, HOU, and IAH. In its financial decision-making, HAS must consider the needs of the overall airport system rather than one airport. Therefore, it was not feasible to separate funding decisions regarding the EFD Master Plan Update CIP without considering the effects on the other airports in the Houston Airport System. As recommended by HAS, this section focuses only on the EFD Master Plan Update CIP and potential funding sources.

9.1 HAS Financial Structure

HAS manages and operates the Airport System Fund (the Fund) as an enterprise fund of the City. The Fund is used to account for services provided to the general public using the Airport System, and its costs are recovered primarily through user rentals, fees, and charges (e.g., landing fees, building and ground rentals, parking fees, and concession fees).

HAS accounts for EFD's operating revenues and expenses through three cost centers:

- General (accounting for the vast majority of the Airport)
- Information Technology
- Spaceport

EFD currently operates at a loss (recovered through nonairline revenues generated at IAH and HOU). Operating revenue is generated chiefly from aeronautical users and tenants. Although a landing fee is charged at EFD, it generates minimal revenue; the primary aeronautical fee is the fuel flowage fee. Facility rents and ground rents are generated by hangars and other facilities, and the relevant rental rates are set and adjusted by HAS according to periodic real estate appraisal reports.

9.2 Master Plan Capital Improvement Program Projects and Capital Costs

The Airport CIP is an amalgamation of the Master Plan Update CIP and the Ongoing CIP. The Ongoing CIP is maintained by HAS on a continuing basis, independent of the Master Plan Update. The version included in this analysis was prepared for 2015 through 2023 (see **Appendix J**). The Master Plan Update CIP features projects identified and discussed in the Master Plan Update.

9.2.1 MASTER PLAN UPDATE CAPITAL IMPROVEMENT PROGRAM

Table 9-1 presents a summary of phased capital costs for the Master Plan Update CIP. Construction costs were estimated by Connico, Inc., in October 2014 (see **Appendix K**). A 12 percent design premium and a 20 percent soft cost premium were assumed (except for land acquisition and runway decommissioning, which have soft costs but no design costs). Project costs consist of construction, design, and soft costs.

Estimated project costs were inflated at an compound annual growth rate of 2.4 percent, which is the 10-year inflation rate for the Houston-Galveston-Brazoria Metropolitan Statistical Area (as measured by the U.S. Department of Labor, Bureau of Labor Statistics, in its Consumer Price Index). The cost of each project was inflated to the midpoint of its planned construction period.

Table 9-1: Master Plan Update Capital Improvement Program (in Thousands of Dollars)

PROJECT	PURPOSE	DRIVER	COST IN 2015 DOLLARS	COST IN INFLATED DOLLARS
Phase 1 (2016-2020)				
Environmental Assessment – Phase 1 Master Plan Update Projects	Planning	Planning	$360	$368
Taxiway Connection between First Spaceport Hangar and Runway 4-22	Expansion	Spaceport	5,779	6,051
General Aviation Activity Center	Expansion	Capacity	5,502	5,882
Environmental Assessment – Phase 2 Master Plan Update Projects	Planning	Planning	600	656
Construction of Runway and Taxiway Shoulders	Safety/security	Safety/security	24,494	26,798
Roadway Intersection Improvements	Expansion	Capacity	3,718	4,068
Phase 1 Total			**$40,453**	**$43,823**
Phase 2 (2021-2025)				
Closure of Taxiway G and a Portion of Taxiway B	Asset removal	Airfield rationalization	$538	$614
Realignment of Taxiway G and Tie-in to Taxiway C	Expansion	Airfield rationalization	18,010	20,551
Realignment of Taxiway E	Expansion	Airfield rationalization	1,478	1,687
Closure of Old Taxiway E Pavement	Asset removal	Airfield rationalization	134	153
Roadway Connection to Beltway 8	Expansion	Capacity	6,989	7,975
Full-length Parallel Taxiway to Runway 4-22, Runway 4-22 Exits, and Runway 35 Tie-in	Expansion	Capacity	38,976	45,391
Land Acquisition around Runway 17R End	Safety / security	Spaceport	900	1,048
Realignment of Perimeter Road and Fence around Runway 17R End	Safety / security	Spaceport	1,344	1,565
Runway 17R End Extension and Taxiway H Extension	Expansion	Spaceport	14,112	17,098
Decommissioning of Runway 17L-35R	Asset removal	Airfield rationalization	806	997
Environmental Assessment – Phase 3 Master Plan Update Projects	Planning	Planning	600	741
Phase 2 Total			**$83,887**	**$97,800**
Phase 3 (2026-2030)				
Rail Spur into Southeast Quadrant	Expansion	Commercial development	$6,720	$8,616
Road into Southeast Quadrant	Expansion	Commercial development	5,376	6,893
Roadway Flyover over Railroad Tracks	Expansion	Commercial development	18,547	23,780
Relocation of Oxidizer Loading Area (OLA) and OLA Taxiway Access	Expansion	Spaceport	7,526	9,826
Realignment of Taxiways B and D and Closure of Old Pavement	Expansion	Airfield rationalization	7,123	9,468
Runway 17R-35L Parallel Taxiway on East Side	Expansion	Spaceport	17,338	23,453
Phase 3 Total			**$62,630**	**$82,036**
MASTER PLAN UPDATE CIP TOTAL COSTS			**$186,970**	**$223,659**

SOURCES: Houston Airport System; Connico, Inc.; and Ricondo & Associates, Inc., March 2015.
PREPARED BY: Ricondo & Associates, Inc., April 2015.

As shown, the Master Plan Update CIP for EFD is estimated to cost approximately $187.0 million in 2015 dollars ($223.7 million in inflated dollars) through the end of the third and final planning phase in 2030. For ease of presentation, the costs discussed in the remainder of this section are presented in inflated dollars.

Below is a brief discussion of each project in the Master Plan Update CIP, organized by the reasons driving the projects:

- Spaceport:
  - **Taxiway Connection between the First Spaceport Hangar and Runway 4-22**. Construction of a new, 16,500-square-yard taxiway is needed for and would be dependent on spaceport operations. This taxiway connection is anticipated to be the first spaceport-specific project that would receive HAS funding.
  - **Relocation of Oxidizer Loading Area (OLA).** The OLA must be located within a buffer perimeter. The optimal location for this OLA is along the east side of Taxiway D. This project includes construction of a connection to Taxiway D.
- Capacity:
  - **General Aviation Activity Center.** The activity center effectively would be a terminal building for general aviation users and tenants. This project would be a redevelopment of an out-of-service ARFF station. The purpose of the activity center would be to attract new and expand existing GA markets, including charter service on larger aircraft.
  - **Roadway Intersection Improvements**. These projects improve the intersections of Old Galveston Road with Challenger 7 Parkway and Clear Lake City Boulevard. Anticipated traffic volumes are expected to exceed the capacity at which these intersections, if unimproved, would have the desired level-of-service.
  - **Runway 17R-35L and Taxiway H Improvements** (land acquisition, realignment of the perimeter road and fence, and extension). These projects together would complete the 1,000-foot (northern) extension of Runway 17R-35L and its parallel Taxiway H. The runway extension to 10,000 feet would enable spacecraft operations, and would allow heavier aircraft to operate at the Airport.
  - **Full-length Parallel Taxiway to Runway 4-22 and Related Improvements.** This new taxiway would run along the entire length of Runway 4-22, and would extend to the south to tie in with the Runway 35L end. The taxiway would provide seven exits from Runway 4-22, and would tie in to the spaceport taxiway connection (as described above).
  - **Roadway Connection to Beltway 8**. This new access road would connect the west (developed) side of the Airport to a road other than Old Galveston Road. There is a need for access redundancy: between Old Galveston Road and the Airport lie railroad tracks, and a freight train can (and occasionally does) block all roadway accesses to the Airport. This project is included in both the City of Houston Major Thoroughfare and Freeway Plan and the Houston-Galveston Area Council Regional Transportation Plan.
  - **Parallel Taxiway to Runway 17R-35L.** This parallel taxiway would run from the northern (extended) end of Runway 17R-35L for approximately 6,300 linear feet along the runway's east

side to Taxiway D. This project is anticipated to be the last Master Plan Update CIP project to be constructed.

- Safety/Security:
  - **Construction of Runway and Taxiway Shoulders.** This project would bring the Airport into compliance with FAA design standards (as of September 2012) for runways and taxiways accommodating ADG IV aircraft and larger. This project would add shoulders to Runways-17R-35L and 4-22 and to several taxiways.
- Airfield Rationalization:
  - **Decommissioning of Runway 17L-35R**. Runway 17L-35R is 4,609 feet long and 80 feet wide. The aircraft that operate on this runway are predominantly flight school propeller-driven aircraft and military helicopters. This runway is not in good condition, and major maintenance would not be justified by the activity accommodated on the runway. Closure of the runway would provide additional on-Airport development space.
  - **Taxiway Realignments and Partial Closures (*all of Taxiway G and Portions of Taxiway B, D and E*).** Portions of Taxiways B, D, and E are not at right angles to Runway 17R-35L and, as such, are recommended to be realigned. Taxiway G would be realigned parallel to Runway 4-22, and would connect with Taxiway C.
- Commercial Development
  - **Rail Spur into the Southeast Quadrant**. This rail spur would branch off the railroad tracks that run parallel to Old Galveston Road. It would terminate on-Airport in the southeast quadrant, which has been designated for commercial development. This project would be demand-driven, based on the need of future tenants for access to freight rail.
  - **Road into the Southeast Quadrant**. Also known as the Ellington Field Bypass, this road would connect Old Galveston Road with Space Center Boulevard, thereby creating an east-side roadway that avoids Clear Lake City. This project would be demand-driven, based on traffic generated by the future development of the southeast quadrant.
  - **Grade-separated Intersection with Railroad Tracks**. This intersection would connect Old Galveston Road to the future Ellington Field Bypass, and would be an improvement over the at-grade crossing that would be constructed without it. This project would be demand-driven, based on traffic generated by the future development of the southeast quadrant. It should be emphasized that this project could be cost-prohibitive and potentially infeasible depending on the extent of roadway design and realignment that would be required to create the grade-separated crossing.

9.2.2 AIRPORT CAPITAL IMPROVEMENT PROGRAM

The Airport CIP in its entirety is discussed in the subsections that follow.

Table 9-2 presents individual annual project costs in relation to the timing in the Implementation Plan presented in Section 8.

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Table 9-2: Individual Annual Costs of the Airport Capital Improvements Program Projects (in Thousands of Inflated Dollars)

PHASE	PROJECT	MP CIP	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
1	Environmental Assessment – Phase 1 MP Projects	MP	$368	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
1	Taxiway Connection between First Spaceport Hangar and Runway 4-22	MP	-	6,051	-	-	-	-	-	-	-	-	-	-	-	-	-
1	General Aviation Activity Center	MP	-	630	5,251	-	-	-	-	-	-	-	-	-	-	-	-
1	Environmental Assessment – Phase 2 MP Projects	MP	-	-	-	656	-	-	-	-	-	-	-	-	-	-	-
1	Construction of Runway and Taxiway Shoulders	MP	-	-	2,871	23,926	-	-	-	-	-	-	-	-	-	-	-
1	Roadway Intersection Improvements	MP	-	-	436	3,632	-	-	-	-	-	-	-	-	-	-	-
1	Cargo Lane to Cargo Ramp		3,769	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1	Grass Island Paving – North Side Phase I		188	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1	Rehabilitation of Scholl Street between Aerospace Avenue and Brantley Avenue		3,392	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1	Rehabilitation of Airfield Service Road		687	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1	Rehabilitation of T-hangar Ramp and Taxiway D Pavement		1,617	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1	Installation of CAT-IIIA Instrument Landing System		829	7,457	-	-	-	-	-	-	-	-	-	-	-	-	-
1	Replacement of the Airport Traffic Control Tower		-	8,330	-	-	-	-	-	-	-	-	-	-	-	-	-
1	FAA Engineering Agreement		-	135	-	-	-	-	-	-	-	-	-	-	-	-	-
1	Replacement of Pavement (R&R) Phase 1		-	-	328	-	-	-	-	-	-	-	-	-	-	-	-
1	New Electrical Vault at Air Operations Area		-	-	3,610	-	-	-	-	-	-	-	-	-	-	-	-
1	Reconstruction of Ramp Pavement Adjacent to Landmark Aviation Phase 1		-	-	263	-	-	-	-	-	-	-	-	-	-	-	-
1	Replacement of Pavement (R&R) Phase II		-	-	-	335	-	-	-	-	-	-	-	-	-	-	-
2	Closure of Taxiway G and a Portion of Taxiway B	MP	-	-	-	-	66	548	-	-	-	-	-	-	-	-	-
2	Realignment of Taxiway G and Tie-in to Taxiway C	MP	-	-	-	-	2,202	18,349	-	-	-	-	-	-	-	-	-
2	Realignment of Taxiway E	MP	-	-	-	-	181	1,506	-	-	-	-	-	-	-	-	-
2	Closure of Old Taxiway E Pavement	MP	-	-	-	-	16	137	-	-	-	-	-	-	-	-	-
2	Roadway Connection to Beltway 8	MP	-	-	-	-	854	7,120	-	-	-	-	-	-	-	-	-
2	Full-length Parallel Taxiway to Runway 4-22, Runway 4-22 Exits and Runway 35 Tie-in	MP	-	-	-	2,432	12,564	20,264	10,132	-	-	-	-	-	-	-	-
2	Land Acquisition around Runway 17R End	MP	-	-	-	-	-	-	1,048	-	-	-	-	-	-	-	-
2	Realignment of Perimeter Road and Fence around Runway 17R End	MP	-	-	-	-	-	168	1,397	-	-	-	-	-	-	-	-
2	Runway 17R End Extension and Taxiway Access	MP	-	-	-	-	-	-	-	6,921	10,177	-	-	-	-	-	-
2	Decommissioning of Runway 17L-35R	MP	-	-	-	-	-	-	-	105	872	-	-	-	-	-	-
2	Environmental Assessment – Phase 3 MP Projects	MP	-	-	-	-	-	-	-	-	-	741	-	-	-	-	-
2	Reconstruction of Ramp Pavement adjacent to Landmark Aviation Phase II		-	-	-	-	-	2,515	-	-	-	-	-	-	-	-	-
2	Improvement of Horsepen Bayou Drainage		-	-	-	-	-	8,804	-	-	-	-	-	-	-	-	-
2	Rehabilitation of Outer Panels on Runway 4-22		-	-	-	-	-	5,869	-	-	-	-	-	-	-	-	-
2	Grass Island Paving – North Side 2 phase II		-	-	-	-	-	-	-	1,963	-	-	-	-	-	-	-
3	Rail Spur into Southeast Quadrant	MP	-	-	-	-	-	-	-	-	-	923	3,846	3,846	-	-	-
3	Road into Southeast Quadrant (Ellington Field Bypass)	MP	-	-	-	-	-	-	-	-	-	369	3,446	3,077	-	-	-
3	Roadway Flyover over Railroad Tracks	MP	-	-	-	-	-	-	-	-	-	1,274	11,890	10,616	-	-	-
3	Relocation of Oxidizer Loading Area (OLA) and OLA Taxiway Access	MP	-	-	-	-	-	-	-	-	-	-	-	1,053	8,774	-	-
3	Realignment of Taxiways B and D, Closure of Old Pavement	MP	-	-	-	-	-	-	-	-	-	-	-	-	1,014	8,453	-
3	Runway 17R-35L Full-length Parallel Taxiway on East Side	MP	-	-	-	-	-	-	-	-	-	-	-	1,256	6,491	10,470	5,235
	TOTAL ANNUAL COSTS (INFLATED)		**$10,850**	**$22,603**	**$12,759**	**$30,981**	**$15,883**	**$65,280**	**$12,577**	**$8,989**	**$11,049**	**$3,307**	**$19,182**	**$19,848**	**$16,279**	**$18,923**	**$5,235**

NOTE: MP CIP = Projects recommended in the Master Plan Update

SOURCES: Houston Airport System, Connico, Inc., and Ricondo & Associates, Inc., March 2015.
PREPARED BY: Ricondo & Associates, Inc., April 2015.

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9.3 Funding Sources

Based on the recommended Airport CIP, its associated costs, and available funding sources, a recommended Funding Plan was developed to maximize the use of external resources and minimize the amount of funding to be derived from local sources. The sources of funds available to implement the Airport CIP and the recommended funding sources are discussed below.

9.3.1 FEDERAL AIRPORT IMPROVEMENT PROGRAM GRANTS

Projects were reviewed to determine their eligibility for federal Airport Improvement Program (AIP) grant funding. As a general rule, only those projects that do not generate revenues are eligible for federal funding (a typical example is an airfield construction project). Federal grant eligibility is generally assumed to be 90 percent for airfield, ramp, and roadway projects. Federal funds are either in the form of entitlement grants based on a formula or discretionary grants distributed by the FAA on the basis of availability and the priority of projects at airports nationwide. In determining eligibility for federal AIP grant funding, it was assumed that AIP grant funding would continue to be in effect throughout the planning period, without any major changes.

It was not assumed that HAS would receive the maximum federal grants for all eligible Airport CIP projects. **Table 9-3** presents projections of annual AIP entitlement grants to be applied to the EFD Master Plan Update CIP. Because the FAA classifies EFD as a reliever airport, it is eligible to receive the lesser of the following: (a) $150,000 per year, or (b) 20 percent of the 5-year cost of its current National Plan of Integrated Airport Systems value.

The latter amount is approximately $10 million, or 20 percent of $50,423,357, which is the value most recently (on March 11, 2015) reported by the FAA for Federal Fiscal Years 2015-2019. Therefore, according to the formula, EFD's annual AIP entitlement grant would be $150,000. As shown in Table 9-3, $2.25 million in EFD federal AIP entitlement grants is projected for the Airport CIP, or 0.8 percent of the total cost of the Airport CIP. The remainder of AIP grant funds is assumed to be a combination of IAH and HOU entitlement grants or discretionary grants, which, including EFD entitlement grants, are projected to account for 24.8 percent of the total cost of the Airport CIP.

9.3.2 PASSENGER FACILITY CHARGES

In May 1991, the FAA issued 14 CFR Part 158, allowing public agencies controlling commercial service airports to impose a passenger facility charge (PFC) per eligible enplaned passenger. A PFC has never been collected at EFD, and there are no plans to collect one in the future. It was, therefore, assumed that HAS will not submit an application to the FAA during the planning period to collect a PFC and use PFC revenues to help fund Airport CIP projects.

Table 9-3: Projected Ellington Airport Federal Entitlement Grants (in Thousands of Dollars)

YEAR	ENTITLEMENT GRANTS
Phase 1	
2016	$150
2017	150
2018	150
2019	150
2020	150
Phase 1 Total	**$750**
Phase 2	
2021	$150
2022	150
2023	150
2024	150
2025	150
Phase 2 Total	**$750**
Phase 3	
2026	$150
2027	150
2028	150
2029	150
2030	150
Phase 3 Total	**$750**
TOTAL	**$2,250**

SOURCE: Ricondo & Associates, Inc., January 2015.
PREPARED BY: Ricondo & Associates, Inc., April 2015.

9.3.3 OTHER FUNDING

Other funding sources were identified for certain Airport CIP projects:

- Tenant/developer funding was previously used for general aviation facilities at EFD. It was assumed that similar funding arrangements would be used for half the cost of the General Aviation Activity Center.
- Improvements to certain roadway intersections off Airport property would be under the purview of the Texas DOT (TxDOT), not HAS. As such, TxDOT funding was assumed to cover the costs of the Roadway Connection to Beltway 8 project.

- Near the end of Phase 2 and during Phase 3, certain demand-driven projects would be funded partially by the tenants that would benefit from them. These projects include:
    - Runway 17R end extension and Taxiway H extension
    - Rail spur into the southeast quadrant
    - Road into the southeast quadrant (Ellington Field Bypass)
    - Relocation of OLA and OLA taxiway access
    - Runway 17R-35L parallel taxiway on east side

In total, $61.3 million of other funding was assumed to pay project costs, accounting for 22.8 percent of the total cost of the Airport CIP. These projects – which are estimated to cost $103.5 million – would be demand-driven and would not be constructed unless and until demand warrants.

9.3.4 LOCAL FUNDING

The remaining $140.1 million (51.3 percent) of project costs would be funded by HAS. As shown in **Table 9-4**, the majority of local funding would be required in Phase 2 (2021-2025), with $82.2 million required, mainly for (a) the full-length parallel taxiway to Runway 4-22 plus Runway 4-22 exits plus the Runway 35L tie-in and (b) the realignment of Taxiway G and the tie-in to Taxiway C.

Project costs not funded with federal grants or third-party funding would most likely be funded through some combination of HAS capital funds and the sale of airport system revenue bonds.

9.3.5 SUMMARY

Table 9-4 presents potential sources of funds for the Airport CIP, including federal grants, other funds, and HAS (local) funds. Future projects would be funded from the Airport Improvement Fund, debt, and grants. Other funds consist of TxDOT funds (for certain roadway intersection improvements) and tenant contributions. Roughly two-thirds of future project costs would be eligible for AIP grants; however, only one-fourth of future project costs were assumed to be funded from this source.

As previously explained, it was assumed that a projected $2.25 million in federal AIP entitlement grants would be applied to Airport CIP projects. In addition, it is anticipated that certain EFD projects would receive federal AIP discretionary grants. Finally, it is anticipated that HAS would re-direct approximately 15 percent of AIP grants for IAH to EFD projects, at the discretion of the HAS Director. HAS can legally distribute federal grants as it deems appropriate among its three airports, depending on need and available funds. For this analysis, it was assumed that HAS would distribute an annual average of $1.0 million of AIP entitlement grants from IAH to EFD.

Table 9-4 (1 of 2): Potential Sources of Funds for the Ellington Airport Capital Improvement Program (in Thousands of Dollars)

			SOURCES OF FUNDS		
PROJECT	**MASTER PLAN PROJECT?**	**TOTAL COSTS (INFLATED)**	**EXPECTED AIP GRANTS**	**OTHER FUNDS**	**HAS SHARE**
Phase 1 (2016-2020)					
Environmental Assessment - Phase 1 MP Projects	Yes	$368	$0	$0	$368
Taxiway Connection between First Spaceport Hangar and Runway 4-22	Yes	6,051	5,446	-	605
General Aviation Activity Center	Yes	5,881	-	2,941	2,940
Environmental Assessment - Phase 2 MP Projects	Yes	656	-	-	656
Construction of Runway and Taxiway Shoulders	Yes	26,797	24,117	-	2,680
Roadway Intersection Improvements	Yes	4,068	-	4,068	-
Cargo Lane to Cargo Ramp		3,769	-	-	3,769
Grass Island Paving - North Side 2 Phase I		188	-	-	188
Rehabilitation of Scholl Street between Aerospace and Brantley Avenues		3,392	-	-	3,392
Rehabilitation of Airfield Service Road		687	-	-	687
Rehabilitation of T-hangar Ramp and Taxiway D Pavement		1,617	-	-	1,617
Installation of CAT-IIIA Instrument Landing System		8,286	-	-	8,286
Replacement of the Airport Traffic Ccontrol Tower		8,330	7,497	-	833
FAA Engineering Agreement		135	-	-	135
Replacement of Pavement (R&R) Phase I		328	-	-	328
New Electrical Vault at Air Operations Area		6,610	-	-	6,610
Reconstruction of Ramp Pavement Adjacent to Landmark Aviation Phase I		263	-	-	263
Replacement of Pavement (R&R) Phase II		335	-	-	335
Phase 1 Total		**$74,761**	**$37,060**	**$7,009**	**$30,692**
Phase 2 (2021-2025)					
Closure of Taxiway G and a Portion of Taxiway B	Yes	$614	$0	$0	$614
Realignment of Taxiway G and Tie-in to Taxiway C	Yes	20,551	-	-	20,551
Realignment of Taxiway E	Yes	1,687	-	-	1,687
Closure of Old Taxiway E Pavement	Yes	153	-	-	153
Roadway Connection to Beltway 8	Yes	7,974	-	7,974	-
Full-length Parallel Taxiway to Runway 4-22 , Runway 4-22 Exits, and Runway 35 Tie-in	Yes	45,392	9,667	-	35,725
Land Acquisition around Runway 17R End	Yes	1,048	943	-	105
Realignment of Perimeter Road and Fence around Runway 17R End	Yes	1,565	1,409	-	156
Runway 17R End Extension and Taxiway H Extension	Yes	17,098	10,499	4,275	2,324
Decommissioning of Runway 17L-35R	Yes	977	-	-	977
Environmental Assessment - Phase 3 MP Projects	Yes	741	-	-	741
Reconstruction of Ramp Pavement Adjacent to Landmark Aviation Phase II		2,515	-	-	2,515
Improvement of Horsepen Bayou Drainage		8,804	-	-	8,804
Rehabilitation of Outer Panels on Runway 4-22		5,869	-	-	5,869
Grass Island Paving - North Side 2 Phase II		1,963	-	-	1,963
Phase 2 Total		**$116,951**	**$22,518**	**$12,249**	**$82,184**

Table 9-4 (2 of 2): Potential Sources of Funds for the Ellington Airport Capital Improvement Program (in Thousands of Dollars)

			SOURCES OF FUNDS		
PROJECT	MASTER PLAN PROJECT?	TOTAL COSTS (INFLATED)	EXPECTED AIP GRANTS	OTHER FUNDS	HAS SHARE
Phase 3 (2026-2030)					
Rail Spur into Southeast Quadrant	Yes	$8,615	$0	$6,461	$2,154
Road into Southeast Quadrant	Yes	6,892	-	5,169	1,723
Roadway Flyover over Railroad Tracks	Yes	23,780	-	17,835	5,945
Relocation of Oxidizer Loading Area (OLA) and OLA Taxiway Access	Yes	9,827	-	4,914	4,913
Realignment of Taxiways B and D and Closure of Old Pavement	Yes	9,467	8,520	-	947
Runway 17R-35L Full-length Parallel Taxiway on East Side	Yes	23,452	-	11,726	11,726
Phase 3 Total		**$82,033**	**$8,520**	**$46,105**	**$27,408**
TOTAL		**$273,745**	**$68,098**	**$61,295**	**$140,284**

NOTE: MP = Projects recommended in the Master Plan Update

SOURCES: Houston Airport System; Connico, Inc.; Ricondo & Associates, Inc., March 2015.
PREPARED BY: Ricondo & Associates, Inc., April 2015.

9.4 Capital Improvement Program Limitations

A broad, aggregate approach was used in developing the Airport CIP, as projects will be refined before implementation. As discussed earlier, the financial analysis presented in this section differs from that of a typical master plan. Given the dynamics of the three airports included in the Houston Airport System, neither a financial feasibility analysis nor a detailed financial analysis could be conducted without isolating EFD from the other airports in the system. This isolation is inconsistent with the financial decision-making conducted by HAS for the three facilities. As a result, HAS recommended that the discussion in this section be limited to the Airport CIP and potential funding levels from various sources to implement the Airport CIP.

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10. Environmental Overview

Major projects at Ellington Airport are recommended in this Master Plan Update through 2030, as described in previous sections. Many of these projects, including extending Runway 17R-35L, constructing new parallel taxiways, constructing new fueling and oxidizer loading facilities, and constructing a new roadway to the Airport's southeast quadrant, could potentially result in environmental impacts that would require assessment before they are implemented. This Environmental Overview identifies potential environmental impacts of the recommended Master Plan Update projects for later environmental assessment. The environmental resource categories included in FAA Orders 1050.1E and 5050.4B are addressed. This section is intended to inform decision makers of the potential environmental impacts of these projects.

This Environmental Overview is not an Environmental Impact Statement or an Environmental Assessment in accordance with the National Environmental Policy Act of 1969; environmental issues are identified, but are not assessed in detail, nor are no action or alternative actions other than the projects in this Master Plan Update considered. As specific projects from this Master Plan Update are implemented, environmental documentation will be prepared in accordance with NEPA and appropriate FAA guidance to disclose the potential environmental impacts of specific projects, along with the environmental impacts of reasonable alternatives and the no action alternative.

10.1 Aircraft Noise

Airport-related noise is generated mostly from the engines of jet aircraft and the rotors and engines of helicopters. Most airport noise is generated when aircraft approach, depart, or taxi within the airport.

As discussed in Section 6, the loudness, or energy content, of noise is most commonly measured in decibels. Noise measured using a spectrum of frequencies that closely matches the sensitivity of the human ear (and therefore is most relevant to assessing impacts to noise-sensitive receptors) is described in terms of A-weighted decibels.

Table 10-1 lists common sounds and their typical sound levels, measured in dBA. The decibel scale is geometric in terms of human perception (i.e., a 10-decibel increase makes the sound seem twice as loud), but logarithmic in terms of sound pressure energy (i.e., a 10-decibel increase has 10 times as much energy).

Table 10-1: Common Sound Levels in Decibels, Loudness and Sound Energy

SOUND	SOUND LEVEL (dBA)	PERCEIVED LOUDNESS RELATIVE TO 60 dBA	SOUND PRESSURE ENERGY RELATIVE TO 60 dBA
Amplified Rock Music	120	64	1,000,000
Thunder, Snowmobile (Operator)	110	32	100,000
Boiler Shop, Power Mower	100	16	10,000
Orchestra Fortissimo at 25 Feet, Noisy Kitchen	90	8	1,000
Busy Street	80	4	100
Interior of Department Store	70	2	10
Ordinary Conversation at 3 Feet	60	1	1
Quiet Automobile Interior at Low Speed	50	0.5	0.1
Average Office	40	0.25	0.01
City Residence	30	0.125	0.001
Quiet Country Residence	20	0.0625	0.0001
Rustle of Leaves	10	0.03125	0.00001
Threshold of Hearing	0	0.015625	0.000001

SOURCE: U.S. Department of Housing and Urban Development, *Aircraft Noise Impact: Planning Guidelines for Local Agencies*, 1972.
PREPARED BY: Brown-Buntin Associates, 2001.

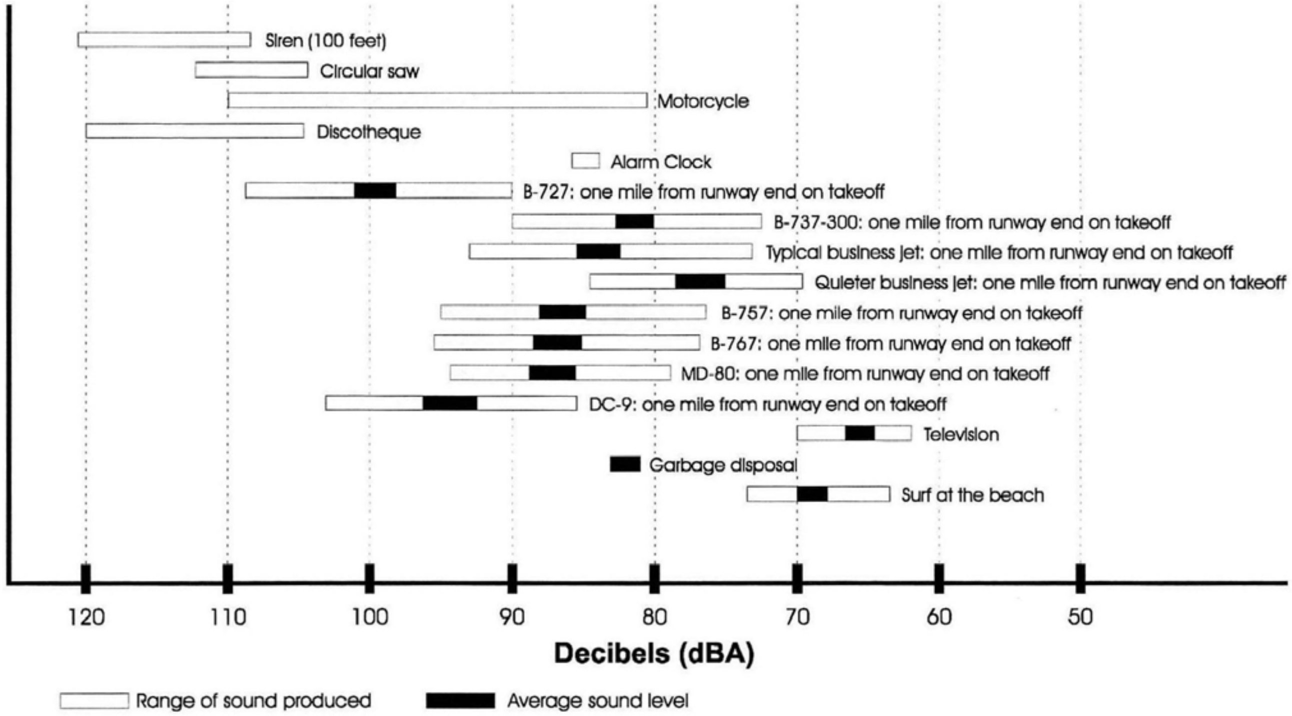
Exhibit 10-1 illustrates the range of sound produced and the average sound level of several aircraft types compared with other sounds, such as sirens, motorcycles, and garbage disposals. Most listeners cannot perceive differences in sounds that differ by 2 dBA or less.

Aircraft noise is expressed in DNL, an integrated noise level in A-weighted decibels. DNL is the equivalent constant noise level of the total energy of actual noise events over time, with nighttime noise events penalized by 10 dBA to account for the quieter noise environment and greater receptor sensitivity at night.

Table 10-2 presents historical and forecast aircraft operations at the Airport. Most operations are by general aviation aircraft, while the military accounts for the second largest number of operations at the Airport. Air carrier aircraft operations at EFD ceased in 2004. Aircraft operations at the Airport after 2012 are forecast to increase at a CAGR of 0.5 percent.

An Airport noise analysis was conducted in 2004. The Integrated Noise Model (INM Version 6) was used to generate contour lines enclosing areas with the same or greater noise levels. **Exhibit 10-2** shows these noise contours for DNL 65, 70 and 75, overlaid onto a 2012 aerial base map.

Exhibit 10-1: Typical Sound Levels

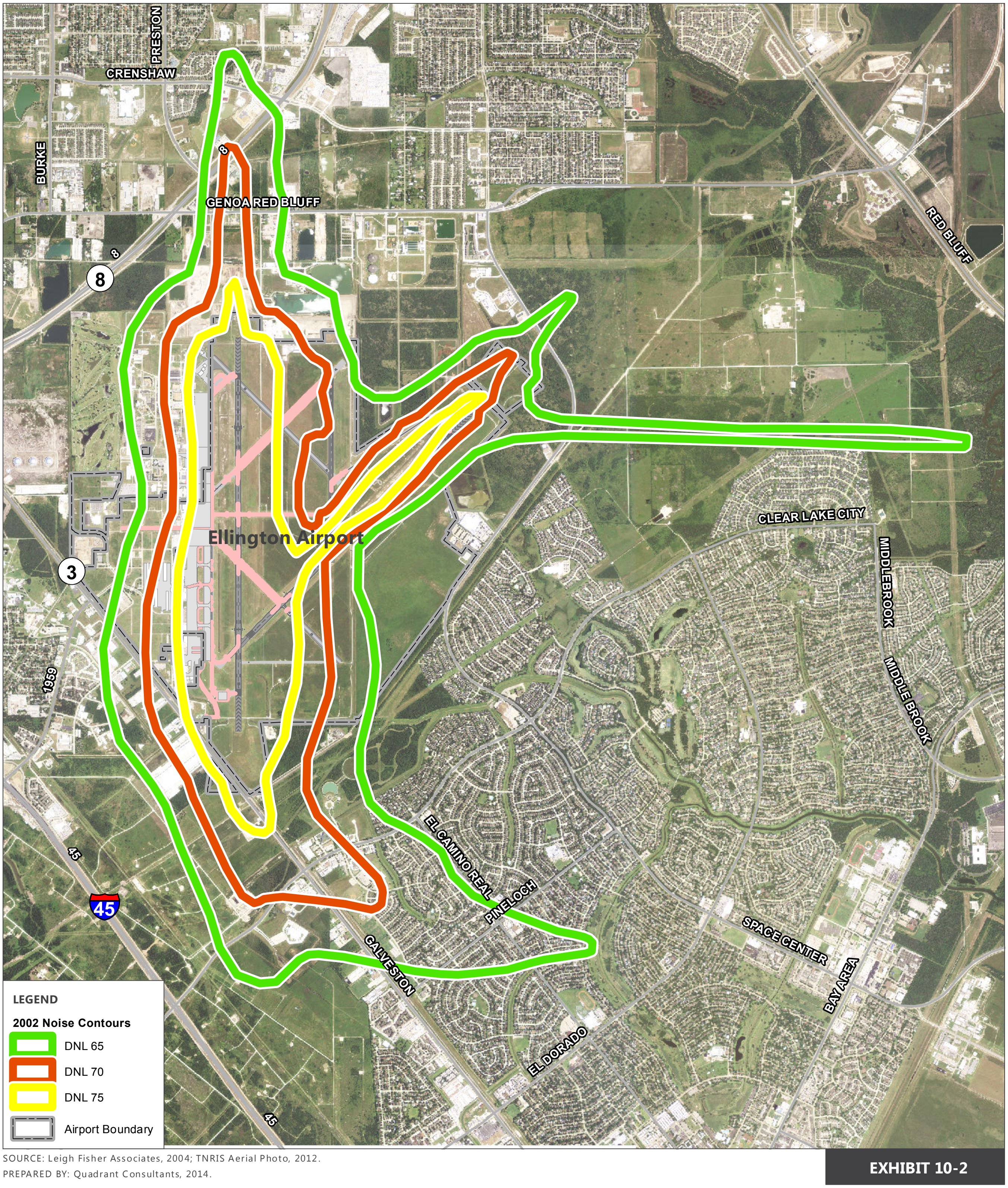


SOURCE: Brown-Buntin Associates, 2001.
PREPARED BY: Brown-Buntin Associates, 2001.

Table 10-2: Historical and Forecast Aircraft Operations at Ellington Airport

YEAR	AIR CARRIER	AIR TAXI	GENERAL AVIATION	MILITARY	AIRPORT TOTAL
Historical					
2006	44	4,270	96,320	30,947	131,581
2007	48	4,450	108,875	34,531	147,904
2008	7	7,150	92,250	36,168	135,575
2009	0	9,748	88,739	28,215	126,702
2010	0	8,592	79,078	22,823	110,493
2011	0	8,160	76,968	23,734	108,862
2012	0	8,827	61,683	27,197	97,707
Forecast					
2013	0	8,960	62,020	27,200	98,180
2014	0	9,100	62,360	27,200	98,660
2015	0	9,230	62,700	27,200	99,130
2020	0	9,850	64,520	27,200	101,570
2030	0	11,280	68,610	27,200	107,090
Compound Annual Growth Rate					
2006-2012	-100%	12.9%	-7.2%	-2.1%	-4.8%
2012-2013	-	1.5%	0.5%	0.0%	0.5%
2012-2015	-	1.5%	0.5%	0.0%	0.5%
2015-2020	-	1.3%	0.6%	0.0%	0.5%
2020-2030	-	1.4%	0.6%	0.0%	0.5%
2012-2030	-	1.4%	0.6%	0.0%	0.5%

SOURCES: Federal Aviation Administration, *Terminal Area Forecast*, 2012; Ricondo & Associates, Inc., 2013.
PREPARED BY: Ricondo & Associates, Inc., 2014.



SOURCE: Leigh Fisher Associates, 2004; TNRIS Aerial Photo, 2012.
PREPARED BY: Quadrant Consultants, 2014.

EXHIBIT 10-2

NORTH

0 3,000 ft.

2002 Noise Contours

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Aircraft operations in 2001 and 2012 are compared in **Table 10-3**. The total number of operations at Ellington Airport was roughly equal in 2001 and 2012; the number of operations in 2012 increased 0.2 percent compared with the number in 2001. The number of operations (led by general aviation) peaked in 2007, and steadily declined through 2012. During that time, substantial changes occurred in the types of aviation activities and the aircraft fleet operating at the Airport. There were 3,356 air carrier aircraft operations at EFD in 2001, but none in 2012, because scheduled commercial air service (Continental Express flights between EFD and IAH) ended at EFD in 2004, while air taxi operations at the Airport increased 56 percent in 2012 compared with 2001. Military aircraft operations decreased 10 percent during that same period, as a result of changes in military priorities. General aviation aircraft operations increased by six percent over this period.

Table 10-3: Comparison of Ellington Airport Aircraft Operations in 2001 and 2012

YEAR	AIR CARRIER	AIR TAXI	GENERAL AVIATION	MILITARY	TOTAL
2001	3,356	5,656	58,217	30,272	97,501
2012	0	8,827	61,683	27,197	97,707

SOURCES: Leigh Fisher Associates, *Comprehensive Master Plan for Ellington Airport,* 2004; Ricondo & Associates, Inc., 2012.
PREPARED BY: Ricondo & Associates, Inc., August 2014.

In summary, air taxi and general aviation aircraft operations increased between 2001 and 2012, while military and air carrier aircraft operations decreased. As air carrier and military aircraft typically generate more noise per operation than air taxi and general aviation aircraft, it could be expected that the noise generated in 2012 would have declined compared to that generated in 2001.

This Master Plan Update includes several recommended airfield changes that could affect noise generation. Decommissioning Runway 17L-35R would eliminate aircraft operations on this runway and noise generation from this source. However, operations would then be relocated to the other runways at the Airport. Extending Runway 17R-35L by 1,000 feet to the north would move the noise exposure area a similar distance northward.

Noise generation at the Airport could also be affected by changes in the aircraft fleet operating at the Airport, including spacecraft. A 50 percent increase in aircraft noise generated would raise noise exposure levels by about 2 decibels. Thus, the forecast increase in air taxi and general aviation aircraft operations by 28 percent and 11 percent, respectively, between 2012 and 2030 would increase noise levels by less than 1 decibel. However, spacecraft noise profiles are not currently available and, if these new aircraft are very noisy and their operations become frequent, they could cause the noise exposure area to increase significantly along the axis of Runway 4-22.

10.2 Compatible Land Use

The FAA has published guidelines in 14 CFR Part 150 regarding the compatibility of residential, institutional, commercial, industrial, and recreational land uses exposed to aircraft noise. **Table 10-4** presents the noise levels that are compatible and incompatible with each land use type. For example, residential land uses are incompatible with the highest aircraft noise levels and is only compatible with lower noise levels with noise reduction measures, while manufacturing land uses are compatible with all noise levels.

As shown in Table 10-4, most land uses are compatible with noise levels below DNL 65 and are incompatible with noise levels above DNL 75. More sensitive land uses are compatible with lower noise levels or noise reduction measures at lower noise levels, and some very sensitive land uses are incompatible with even low levels of aircraft noise exposure.

The following categories of land use are present in the vicinity of the Airport:

- Residential (single family, multifamily, mobile home)
- Commercial (business and professional offices, retail)
- Industrial (warehouses, manufacturing, etc.)
- Public recreational use (public parks, etc.)
- Private recreational use (private golf courses, etc.)
- Institutional (schools, places of worship, public places of assembly)
- Utility and transportation rights-of-way
- Undeveloped (vacant land)

Exhibit 10-3 shows 2011 land uses near the Airport overlaid by the 2002 aircraft noise contours for the Airport. In general, areas southeast, north, and northwest of the Airport are densely developed in mostly residential land uses; areas northeast, west, and southwest of the Airport are less densely developed with some industrial and commercial land uses and some residential land uses. Areas east and south of the Airport have large tracts of undeveloped land. The Pasadena Municipal Golf Course is a recreational land use located west of the Airport.

About 957 homes southeast of the Airport and 11 homes and an apartment building north of the Airport are located within the area exposed to DNL 65, according to the noise contours prepared in 2004. Thirteen homes directly southeast of the Airport are located within the area exposed to DNL 70, according to the contours prepared in 2004. The 2004 noise contours prepared for the Airport indicate that no residential land is located within the area exposed to DNL 75.

Table 10-4: Land Use Compatibility Guidelines

	LAND USE	DNL 65 TO 70	DNL 70 TO 75	GREATER THAN DNL 75
Residential	Residential other than mobile homes and transient lodgings	NLR required	NLR required	Incompatible
	Mobile homes	Incompatible	Incompatible	Incompatible
	Transient lodgings (hotels and motels)	NLR required	NLR required	Incompatible
Public Use	Schools, hospitals and nursing homes	NLR required	NLR required	Incompatible
	Churches, auditoriums and concert halls	NLR required	NLR required	Incompatible
	Governmental services	Compatible	NLR required	NLR required
	Transportation	Compatible	Compatible	Compatible
	Parking	Compatible	Compatible	Compatible
Commercial Use	Offices, business and professional	NLR required	NLR required	NLR required
	Wholesale and retail-building materials, hardware, and farm equipment	Compatible	Compatible	Compatible
	Retail trade (general)	NLR required	NLR required	NLR required
	Utilities	Compatible	Compatible	Compatible
	Communication	NLR required	NLR required	NLR required
Manufacturing and Production	Manufacturing (general)	Compatible	Compatible	Compatible
	Photographic and optical	Compatible	NLR required	NLR required
	Agriculture (except livestock) and forestry	Compatible	Compatible	Compatible
	Livestock farming and breeding	Compatible	Compatible	Incompatible
	Mining and fishing resources production and extraction	Compatible	Compatible	Compatible
Recreational	Outdoor sports arenas and spectator sports	Compatible	Compatible	Incompatible
	Outdoor music shells, amphitheaters	Incompatible	Incompatible	Incompatible
	Nature exhibits and zoos	Compatible	Incompatible	Incompatible
	Amusements, parks, resorts and camps	Compatible	Compatible	Incompatible
	Golf courses, riding stables and water recreation	Compatible	Compatible	Incompatible

NOTES:

DNL = Day-night average sound level, in A-weighted decibels.

Compatible = No special noise attenuating materials are required to achieve an interior noise level of 45 L_{dn} in habitable spaces, or the activity (whether indoors or outdoors) would not be subject to a significant adverse impact by the outdoor noise level.

Incompatible = The land use, whether in a structure or an outdoor activity, is incompatible with the outdoor noise level even if special attenuating materials were to be used in the construction of the building.

NLR = Noise Level Reduction. NLR is used to denote the total amount of noise transmission loss in decibels required to reduce an exterior noise level in habitable interior spaces to 45 L_{dn}. In most places, typical building construction automatically provides an NLR of 20 decibels. Therefore, if a structure is located in an area exposed to aircraft noise of 65 L_{dn}, the interior noise level would be about 45 L_{dn}. If the structure is located in an area exposed to aircraft noise of 70 L_{dn}, the interior noise level would be about 50 L_{dn}, so an additional NLR of 5 decibels would be required if not afforded by the normal construction. This NLR can be achieved through the use of noise attenuating materials in the construction of the structure.

Residential land use is generally incompatible with aircraft noise and should only be permitted in areas of infill in existing neighborhoods or where the community determines that the use must be allowed.

NLR is only required in offices or other areas with noise-sensitive activities.

Outdoor sports arenas are compatible with noise levels up to 75 Ldn provided special sound reinforcement systems are installed.

SOURCE: U.S. Department of Transportation, Federal Aviation Administration, *Federal Aviation Regulations* Part 150, “Airport Noise Compatibility Planning,” Code of Federal Regulations, Title 14, Chapter I, Subchapter I, Part 150, Table 1, January 18, 1985, as amended.
PREPARED BY: Quadrant Consultants, 2013.

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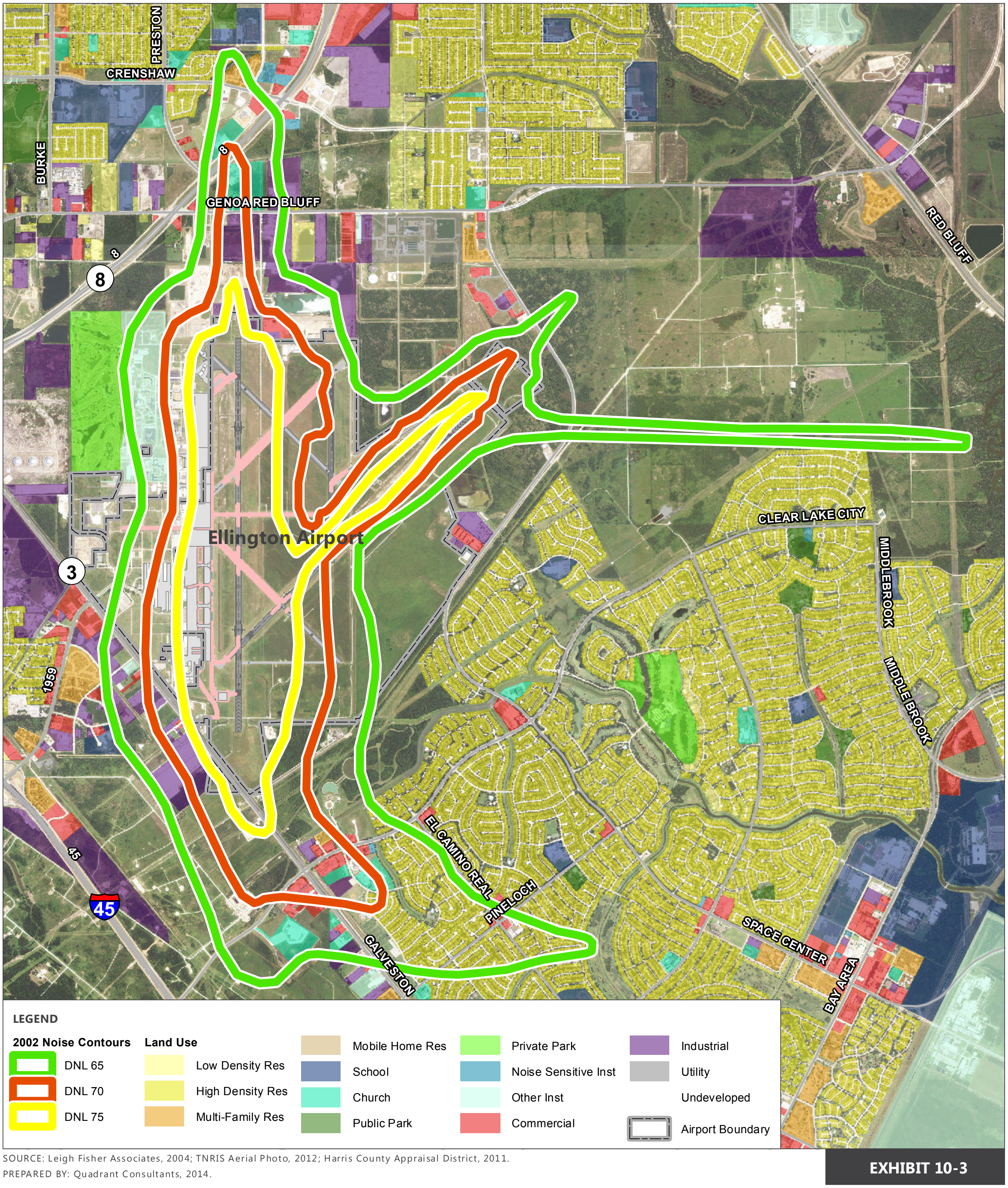

SOURCE: Leigh Fisher Associates, 2004; TNRIS Aerial Photo, 2012; Harris County Appraisal District, 2011.
PREPARED BY: Quadrant Consultants, 2014.

EXHIBIT 10-3

NORTH

0 3,000 ft.

2002 Noise Contours with 2011 Land Use

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10.2.1 FUTURE CONDITIONS

As the number of aircraft operations at EFD is expected to gradually increase, the area exposed to aircraft noise around the Airport may increase slightly. Future noise contours are likely to encompass more area north of the Airport as a result of the recommended extension of Runway 17R-35L. Approximately 20 to 50 more residences may be exposed to DNL 65 as a result of operations on the extended runway. However, if spacecraft generate much more noise than the current aircraft fleet operating at the Airport, the area exposed to aircraft noise could change significantly. Further analysis of noise impacts and land use compatibility would be required as projects supporting the spaceport are implemented.

10.2.2 ORDERLY DEVELOPMENT

This Master Plan Update highlights areas surrounding the Airport that are likely to have incompatible land uses. Although the Master Plan Update would not affect current or planned development in surrounding areas, it would result in changes in noise exposure and, therefore, should be accompanied immediately by an amendment to Houston’s land use control ordinance for the area around the Airport. This ordinance protects the Airport from height hazards and surrounding land from being developed in incompatible land uses. As projects that could affect noise exposure are implemented on the Airport, the locations of incompatible land uses will change and, therefore, the areas designated for land use control tiers should also change. Timely amendment to the land use control ordinance would ensure orderly development of compatible land uses near the Airport.

10.3 Socioeconomic Impacts, Environmental Justice, and Children’s Environmental Health and Safety Risks

Airport development can also affect the human environment by displacing homes and businesses or by changing access, traffic patterns, and aesthetics. Potential social and economic impacts that may result from Airport development are discussed below.

10.3.1 RELOCATIONS OF RESIDENCES AND BUSINESSES

The recommended Master Plan Update projects would lead to the acquisition of approximately 47 acres of land north of Runway 17R-35L. This land currently accommodates industrial and undeveloped land uses. Up to two businesses would need to be relocated. Ample land is available nearby to rebuild these businesses, which would occur with HAS assistance.

In addition, 13 residences southeast of the Airport are within the area exposed to DNL 70 and would be relocated or soundproofed. These homes are in Clear Lake City, a large residential community with many similar homes currently available for purchase. HAS would assist with relocating these residents.

10.3.2 COMMUNITY COHESION AND ACCESS TO SOCIAL SERVICES

Areas southeast and northwest of the Airport (from the 2007-2011 American Community Survey by the U.S. Department of Commerce, Bureau of the Census) are relatively populous. Areas northeast and west of the Airport are moderately populated, while areas to the east and southwest are less populous.

Low-income populations (families whose household incomes below the poverty level, as defined by the U.S. Department of Housing and Human Services) west and northwest of the Airport range from 25 percent to 35 percent of the total population, which is higher than the Houston average of 18 percent. Conversely, the area southeast of the Airport has low-income populations ranging from 0 to 10 percent of the total population.

Racial minorities (African American, American Indian, Asian, others, and more than one race) are broadly distributed in the Airport vicinity. The proportions of residents that categorize themselves into one of these racial minority populations are slightly higher toward the west side of the Airport. Likewise, the proportions of residents that identified themselves as Hispanic are evenly distributed, with a slight increase west and northwest of the Airport.

In summary, the area within 3 miles of the Airport is home to racial and ethnic minorities, and the area north and west of the Airport is home to more than the Houston average of 18 percent of families with income below the federal poverty level. Consequently, actions that affect populations near the Airport (such as property acquisition and noise level changes), especially those projects that affect communities north and west of the Airport, could affect minority or low-income populations disproportionately, and an environmental justice assessment may be required during the planning for specific Airport projects.

10.3.3 EMPLOYMENT

The recommended Master Plan Update projects would displace two industrial businesses, but it is expected that these businesses could relocate nearby, resulting in no change in employment. Furthermore, Airport improvements would create jobs during construction, and new and expanded facilities at the Airport would create new permanent jobs.

10.3.4 RAIL AND ROADWAY TRAFFIC NOISE

A new rail spur from the Union Pacific Railroad tracks is recommended parallel to SH 3 to the southeastern area of the Airport, as well as a connector road from Old Galveston Road to the southeast quadrant at EFD. If either of these projects is completed (both are demand/need driven), they would result in a change in rail and roadway traffic. The rail spur may carry oxidizer to tanks at the Airport. The new road would provide access to the proposed spacecraft hangar and education center in the southeast quadrant, and could also divert vehicular traffic that currently routes through Clear Lake City. The new railroad and roadway would bring noise-generating vehicles (railcars and locomotives, and cars and trucks, respectively) closer to homes in Clear Lake City southeast of the Airport. However, these facilities would function as spurs for vehicles destined for Ellington Airport only and, therefore, traffic on both would be light. Noise from these facilities would need to be the subject of environmental assessments preceding the design phase for these projects.

Overall, the modest aviation activity growth forecast at Ellington Airport is expected to cause little change in automobile and truck traffic on Old Galveston Road related to the Airport; therefore, traffic noise related to the Airport is not expected to significantly change.

10.4 Secondary (Induced) Impacts

Secondary impacts (also called induced or indirect impacts) occur when a project enables additional development that causes additional environmental impacts. An example of a secondary impact for an airport expansion project could be demand for additional warehouse and light industry resulting from the additional aviation activity, which causes additional land development and consequent loss of habitat and water pollution.

The recommended projects in this Master Plan Update would increase both the capacity of the Airport and the types of aviation activity served. However, only modest growth in aviation operations is forecast at the Airport through 2030. Therefore, new businesses on and around the Airport would be mostly in support of the proposed spaceport. It is estimated that such secondary development would affect about 50 acres of undeveloped land on the east side of the Airport. This induced development could cause additional environmental impacts during construction, including loss of forest and wetlands, water pollution by erosion and sedimentation, air pollution by fugitive dust and emissions from construction equipment, and increased storm water runoff because of increased impermeable surfaces. However, any new development would be subject to federal, state of Texas, and local laws requiring control of air and water pollution and management of hazardous materials. Secondary environmental impacts from Master Plan Update projects would be analyzed before design and construction of any Airport facilities are initiated.

10.5 Air Quality

Procedures to analyze and evaluate air quality at airports are described in the FAA report *Air Quality Procedures for Civilian Airports and Air Force Bases*, and the U.S. EPA report *An Air Pollution Impact Methodology for Airports: Phase 1*. The types of air quality analyses that might be required for projects recommended in this Master Plan Update are discussed in the subsections that follow.

10.5.1 REGULATORY REQUIREMENTS

The Clean Air Act of 1970 requires states to identify areas where national ambient air quality standards are not met for six criteria pollutants. The U.S. EPA designates such areas as nonattainment areas. A state with a nonattainment area must prepare a State Implementation Plan that details the programs and requirements for the state to meet the air quality standards by specified deadlines.

The Clean Air Act Amendments of 1990 require federal agencies to ensure that their actions not only conform to State Implementation Plans, but also reduce the severity and number of violations of air quality standards to achieve expeditious attainment of the standards. Actions or projects funded and approved by the FAA are subject to the General Conformity regulations of the Clean Air Act Amendments (40 CFR Part 93, Subpart B).

To comply with the General Conformity regulations, two criteria must be met:

- Total direct and indirect pollutant emissions from a project in a nonattainment area must be included in a SIP budget, or must be below *de minimis* emissions levels established for the nonattainment area; and
- Pollutant emissions from the project must not be "regionally significant;" the project must not contribute 10 percent or more of the region's total emissions of a criteria pollutant.

If total annual pollutant emissions from a project (including its indirect effects) would be below *de minimis* levels and would not be regionally significant, the project is presumed to conform to the SIP and no further air quality analysis is required. If a project's total annual emissions would exceed *de minimis* levels, a conformity determination and pollution assessment, including pollutant dispersion analysis, would be required.

Many projects at airports are too small to require a detailed pollution assessment; only a few projects in nonattainment areas have been broad enough in scope to require determination of air quality conformity through an emissions inventory and dispersion analysis. However, the number of airport projects for which conformity determinations have been required in the past decade has increased.

10.5.2 CURRENT AIR QUALITY

Ellington Airport is in the Houston-Galveston-Brazoria air quality control region, which is currently designated as being in marginal nonattainment for ozone. Ozone is not emitted directly, but is the product of the atmospheric chemical reaction of the ozone precursors, nitrogen oxides (NO_x) and volatile organic compounds (VOC), in the presence of sunlight. The *de minimis* emission level for each of these pollutants is 25 tons per year.

Each project recommended in the Master Plan Update, as it undergoes preliminary design, would be evaluated for its impact on air quality under NEPA during the preparation of an environmental impact assessment. **Table 10-5** lists the major projects recommended in this Master Plan Update, and indicates the types of air quality assessments that would be required before each project may receive FAA approval. The four types of air quality assessments listed in Table 10-5 are discussed below.

Table 10-5: Air Quality Analyses for Master Plan Update Projects

PROJECT	OPERATIONS EMISSIONS INVENTORY	CONSTRUCTION EMISSIONS INVENTORY	CARBON MONOXIDE ASSESSMENT	GENERAL POLLUTION ASSESSMENT
Phase 1 Projects				
Decommission Runway 17L-35R	✓			
Construct two T-hangar buildings along Taxiway K		✓		✓
Construct GA Activity Center on south ramp	✓	✓		✓
Construct first spaceport hangar, taxiway extension, education facilities, and Incubator Space on southeast airfield	✓	✓		✓
Construct temporary oxidizer storage area in southeast airfield	✓	✓		✓
Construct roadway from SH 3 to education facilities		✓	✓	
Construct spacecraft fuel storage facility	✓	✓		✓
Phase 2 Projects				
Acquire land on north end of Airport				
Extend Runway 17R-35L to the north	✓	✓		✓
Close Taxiway G and parts of Taxiways B, C, and E	✓			
Construct parallel taxiway for Runway 17R-35L extension	✓	✓		✓
Construct parallel taxiway for Runway 4-22 with tie-in to Runway 35L	✓	✓		✓
Construct hangars south of existing T-hangars		✓		✓
Construct roadway connector to Sam Houston Parkway		✓	✓	
Phase 3 Projects				
Construct parallel taxiway along Runway 17R-35L	✓	✓		✓
Construct permanent oxidizer storage and loading areas off Taxiway C	✓	✓		✓
Construct rail spur into southeast airfield	✓	✓		✓
Construct roadway flyover ramp over SH 3		✓	✓	

SOURCE: Ricondo & Associates, Inc., August 2014.
PREPARED BY: Quadrant Consultants, September 2014.

10.5.3 OPERATIONS EMISSIONS INVENTORY

An operations emissions inventory is performed to assess the quantities of pollutant emissions resulting from changing airport activity levels or changes in how aircraft operate at the airport as a result of runway or taxiway modifications. If, because of an airport project, the number, type, or operating patterns of mobile sources, such as aircraft, GSE vehicles, or passenger vehicles change, or if the number or emissions rates of point sources, such as boilers and fuel tanks, change, then an operations emissions inventory analysis is warranted. If project-related emissions (direct and indirect) are shown to not exceed *de minimis* thresholds over the planning period, then no further air quality analysis is required. If project-related emissions are calculated to exceed the *de minimis* thresholds over the planning period, a general conformity analysis is required. The FAA and the U.S. EPA have approved the Emissions and Dispersion Modeling System (EDMS) for use in estimating emissions and pollutant concentrations at airports. The FAA is anticipated to release the Aviation Emissions Development Tool, which will replace EDMS, in 2015.

10.5.4 CONSTRUCTION EMISSIONS INVENTORY

A construction emissions inventory is conducted to assess emissions caused by temporary construction and demolition activities during project implementation. Typical sources of construction-related emissions are off-road equipment (backhoes, drilling rigs, and mixers), on-road equipment (dump trucks and concrete trucks) and passenger vehicles used by construction employees. Several projects recommended in this Master Plan Update involve construction or demolition of landside or airside facilities and may require a construction emissions inventory.

Construction emissions analyses are not modeled. Emissions for construction equipment are calculated from factors presented in U.S. EPA Report AP-42, *Compilation of Air Pollutant Emissions Factors,* Volume 11: “Mobile Sources,” Fourth Edition. Similar to the operations emissions inventory, the construction emission inventory triggers a pollution assessment if the direct and indirect emissions of the project exceed *de minimis* thresholds. Construction-related emissions for most airport projects are below *de minimis* thresholds, but emissions caused by on-road construction vehicle trips may require general pollution assessments (described in Section 10.5.6).

10.5.5 CARBON MONOXIDE ASSESSMENT

If a project would substantially increase traffic volume at roadway intersections on or near the airport, it has the potential to cause harmful levels of carbon monoxide (CO) near those intersections. CO is a poisonous gas byproduct of incomplete fuel combustion. The purpose of conducting a carbon monoxide assessment is to determine if project-related emissions of CO from motor vehicles would cause an exceedance of the national ambient air quality standard. Intersections predicted to have high traffic volumes and low levels of service are modeled using the MOBILE 6 emissions model and the CAL3QHC dispersion model.

10.5.6 GENERAL POLLUTION ASSESSMENT

If total pollutant emissions from an airport project (including indirect causes) could exceed *de minimis* thresholds in a nonattainment area, and/or pollutant concentrations could exceed national ambient air quality standard for any of the six criteria pollutants, a general pollution assessment is performed. For a general pollution assessment, future project emissions are estimated for no action and each project alternative. The dispersion of future emissions is then modeled using EDMS to determine future pollutant concentrations, which are then added to background concentrations and compared to the standard. If expected pollutant concentrations would not exceed the standard, the project can obtain an air quality certificate from the Texas Commission on Environmental Quality and the pollution assessment is complete. If expected pollutant concentrations would exceed the standard, emissions must be mitigated or offset, the project must be redesigned to reduce emissions, or a general conformity analysis must be performed.

10.6 Water Quality

Two streams flow near Ellington Airport: Armand Bayou to the east and Horsepen Bayou to the south. Both flow to Clear Creek, which then flows to Galveston Bay. Both Armand Bayou and Horsepen Bayou are waters of the United States, but neither is a navigable water of the United States near Ellington Airport.

Airport stormwater drains to two ditches. Most of the Airport stormwater drains to a ditch that runs along the southern boundary of the Airport and flows east to Horsepen Bayou. The northeast end of Runway 4-22 drains to a ditch that crosses the Airport from northwest to southeast and also flows to Horsepen Bayou. These ditches appear to have been cut from uplands and do not appear to be waters of the United States. If any Master Plan Update project would affect these drainage features, a wetland determination should be conducted to determine their jurisdictional status.

The 2012 list of impaired stream segments under Section 303(d) of the Clean Water Act and published by the Texas Commission on Environmental Quality[1] shows that the Airport does not include a threatened or impaired stream segment, but is within 5 miles upstream of such a stream. Horsepen Bayou Tidal (Segment 1113B) is listed as impaired due to fecal coliform bacteria counts. Coordination with the TCEQ would be required for total maximum daily loads.

Construction of Airport facilities would be required to comply with TCEQ's Construction General Permit, which is an element of the Texas Pollutant Discharge Elimination System (TPDES). To comply, best management practices would be used on projects to reduce erosion and sedimentation in streams during construction, and to reduce long-term inputs of suspended solids. Examples of such practices are silt fences, rock or hay filter dikes, sodding or mulching bare slopes, and vegetation filter strips. If the site exceeds an acre, a Notice of Intent to comply with the permit would be filed with the TCEQ before construction, and if the site exceeds 5 acres, a Storm Water Pollution Prevention Plan would be prepared and maintained at the Airport.

Ellington Airport's water is supplied by the City of Houston from surface water resources in the San Jacinto and Trinity River watersheds. Groundwater is not used at the Airport except in cases of unexpected interruption of surface water supplies. These emergency groundwater supplies come from the Chicot and Evangeline aquifers, for which wells are drilled at least 1,000 feet deep. Surficial groundwater in the Airport vicinity is usually encountered at a depth of 10 to 15 feet; this water is not of potable quality and yields poorly from the clayey soils typically found at such depth.

10.7 DOT Act, Section 4(f) Lands

Section 4(f) of the Department of Transportation Act of 1966 specifies that transportation projects cannot take land from public parks, historic sites, or wildlife refuges without first determining that there is no reasonable and prudent alternative. Takings can include physical acquisition of these lands, or environmental impacts, such as high noise levels, that would make these lands unsuitable for their desired uses.

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[1] Texas Commission on Environmental Quality, *Draft 2012 Texas Integrated Report - Texas 303(d) List (Category 5)*, 2013, http://www.tceq.state.tx.us/waterquality/assessment/waterquality/assessment/12twqi/twqi12. Accessed September 2014.

No public park, SPARK[2] park, known historic site, or wildlife refuge would be either directly taken or rendered unsuitable for use by a recommended project in this Master Plan Update. No Section 4(f) land would be affected by any recommended project in the Master Plan Update. If any Master Plan Update project would affect an existing structure, an assessment to determine eligibility for listing in the National Register of Historic Places should be conducted.

10.8 Historic, Architectural, Archaeological, and Cultural Resources

Two applicable federal laws affect historic, architectural, archaeological, and cultural resources:

- The National Historic Preservation Act of 1966 establishes the Advisory Council on Historic Preservation to advise the President and Congress on historic preservation matters, recommend measures to coordinate federal historic preservation activities, and comment on federal actions affecting properties listed in (or eligible for) the National Register of Historic Places.
- The Archaeological and Historic Preservation Act of 1974 provides for the survey, recovery, and preservation of significant scientific, prehistoric, historical, archaeological, or paleontological data when such data may be destroyed or irreparably lost due to a federal, federally funded, or federally licensed project.

The Texas Historical Commission's *Texas Historic Sites Atlas*[3] shows no site listed in the National Register of Historic Places, no State Archaeological Landmark, no Official State Historical Marker, and no Recorded Texas Historic Landmark within one mile of the Airport. If any Master Plan Update project would affect an existing structure, an assessment to determine eligibility for listing in the National Register of Historic Places should be conducted. Additionally, if any Master Plan Update project would affect undisturbed land areas, an archaeological survey should be conducted to determine the presence/absence of archaeological resources.

10.9 Biotic Communities

Biotic communities consist of vegetation and wildlife in their habitats. The biotic community of Ellington Airport is mostly mowed grasses with a few remnant woods, especially in the less-developed southeast quadrant of the Airport.

The recommended airfield modifications (i.e., decommissioning of Runway 17L-35R, extension of Runway 17R-35L, new taxiways parallel to Runways 17R-35L and 4-22) would affect only mowed grassed areas and not woodland. The 47 acres of land to be acquired at the north end of Runway 17R-35L are in industrial uses and are paved or have mowed grasses. Building the roadway connector to the Sam Houston Parkway along the

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[2] SPARK stands for "School Park Program," in which public school playgrounds are used as public parks after school hours.

[3] Texas Historical Commission, *Texas Historic Sites Atlas*, 2013. http://atlas.thc.state.tx.us/index.asp. Accessed September 2014.

west side of the Airport and the Pasadena Golf Course would require cutting about 20 trees along a fence row. These recommended projects would not result in significant impacts to biotic communities. However, before any Master Plan Update project is implemented, a review of federal and State databases should be conducted to determine any known occurrences of threatened or endangered species or critical habitat. Additionally, the Migratory Bird Treaty Act protects migratory birds from take or harassment; surveys to determine the presence/absence of nesting migratory birds should be conducted prior to initiation of construction activities.

10.10 Endangered and Threatened Species of Flora and Fauna

Endangered species of plants or animals are species that are in danger of extinction throughout all or much of their ranges. Threatened species are likely to become endangered soon. The U.S. Fish and Wildlife Service is responsible for determining which species are endangered and providing for their continued survival. The U.S. FWS also lists candidate species, which are proposed for listing as endangered or threatened, but have not yet been so confirmed. The Texas Parks and Wildlife Department also lists endangered and threatened species in Texas, along with species and habitats of concern (which have no protection status) and works to preserve them.

The U.S. FWS and the TPWD were contacted to provide comments on Ellington Airport regarding these listed species and habitats. The FWS indicated that the recommended projects in the Master Plan Update would have no effect on known endangered, threatened, or candidate species. The TPWD indicated that the recommended projects in the Master Plan Update would not affect known endangered or threatened species, species of concern, or habitat of concern.

Field observations at Ellington Airport and in the land proposed for acquisition discovered no endangered species habitat. As projects are selected for implementation, coordination with the U.S. FWS and the TPWD would need to occur to confirm no effects on endangered or threatened species or critical habitat.

10.11 Wetlands

Wetlands are habitats that are frequently inundated or saturated with water, have soils that show the effects of saturation, and support species of plants that are adapted to wet conditions. Different wetlands perform different ecological services that are valuable to society, including water quality improvement, wildlife habitat, storm water detention, and ground water recharge.

Executive Order 11990, *Protection of Wetlands*, directs federal agencies to minimize the destruction, loss, or degradation of wetlands on federal property or on projects with federal funding. Wetlands that are adjacent to waters of the United States, or have a significant physical, chemical, or biological nexus with such waters are also considered waters of the United States. These jurisdictional wetlands are protected under Section 404 of the Clean Water Act of 1972 and require a permit from the U.S. Army Corps of Engineers before they may be filled.

Wetlands were identified within the Airport boundary during field observations. These wetlands are northeast of the end of Runway 4-22 in the fenced runway protection zone. No recommended project in this Master Plan Update would affect these wetlands.

Field verification and delineation would be required to determine whether wetlands are present, their extent, and whether they are jurisdictional under Section 404. During environmental assessment of projects recommended in this Master Plan Update, a field delineation (as necessary) using the technical guidelines and methods described in the *2009 Regional Supplement to the 1987 Corps of Engineers Wetland Delineation Manual for the Atlantic and Gulf Coastal Region* would be performed to confirm hydrologic, vegetation, and soil indicators, as well as connections to waters of the United States.

10.12 Floodplains

The 100-year floodplain is the area that has a 1.0 percent chance of flooding in any given year. Executive Order 11988, *Floodplain Management*, requires federal agencies to avoid or minimize activities that directly or indirectly result in developing floodplain areas. The City of Houston is a participant in the National Flood Insurance Program.

Approximately 146 acres at the southern end of the Airport are in the 100-year floodplain. None of the recommended projects in this Master Plan Update, and none of the land recommended for acquisition in this Master Plan Update, would be in the 100-year floodplain.

Each development in Harris County is required to have a plat of the development approved by the Harris County Flood Control District. The purpose of the approval process is to ensure compliance with design criteria, rules, and regulations for the area to be developed. The City of Houston must also review and approve the drainage plans for new development within the City limits.

For development areas over 10 acres, the provision of on- or off-site detention ponds is required to mitigate storm water runoff. For development areas that are 10 acres or less, a fee is paid to the Harris County Flood Control District to compensate for the increased water runoff. The District is responsible for providing the necessary drainage infrastructure improvements to accommodate the increase in storm water runoff from development areas that are less than 10 acres.

10.13 Coastal Zone Management Program

The Texas Coastal Management Plan, administered by the Texas General Land Office, governs coastal resources along the Texas Gulf Coast. Projects for which State support is sought must be consistent with the

Texas Coastal Management Plan. The Airport is in the area encompassed by the Coastal Management Plan. Before a Master Plan Update project is implemented, HAS would ensure that the proposed activity, its associated facilities, and their probable effects comply with the relevant enforceable policies of the Texas Coastal Management Plan, and that the proposed activity will be conducted in a manner consistent with such policies.

10.14 Coastal Barriers

Coastal barriers are narrow islands or margins along the Texas Gulf Coast with active dunes (or structures built to replace them). In Texas, these barriers are managed to prevent beach erosion. The Airport is not on a coastal barrier, and Master Plan Update projects will not affect coastal barriers.

10.15 Wild and Scenic Rivers

Wild and scenic rivers are designated by the U.S. Department of the Interior to protect the most beautiful and unspoiled rivers in the nation under the Wild and Scenic Rivers Act. These rivers have exceptional beauty, are historic and natural resources, provide aquatic and wildlife habitats, and have geological value. Only one river in Texas, the Rio Grande at Big Bend, is designated as a wild and scenic river. The Airport is not near this river and, therefore, the Master Plan Update projects will not affect a wild and scenic river.

10.16 Farmland

Preservation of prime farmland is a priority goal for the U.S. Department of Agriculture, and the impacts on prime farmland of projects with federal support must be assessed. The Airport is in an urban area. No farmland is on or adjacent to the Airport, and no farmland would be lost due to the Master Plan Update projects.

10.17 Energy Supply and Natural Resources

The projects recommended in this Master Plan Update would add facilities within the current Airport boundary and 47 acres of land at the northern end of the Airport would be acquired. Paved areas or grasslands would be developed and few natural resources, such as wildlife habitat and stream habitat, would be affected. The Airport is not a major consumer of regional fresh water supplies.

The Master Plan Update projects would increase the capacity of the Airport to accommodate future demand by existing and future aircraft types. The Airport and aircraft operating at the Airport would consume more energy in the future because of the increased demand for aviation services. Most of the energy would be consumed in the form of fuel for aircraft and GSE, specifically jet fuel (Jet A), propeller aircraft fuel (100LL), spacecraft fuel and oxidizer, and gasoline and diesel fuel. Fuel suppliers are anticipated to have adequate supplies of fuel to supply Ellington Airport throughout the planning period.

Increased consumption of electricity to power airfield and landside lighting, air conditioning and heating inside terminals and other buildings, and many other functions would also occur. Electricity consumption would most likely increase less than 10 percent of current consumption, with increasing numbers of facilities consuming power being partially offset by energy conservation measures. Currently, NRG Energy, which is among the largest power marketers in North America, provides electric power to Ellington Airport. NRG Energy and other Texas energy suppliers are expected to meet demand through the planning period (2030), including the energy requirements for the Airport.

10.18 Light Emissions and Visual Impacts

Light emissions from navigational aid lights on the airfield and illumination of ramp areas can annoy residents near the Airport if their homes are on a line of sight with Airport light sources. Navigational aid light sources are present throughout the airfield and beyond the ends of the runways, and the ramp area lights are mostly around buildings. The recommended extension of Runway 17R-35L would place runway lights about 1,200 feet further north, but there are no light-sensitive receptors, such as residences, nearby that would be affected by this light source. Therefore, light emissions would not significantly affect receptors near the Airport.

Light emissions would also occur during construction if airfield construction is performed at night. Construction light emissions from projects in the southern and southeastern parts of the airfield would be most likely to affect residential areas. Construction lighting would be restricted to work areas and shielded to reduce impacts to adjacent residential areas.

10.19 Hazardous Material, Pollution Prevention and Solid Waste

10.19.1 MUNICIPAL SOLID WASTE LANDFILL SITES

The Airport generates moderate amounts of solid waste that must be disposed of at secure and regulated disposal sites to prevent water pollution and contamination of surrounding areas. The volume of solid waste from the Airport is expected to increase slightly as the Master Plan Update projects are constructed. Area landfills have adequate capacity to accommodate the solid waste stream from the Airport through the planning period.

10.19.2 HAZARDOUS MATERIALS

Records from the U.S. EPA and the TCEQ as of February 6, 2014, show that no site poses a threat of contamination to the Airport. Nevertheless, for Master Plan Update projects near potentially contaminating facilities, such as fuel tanks and machine shops, a Phase 1 level environmental site assessment should be conducted, including visual inspection of the project area and surroundings, to determine if contamination may have occurred.

10.20 Construction Impacts

Construction activities can create effects at the construction site and in the surrounding area. These effects are generally temporary in nature, subsiding once construction is completed. The affected environmental categories include air quality, noise, water quality, traffic, and solid and hazardous waste.

10.20.1 AIR QUALITY

Construction activities can affect air quality around the Airport through emissions of pollutants from construction equipment and through the generation of fugitive dust from demolition, construction, and material and waste hauling. A general conformity analysis will be necessary for each construction project. Table 10-5, presented earlier, indicates which Master Plan Update projects will require an air quality analysis for construction.

Construction of the Master Plan Update projects would generate fugitive dust when dry, bare soil is exposed to wind erosion, especially during clearing and earth-moving operations. The effect of fugitive dust generation during construction would be an increase in dust downwind of the area of active construction, generally within the construction area. Construction contracts should include provisions to water bare soil to prevent wind erosion and fugitive dust generation.

10.20.2 NOISE

Noise would be generated during construction by onsite equipment and heavy vehicles entering and leaving construction sites. Most vehicles delivering items to the construction sites would be expected to be active only during daylight hours. Construction on the southeastern and eastern sides of the Airport would be close to residential areas; construction contracts for work in these areas should specify that equipment will only be operated during daylight hours.

10.20.3 WATER QUALITY

Construction activities can cause erosion or siltation mainly due to storm water runoff. A TPDES construction permit application, which is required for all construction areas of 5 acres or more, must be filed with the TCEQ for all construction activities related to the recommended projects. As part of the TPDES permit application, a construction Storm Water Pollution Prevention Plan would also be prepared. This plan would require erosion and siltation control measures, such as silt fences, hay bales, and retention basins, to protect water quality during construction.

10.20.4 SOLID AND HAZARDOUS WASTE

Construction would generate solid waste from demolition activities and excavation. This material would be removed from the Airport property and disposed of in an appropriate landfill. Construction of recommended projects would not be expected to generate significant amounts of hazardous material, but further analysis would be required to confirm this. Any hazardous waste would be disposed of according to applicable local, State, and federal regulations.

10.20.5 TRAFFIC

Construction traffic would access the Airport via major thoroughfares and streets in industrial areas wherever possible and not via residential streets. Temporary disruption of traffic flow is possible during construction, but would occur during off-peak hours whenever possible.

Appendix A

List of Acronyms

Appendix A List of Acronyms

AAC	Aircraft Approach Category
AC	Advisory Circular
ADG	Airplane Design Group
AGL	Above Ground Level
AIP	Airport Improvement Program
ALP	Airport Layout Plan
ALS	Approach Lighting Systems
AOI	Area of Influence
ARC	Airport Reverence Guide
ARFF	Aircraft Rescue and Firefighting
ARNG	United States Army National Guard
ARTCC	Air Route Traffic Control Center
ASC	Airfield Services Complex
ASV	Annual Service Volume
ATC	Air Traffic Control
ATCT	Airport Traffic Control Tower
ATSA	Aviation and Transportation Security Act
avgas	Aviation Gasoline
BRL	Building Restriction Line
CAGR	Compound Annual Growth Rate
CAT	Category
CBO	Corporate Business Operator
CBP	United States Customs and Border Protection
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CERCLIS	Comprehensive Environmental Response, Compensation, and Liability Information System

CIP	Capital Improvement Program
CO	Carbon Monoxide
COCOM	Combatant Command
dB	Decibels
dBA	A-weighted Decibels
DHS	Department of Homeland Security
DME	Distance Measuring Equipment
DNL	Day-Night Average Sound Level
DOD	United States Department of Defense
DOT	Department of Transportation
EDMS	Emissions and Dispersion Modeling System
EFD	Ellington Airport
EFJRB	Ellington Field Joint Reserve Base
EPA	United States Environmental Protection Agency
FAA	Federal Aviation Administration
FBO	Fixed Base Operator
FEMA	Federal Emergency Management Agency
FM	Farm to Market
FWS	United States Fish and Wildlife Service
GA	General Aviation
GDP	Gross Domestic Product
GIMS	Geographic Information and Management System
GPS	Global Positioning System
GRP	Gross Regional Product
GSE	Ground Support Equipment
HAS	Houston Airport System
HCAD	Harris County Appraisal District
HIRL	High-Intensity Runway Lights
HOU	William P. Hobby Airport
IAH	George Bush Intercontinental Airport/Houston
IBD	Inhabited Building Distance
IFR	Instrument Flight Rules
ILS	Instrument Landing System
IMC	Instrument Meteorological Conditions
INM	Integrated Noise Model
JP8	Jet Propellant 8

kV	Kilovolt
LIRL	Low-Intensity Runway Lights
LOC	Localizer
MALSF	Medium-Intensity Approach Lighting System with Sequenced Flashers
MALSR	Medium-Intensity Approach Lighting System with Runway Alignment Indicatory Lights
MIRL	Medium-Intensity Runway Lights
MMD	Municipal Management Districts
MRO	Maintenance, Repair, and Overhaul
MSA	Metropolitan Statistical Area
MSL	Mean Sea Level
MTFP	Major Thoroughfare and Freeway Plan
MTOW	Maximum Takeoff Weight
NASA	National Aeronautics and Space Administration
NCDC	National Climatic Data Center
NAAQS	National Ambient Air Quality Standards
NEPA	National Environmental Policy Act of 1969
NEZ	Neighborhood Empowerment Zone
NOx	Nitrogen Oxide
O&M	Operating and Maintenance
OAPM	Optimization of Airspace and Procedures in the Metroplex
OFZ	Object Free Zone
OLA	Oxidizer Loading Area
OSP	Outside Plant
PAL	Planning Activity Levels
PAPI	Precision Approach Path Indicator
PID	Public Improvement Zone
PMAD	Peak Month and Peak Month Average Day
RCRA	Resource Conservation and Recovery Act
RDC	Runway Design Codes
REDIM	Runway Exit Design Interactive Model
RNAV	Area Navigation
ROFA	Runway Object Free Area
RPZ	Runway Protection Zone
RSA	Runway Safety Area
SH	State Highway

SIP	State Implementation Plan
TACAN	Tactical Air Navigation System
TAF	Terminal Area Forecast
TCEQ	Texas commission on Environmental Quality
TDG	Taxiway Design Group
TDZL	Touchdown Zone Lights
TEZ	Texas Enterprise Zone
TIRZ	Tax Increment Reinvestment Zone
TPDES	Texas Pollutant Discharge Elimination System
TPWD	Texas Parks and Wildlife Department
TRACON	Terminal Radar Approach Control
TSA	Transportation Security Administration
TxANG	Texas Air National Guard
UAV	Unmanned Aerial Vehicle
UHF	Ultrahigh Frequency
UPS	United Parcel Service
USCG	United States Coast Guard
VFR	Visual Flight Rules
VHF	Very High Frequency
VMC	Visual Meteorological Conditions
VOC	Volatile Organic Compounds
VOIP	Voice Over Internet Protocol
VOR	Very High Frequency Omnidirectional Range
WIG	Wildly Important Goals

Appendix B

Workshops

PHOTOS COURTESY OF HOUSTON AIRPORT SYSTEM

Ellington Airport

Airport Master Plan Update
Strategic Planning Meeting #1

April 17, 2014

Meeting Agenda

- Purpose of this planning meeting
- Current status of Master Plan Update (MPU)
- Review of initial identified goals of MPU – key issues to address
- Discussion and review of development alternatives and potential strategies
    - Existing EFD land use
    - Proposed runway improvements
    - Proposed taxiway improvements
    - Potential development opportunities
    - Land Use considerations
    - Elements of Implementation plan

STATUS - FEEDBACK - GUIDANCE

Current Status of Master Plan Update

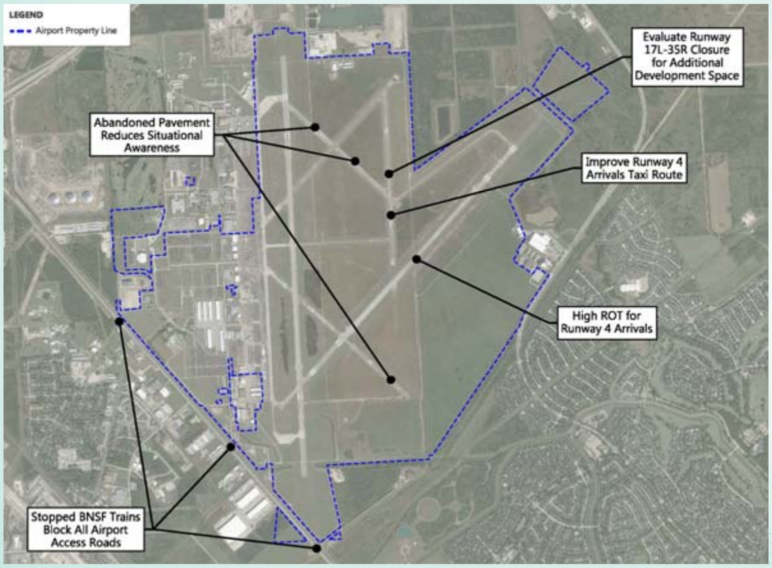
- Data Collection and Inventory – 100%
- Forecasts of Aviation Activity – 100%
- Identification of master plan requirements – 95%
- Alternatives analysis – 85%
- Implementation Plan – 10%
- Environmental overview – 5%
- Financial and CIP – 10%
- Documentation – 60%
- Airport Layout Plan (existing and future layout plan sheets only) – 90%

Key Issues to Address in the Master Plan Update

Master Plan Update Goal: *To make sure these issues (and others?) are met, while ensuring that the Master Plan Update defines the path and tools for HAS to pursue future development goals.*

- Airfield:
  - Reduce runway occupancy times (ROT) on Runway 4
    - Add exit taxiways
  - Improve taxi routes for Runway 4 arrivals
    - Avoid taxiing on Runway 17L-35R
  - Increase situational awareness
    - Taxiway E aligned with Runway 4
    - Presence of abandoned pavement is confusing to pilots
  - Customs and Border Protection (CBP) services at EFD
- Landside access:
  - Negative image of Airport and entrance roadways
  - Airport access can be blocked when BNSF trains stop abeam the Airport
  - Perception that HOU is much closer to downtown Houston than EFD
- Land Use Development:
  - Identify key issues affecting potential on-Airport development at EFD
  - Consider decommissioning Runway 17L-35R to create additional developable land with airside access

Background: Existing Issues



Background: Current Projects Status

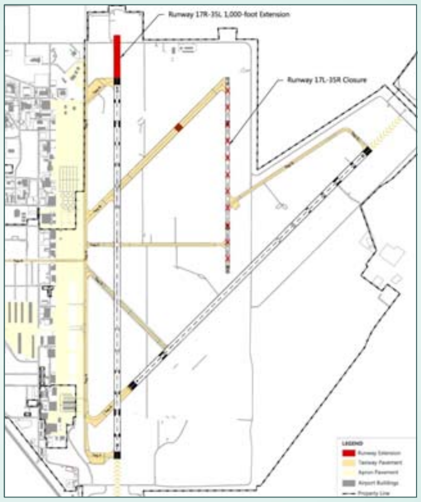
Background: Existing Land Uses

Land Use: Potential Development Opportunities

- General Aviation Hangars (T-hangars and conventional hangars)
- Ultra-Low Cost Air Carrier Service (ULCC)
- Aircraft Maintenance, Repair and Overhaul (MRO)
- Spaceport
- Air cargo
- Aircraft manufacturing
- Education/Incubator Space
- Houston Police Department – Air Support relocation
- Restaurant (or Food Truck Park?)
- Office space
- Budget hotel
- Others?

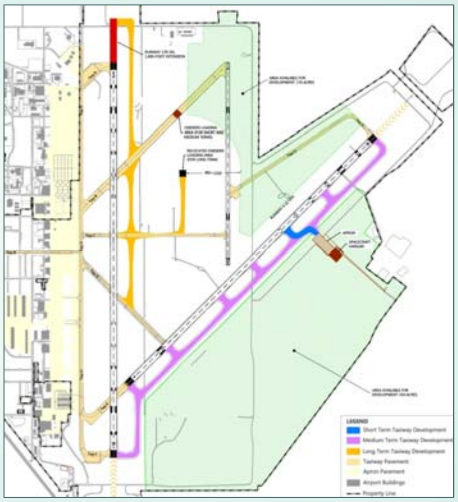
Airfield: Proposed Runway Improvements

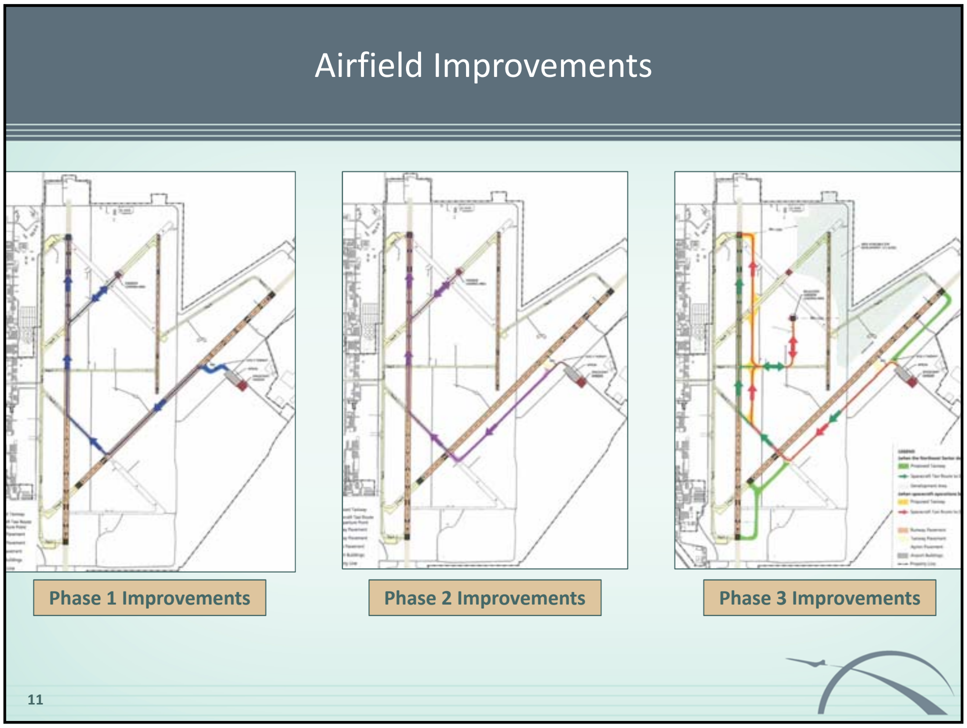
- Runway 17R-35L extension:
  - 1,000-foot extension to the north would accommodate most spacecraft and most cargo aircraft
  - A 3,000-foot extension would only be required for the Stratolaunch Carrier Aircraft, which is not anticipated to operate at EFD in the short term
- Decommission Runway 17L-35R when major maintenance would be required to sustain it, or if valuable development opportunity arises



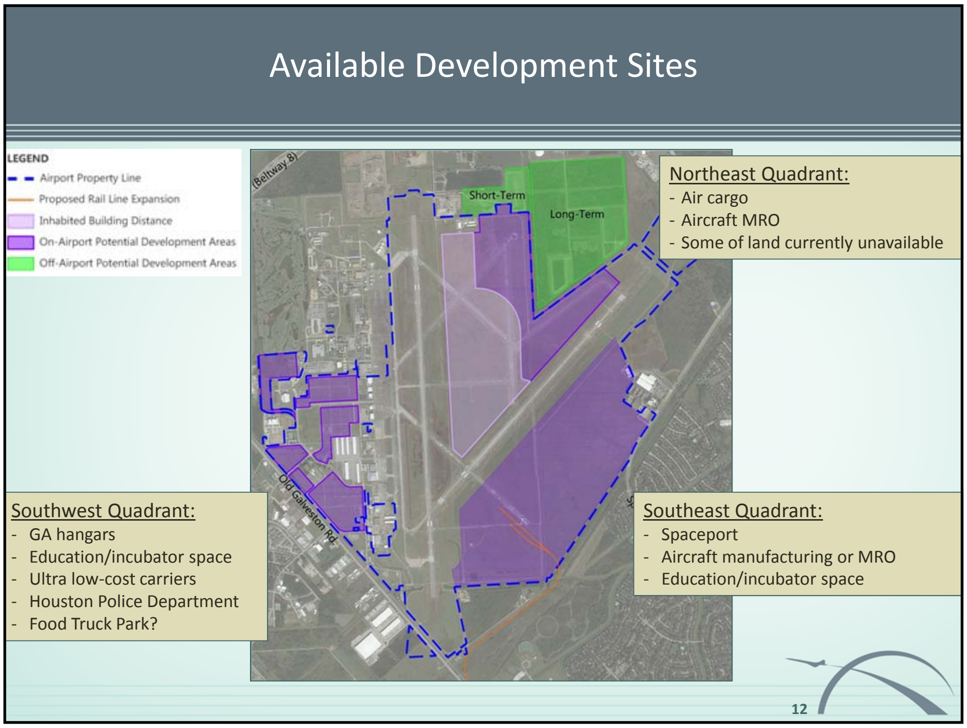
Airfield: Proposed Taxiway Improvements

- Parallel taxiway to Runway 4-22 (south side) with tie-in to Runway 35L end
  - Improved access to Runway 4-22
  - Per FAA Standards:
    - Parallel taxiway required when approach minimums are ½ SM or less
    - Recommend removing "aligned taxiway" (Taxiway E onto Runway 4)
- Parallel taxiway on east side of Runway 17R-35L (long-term, pending development in south quadrant)
  - Reduces impacts of IBD (spacecraft ops)
  - Reduces runway crossings
- Spaceport-Related:
  - Consider IBD impacts on development area
  - Relocated OLA access taxiway (long-term)
  - Increased runway-taxiway separations for Stratolaunch Carrier Aircraft
- Recommend: All future improvements made to Group V standards





Airfield Improvements



Available Development Sites

LEGEND

- ▬ ▬ Airport Property Line
- ▬ Proposed Rail Line Expansion
- ▨ Inhabited Building Distance
- ▨ On-Airport Potential Development Areas
- 🟩 Off-Airport Potential Development Areas

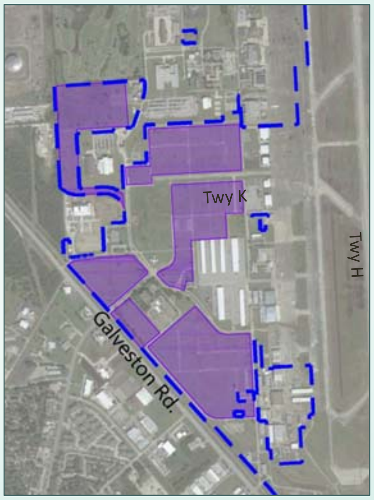
Northeast Quadrant:
- Air cargo
- Aircraft MRO
- Some of land currently unavailable

Southwest Quadrant:
- GA hangars
- Education/incubator space
- Ultra low-cost carriers
- Houston Police Department
- Food Truck Park?

Southeast Quadrant:
- Spaceport
- Aircraft manufacturing or MRO
- Education/incubator space

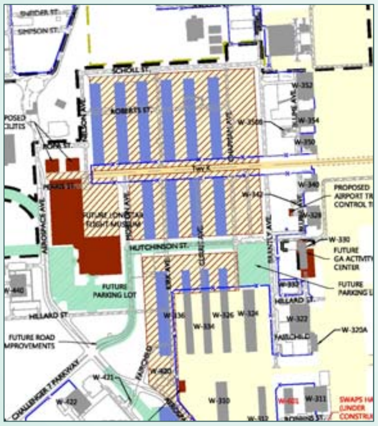
Southwest Quadrant

- GA Hangars
  - T-hangars along Taxiway K
  - Conventional hangars (CBO) south of existing T-hangars
- ULCC terminal/facility
  - Collocated with General Aviation Activity Center
- Educational/incubator space
  - Along Old Galveston Road
- Houston Police Department
- Food Truck Park??
  - Adjacent to the “Vomit Comet” ☺
- Other development options?

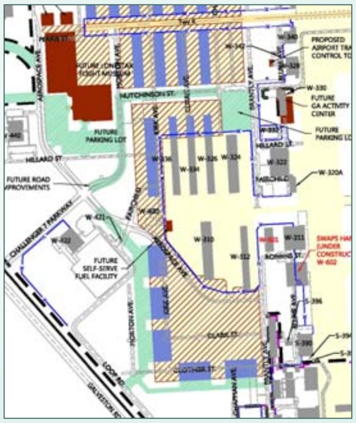


General Aviation Hangars: Numerous Alternatives

- T-Hangars



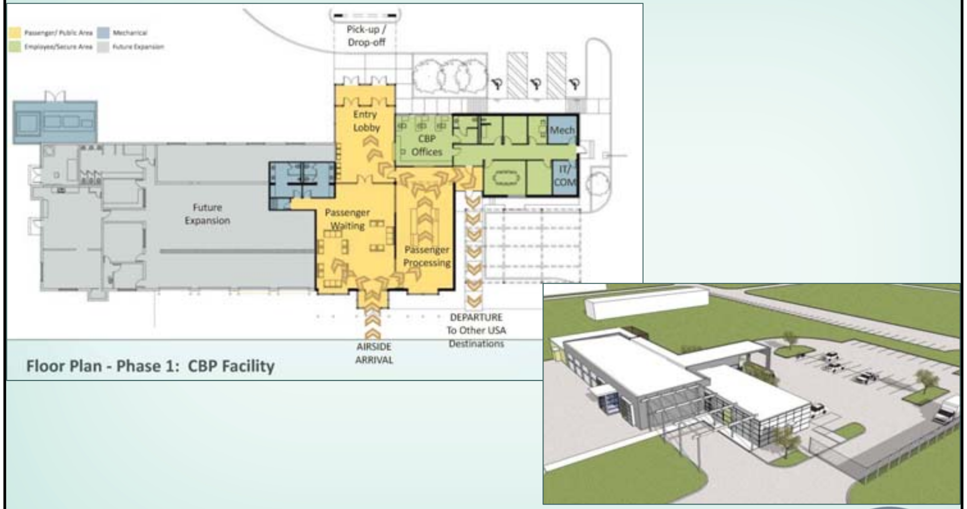
- Conventional Hangars



Land Use: Ultra-Low Cost Carrier Service

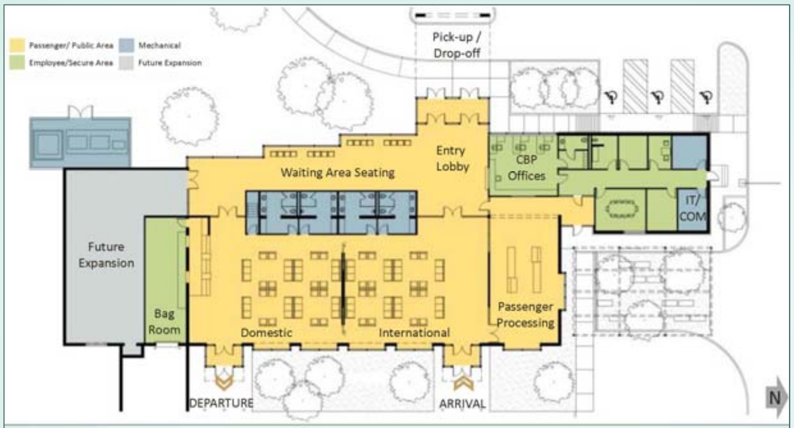
- Use the proposed General Aviation Activity Center as a passenger terminal
  - Need to plan for ticketing, automobile parking, meet/greet areas

Phase 1 – CBP Facility



Floor Plan - Phase 1: CBP Facility

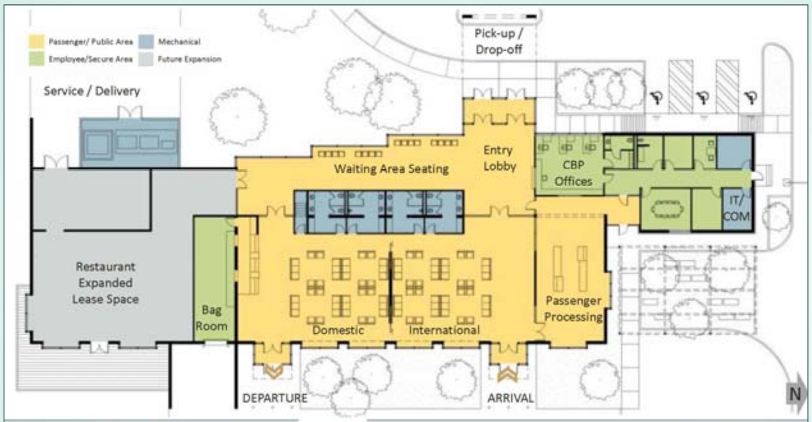
Phase 2 – CBP and Domestic Facility



Floor Plan - Phase 2: CBP & Domestic Facility

Phase II - $2.8 Million

Phase 3 – CBP and Domestic Facility

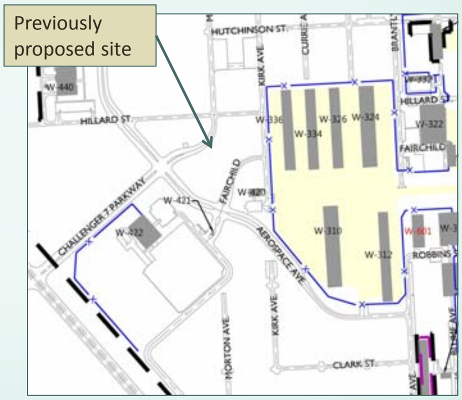


Floor Plan - Phase 3: CBP & Domestic Facility

Phase III - $871 Thousand

Houston Police Department Relocation to EFD

- Advantages
  - Makes valuable real estate available at HOU Airport (adjacent to Southwest and Signature FBO)
  - Significant improvement in quality of facility
  - Reduction of O&M cost during hurricanes or severe storms
  - Reduction of helicopter operations at Hobby
- Disadvantages
  - Expensive development (previous proposal)



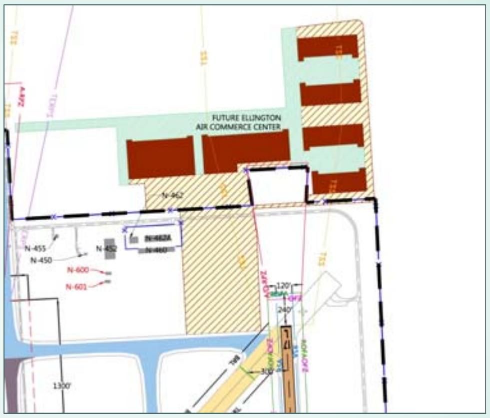
Previously proposed site

Land Use: Northeast Quadrant

- Air Cargo
  - Private (off-Airport) or on-Airport
- MRO facilities
  - Potentially ideal location due to distance from residential areas (run-up noise)
- Potential for expanded off-Airport development as well
- Protect explosive loading areas (short-term) for spaceport operation
- Closure of Runway 17L-35R dependent on pavement condition (maintenance) or development potential of land

Proposed Air Cargo Facility (Off-Airport Development)

- Proposed cargo development would be served by ramp (on-Airport property) adjacent to the existing Airport maintenance facilities
- Direct access to Runway 17R-35L
- Would not immediately force the closure of Runway 17L-35R



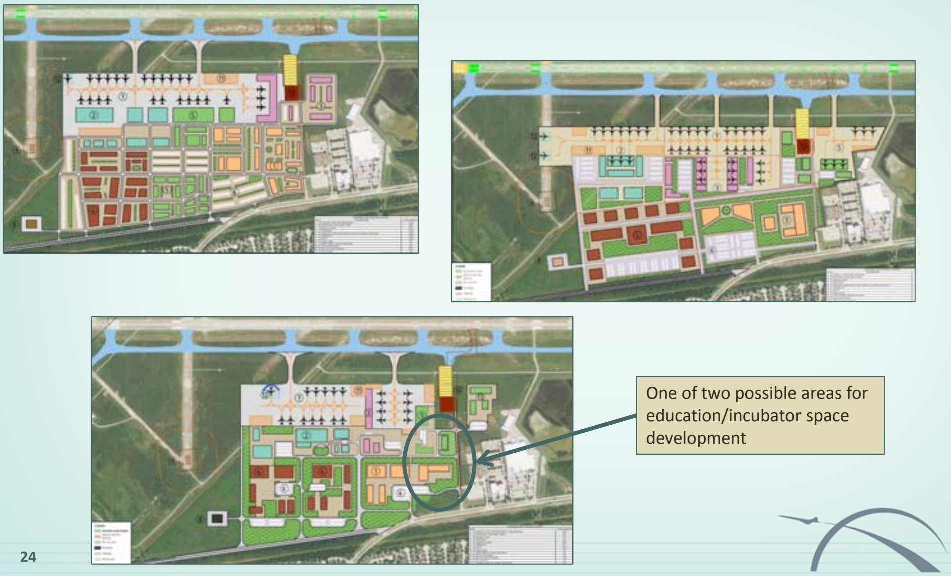
Land Use: Southeast Quadrant

- Maximum amount of contiguous land available
- Will require vehicle roadway access (spur), including intersection with Old Galveston Rd
- Recommended development options include:
  - Spaceport
  - Aircraft Manufacturing
  - Education/incubator space
  - Commercial (if supporting spaceport or manufacturing)

Initial Spaceport Hangar (Sierra Nevada or other operator)

- Recommend development on far north end of Southeast quadrant due to presence of existing utilities and access
- Alternate site could be on the far south end, or even within the west quadrant

Various Large-Aircraft Manufacturing Facility Layouts



One of two possible areas for education/incubator space development

Spaceport Development Concept

OURCE: XSC, 2013 HOUSTON SPACEPORT DESCRIPTION

OURCE: XSC, 2013 HOUSTON SPACEPORT VIEWED FROM NASA SONNY CARTER TRAINING FACILITY

Education/Incubator Space

- What potential functions will the space accommodate?
  - Aircraft parts testing
  - Education
  - Research and development
  - Prototype creation
  - Other
- Current HAS planning/design needs
- Similarity to WSU Technology II facilities (PEC is the lead designer for new facility)
  - Approx. 75,000 SF
  - Construction Cost: $8.1M

INNOVATION CAMPUS CONCEPTUAL SITE PLAN

1st Floor Concept Plan

TECHNOLOGY II CONCEPTUAL SITE PLAN

Land Use: General Land Use Observations

- On-Airport land use planning:
  - Emphasis on entrance of Airport, and the momentum for developing a “cultural” area of the Airport in conjunction with additional T-hangars and a passenger terminal
- Off-Airport land use planning:
  - Improved access and “visibility” of EFD

EXTRAS

Ellington Airport

Airport Master Plan Update
Senior Management Briefing

March 4, 2015

PHOTOS COURTESY OF HOUSTON AIRPORT SYSTEM

Briefing Agenda

- Purpose of master plan update briefing
  - Review/confirm MPU recommendations
  - Begin planning for public meeting
    - Review of public meeting presentation materials on Tuesday, March 24
    - Public meeting scheduled for Tuesday, March 31

- Status of master plan update
- MPU recommendations to discuss:
  - Objectives/Goals of MPU
  - Runway/taxiway improvements
  - Development opportunities
  - On-Airport land use
  - Elements of implementation plan (preliminary)

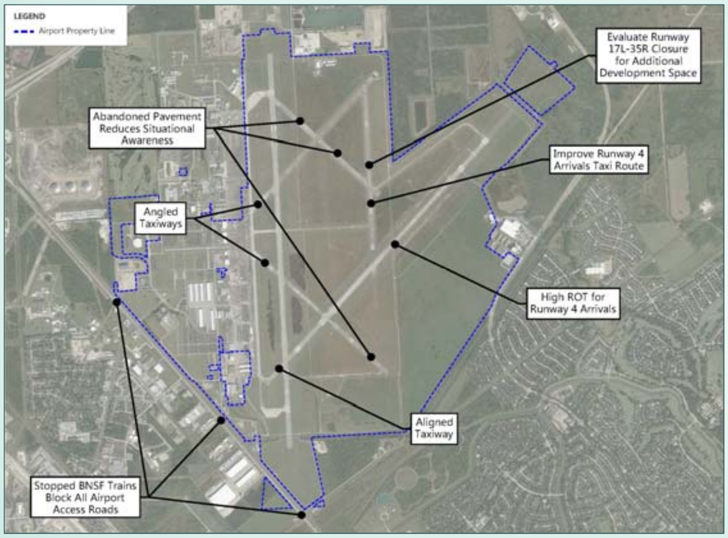
Status of Master Plan Update

- Data Collection and Inventory – 95%
- Forecasts of Aviation Activity – 95%
- Identification of master plan requirements – 95%
- Alternatives analysis – 90%
- Land Use – 80%
- Implementation Plan – 80%
- Environmental overview – 80%
- Financial and CIP – 80%
- Documentation – 80%
- Airport Layout Plan – 80%

Objectives and Goals of the Master Plan Update

- Objectives
  - Prepare a master plan which synergizes with the certification, development and operation of EFD as a Spaceport
  - Identify optimal land uses for future revenue enhancement opportunities
  - Elevate perception(s) of EFD
- Goals
  - Airfield:
    - Short-term and long-term readiness for Spaceport operations
    - Changing FAA design criteria and improved situational awareness
    - Reduce runway occupancy times (ROT) on Runway 4, and taxi routes for Runway 4 arrivals
    - Customs and Border Protection (CBP) services at EFD
  - Landside access:
    - Access to southeast quadrant (vehicular and potentially rail)
    - Additional Airport ingress/egress (if train simultaneously blocks Airport entrances)
  - Land Use Development:
    - Identify key issues affecting potential on-Airport development at EFD
    - Evaluate future status of Runway 17L-35R

Existing Issues



Evaluate Runway 17L-35R Closure for Additional Development Space

Abandoned Pavement Reduces Situational Awareness

Improve Runway 4 Arrivals Taxi Route

Angled Taxiways

High ROT for Runway 4 Arrivals

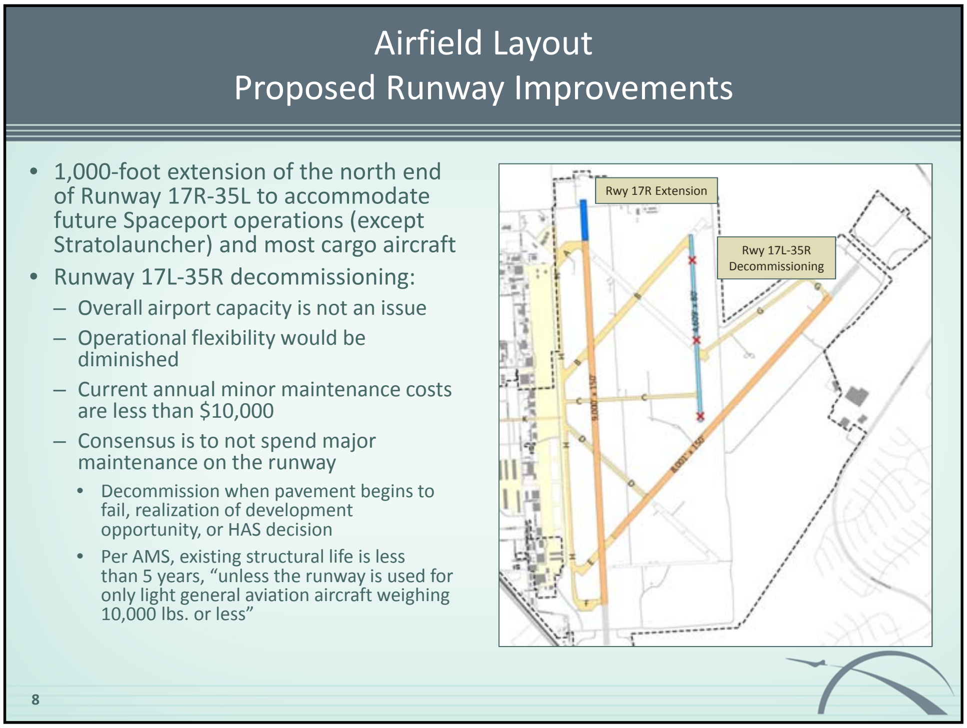
Aligned Taxiway

Stopped BNSF Trains Block All Airport Access Roads

Existing Land Uses

Ellington Airport

PROPOSED MASTER PLAN UPDATE RECOMMENDATIONS

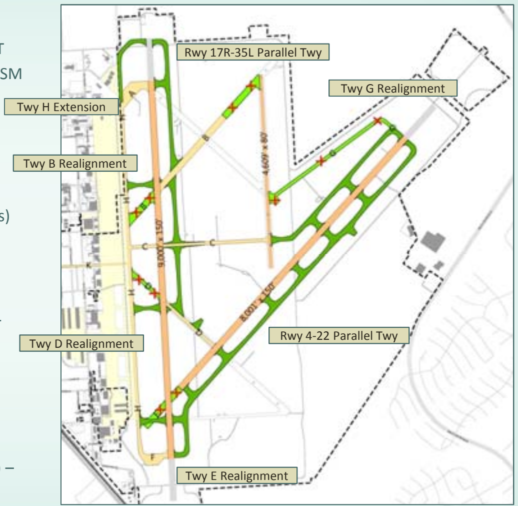


Airfield Layout
Proposed Runway Improvements

- 1,000-foot extension of the north end of Runway 17R-35L to accommodate future Spaceport operations (except Stratolauncher) and most cargo aircraft
- Runway 17L-35R decommissioning:
  - Overall airport capacity is not an issue
  - Operational flexibility would be diminished
  - Current annual minor maintenance costs are less than $10,000
  - Consensus is to not spend major maintenance on the runway
    - Decommission when pavement begins to fail, realization of development opportunity, or HAS decision
    - Per AMS, existing structural life is less than 5 years, “unless the runway is used for only light general aviation aircraft weighing 10,000 lbs. or less”

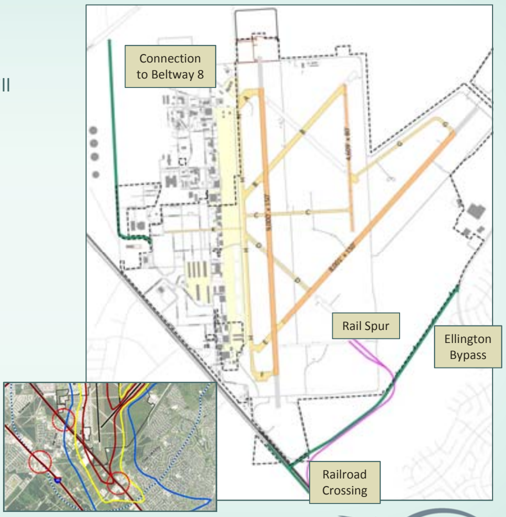
Airfield Layout
Proposed Taxiway Improvements

- Parallel taxiway to Rwy 4-22 and tie-in to Rwy 35L
  - Access to SE quadrant development and reduce ROT
  - FAA req. when approach minimums are less than ½ SM (currently 3/8 SM visibility)
- Realign Twy G
  - Existing Twy G structural life < 5 years
  - Eliminate taxiing on Rwy 17L-35R
- Extension of Twy H
  - Access to Runway 17R (design to Group IV standards)
  - Requires relocation of military hangars
- Realign Twy E
  - Remove "aligned taxiway"
  - Remove angled taxiway crossing of Runway 17R-35L
- Realign Taxiways B and D
  - Remove angled taxiways
- Parallel taxiway east of Rwy 17R-35L (long-term)
  - Reduce runway crossings
- Spaceport related
  - IBD impacts on development area (North Quadrant) – IBD now exists only around the OLA
  - Relocated OLA access taxiway (long-term)



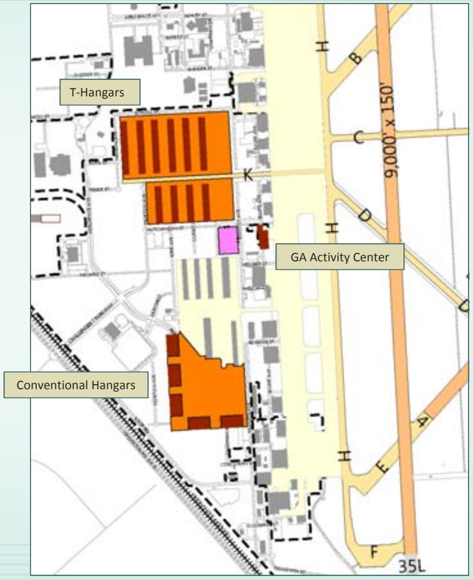
Landside Access
Proposed Improvements

- Ellington bypass road (provides vehicular access to the southeast quadrant)
  - Grade-separated crossing of railroad tracks will be very expensive
  - At-grade crossing may require closure of one of other railroad crossings
- Rail spur into southeast quadrant
- Beltway 8 connector (reserve)
  - Would provide exit route if other entrances are blocked by unit train
- Focus on three Airport gateways for beautification (including wayfinding, streetscaping, public art, etc.)
  - Main Airport entrance
  - I-45 and Dixie Farm Rd intersection (recently reconstructed)
  - Galveston Rd and Clear Lake City Blvd intersection



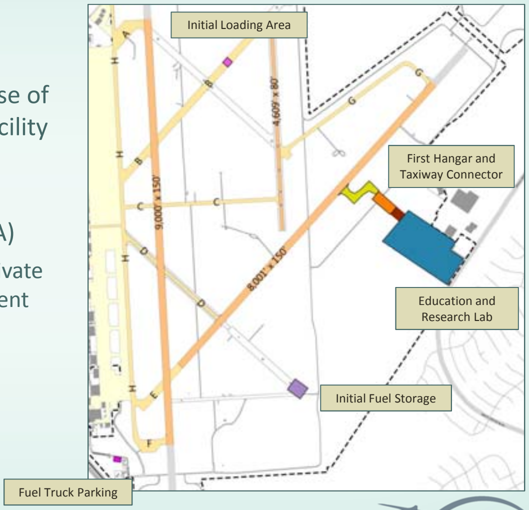
Tenants/Users Facilities
Proposed Improvements

- GA T-hangars or corporate hangars adjacent to Taxiway K
  - Restricted to Group II aircraft without modification to facilities at the throat of Taxiway K
- Conventional hangars (CBO) south of existing T-hangars
- Potential for development of General Aviation Activity Center



Spaceport Facilities
Proposed Developments

- Site for development of first Spaceport hangar/apron
- Site for development of first phase of "Education and Research Lab" facility
  - Timing and scope for advanced planning; project parameters
- Initial Oxidizer Loading Area (OLA)
  - Long-term relocation based on private investment or need for development of north quadrant
- Initial Fuel Storage Area (FSA)
- Taxiway connector and initial operations plan



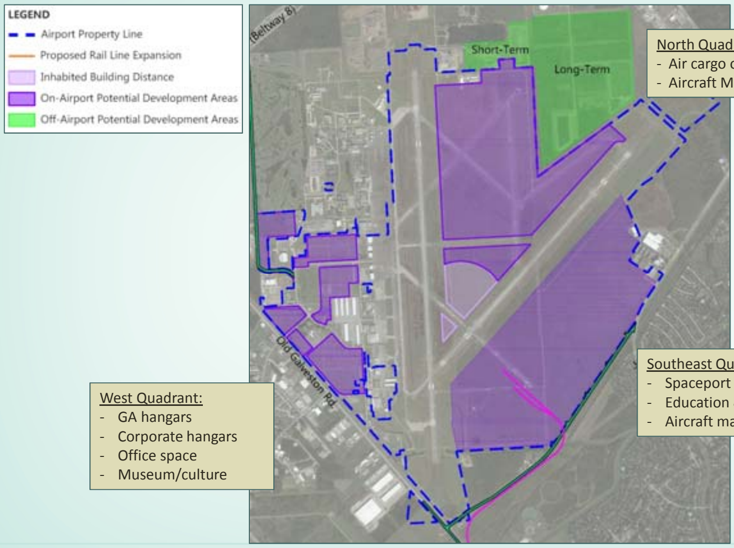
Long-Term Airport Development Plan

Ellington Airport

AVAILABLE DEVELOPMENT SITES AND POTENTIAL LAND USES

EG13

Available Development Sites



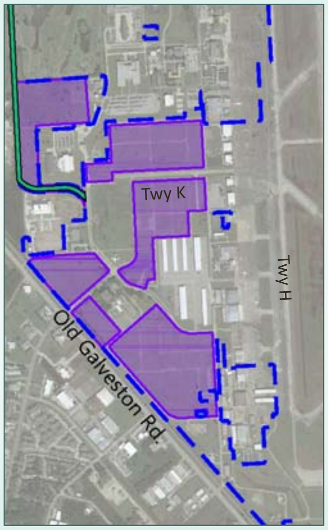
North Quadrant:
- Air cargo operations
- Aircraft MRO

Southeast Quadrant:
- Spaceport operations
- Education & Research Laboratories
- Aircraft manufacturing or MRO

West Quadrant:
- GA hangars
- Corporate hangars
- Office space
- Museum/culture

Potential Land Uses
West Quadrant

- General Aviation facilities
  - Focus development on land adjacent to Taxiway K
- Corporate hangars and facilities
  - Focus development on land south of existing T-hangars
- Museum and cultural facilities
- HAS Administration and other office/retail
- Image-enhancing projects along Old Galveston Road



Potential Land Uses
North Quadrant

- Air cargo operations
  - Private (off-Airport) or on-Airport
- MRO facilities
  - Potentially ideal location due to distance from residential areas (run-up noise)
  - Potential to expand off-Airport if additional space needed
- Need to protect for the IBD in the short-term (for Spaceport operation)
- Closure of Runway 17L-35R
  - Timing based on pavement failure, realization of a development opportunity, or decision by HAS

🟪 On-Airport Potential Development Areas
🟩 Off-Airport Potential Development Areas

Potential Land Uses
Southeast Quadrant

- Recommended development
  - Spaceport operations (priority), beginning with Education and Research Laboratories
  - Aircraft manufacturing facilities
  - Commercial facilities (if supporting spaceport or manufacturing)
- Maximum amount of contiguous land available on Airport property
- Will require:
  - Utility improvements
- Recommended improvement:
  - Vehicle roadway access from Old Galveston Road (will require railroad crossing)

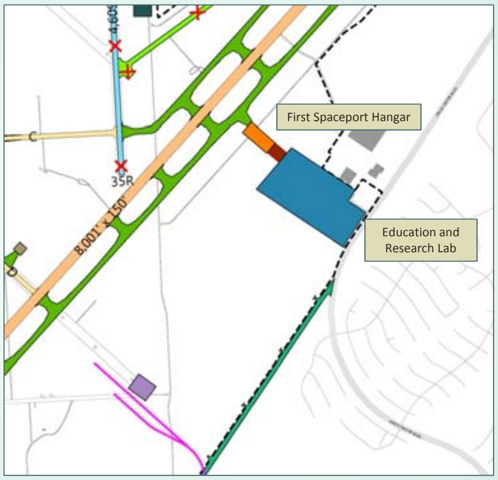
Spaceport Development Concept


OURCE: XSC, 2013 HOUSTON SPACEPORT DESCRIPTION

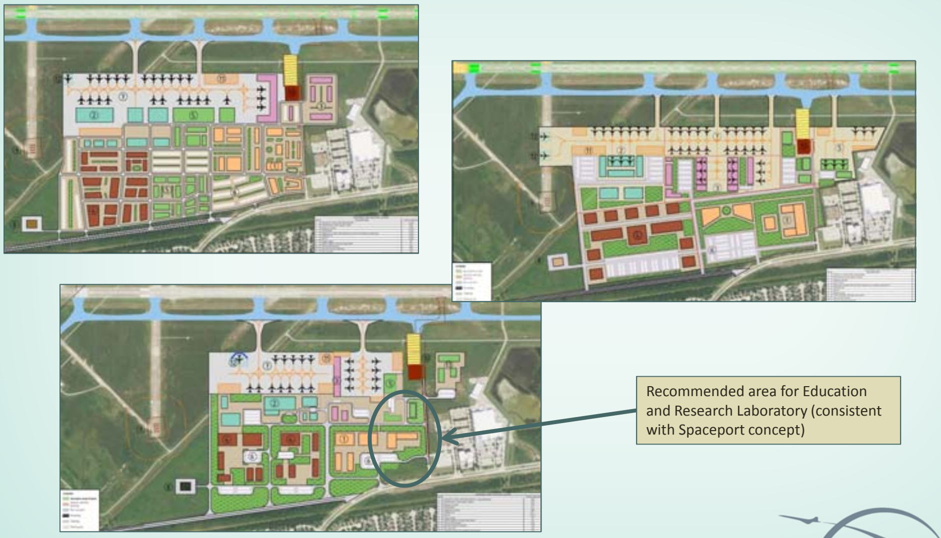
OURCE: XSC, 2013 HOUSTON SPACEPORT VIEWED FROM NASA SONNY CARTER TRAINING FACILITY

First Spaceport Hangar and Education & Research Lab

- Recommend development on far north end of southeast quadrant due to presence of existing utilities and accessibility from Space Center Blvd.
- Alternate site could be on the far south end, or even within the west quadrant



Various Large-Aircraft Manufacturing Facility Layouts



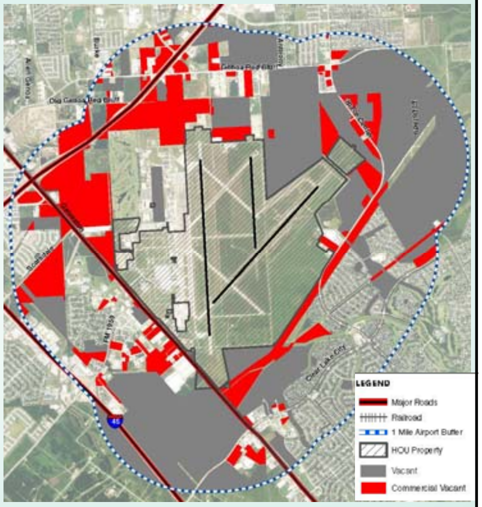
Recommended area for Education and Research Laboratory (consistent with Spaceport concept)

Ellington Airport

ON-AIRPORT AND OFF-AIRPORT LAND USES

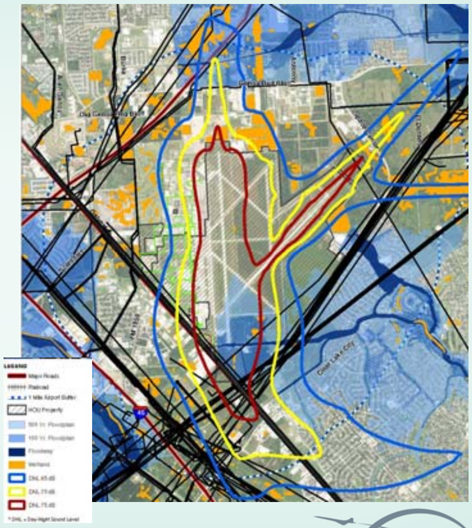
Environs Land Use Development Opportunities

- Abundance of vacant land ready for development (hotels, retail centers, etc.)
- Excellent transportation connectivity
- Flat topography
- Old Galveston Road corridor is in need for redevelopment
- Located in aerospace cluster



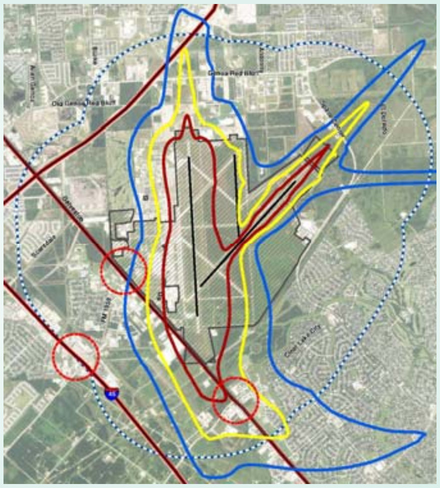
Environs Land Use Development Constraints

- Pipelines (gas and hazardous liquid)
- High transmission power line along Interstate 45 (tall structures, signal interference?)
- Floodplain/wetlands
- Majority of agricultural lands are oil fields
- Noise impacts from previous master plan (> DNL 65 is incompatible with residential communities)
- Lack of connectivity between land uses



Environs Land Use Development
Gateways

- Develop gateway entry points along:
  - Intersection of Old Galveston Road and Challenger Road
  - Intersection of Old Galveston Road and Clear Lake City Blvd
  - Interstate 45 exit and associated intersection
- Gateways can be created using wayfinding, streetscaping, public art, lighting, or other features

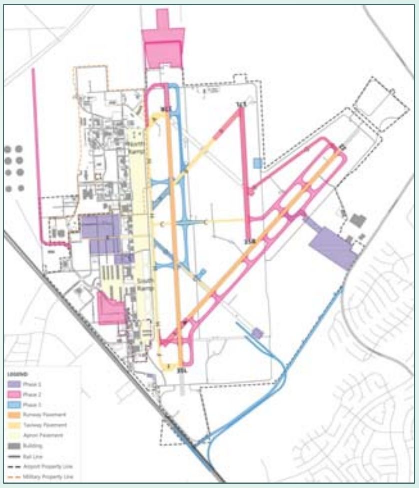


Ellington Airport

(DRAFT) IMPLEMENTATION PLAN

(Draft) Implementation Plan

- **Phase 1 (2016-2020)**
  - GA hangars in southwest quadrant
  - First spaceport facilities
  - Taxiway connection to southeast quadrant spaceport facilities
  - GA activity center
- **Phase 2 (2021-2025)**
  - Rwy 4-22 parallel taxiways (both sides)
  - Realignment of Twy E
  - Roadway Connection to BW 8
  - GA hangars in southwest quadrant
  - Rwy 17R end extension & enabling projects
  - Decommissioning of Rwy 17L-35R
- **Phase 3 (2026-2030)**
  - Permanent OLA/OSA
  - road & rail access into southeast quadrant
  - Rwy 17R-35L parallel taxiway (east side)
  - Realignment of Twys B & D (partial)



(Draft) Project Cost Estimates and Funding Sources

Phase 1 (2016-2020)

Year	Project Description	HAS Cost (000)	FAA Grant (000)	Tenant Cost (000)
2016	Phase 1 Master Plan Projects - Environmental Study	$600		
2017	Construction of T-Hangars along Taxiway K			✓
2017	Construction of the First Spaceport Hangar			✓
2017	Construction of a Spacecraft Fuel Storage Area			✓
2017	Construction of a Temporary Spacecraft Oxidizer Storage Area			✓
2017	Construction of a Temporary Spacecraft Oxidizer Loading Area			✓
2017	Construction of a Taxiway Connection between Rwy 4-22 and the Spaceport Hangar	$600	$5,400	
2017	Construction of Education and Incubator Facilities in the Southeast Quadrant			✓
2018	Construction of a General Aviation Activity Center			$2,900
2020	Phase 2 Master Plan Projects - Environmental Study	$650		
	Roadway Intersection Improvements in the Southwest Quadrant			
	Phase 1 Total	$1,850	$5,400	

Note: Master Plan projects only.

(Draft) Project Cost Estimates and Funding Sources

Phase 2 (2021-2025)

Year	Project Description	HAS Cost (000)	FAA Grant (000)	Tenant Cost (000)
2021	Construction of Full-Length Parallel Taxiway to Rwy 4-22 and Rwy 4-22 Exits	$35,000	$9,500	
2021	Construction of Rwy 35L End and Rwy 4-22 Parallel Taxiway Tie-In			
2021	Realignment of Taxiway G and Tie-In to Twy C	$21,500		
2021	Closure of Twy G and a Portion of Twy B Pavement	$600		
2021	Realignment of Twy E & Closure of Old Twy E Pavement	$1,800		
2021	Construction of a Roadway Connection to Beltway 8		$8,000 (TxDOT)	
2021	Construction of Conventional Hangars South of Existing HAS T-Hangars			✓
2022	Land Acquisition North of Runway 17R End & Obstruction Removal	$100	$950	
2022	Realignment of Perimeter Road and Fence Around the Runway 17R End	$150	$1,400	
2023	Runway 17R End & Taxiway H Extension	$2,500	$11,500	$4,500
2024	Decommissioning of Runway 17L-35R	$1,000		
2025	Phase 3 Master Plan Projects - Environmental Study	$750		
	Phase 2 Total	$63,400	$31,350	

Note: Master Plan projects only.

(Draft) Project Cost Estimates and Funding Sources

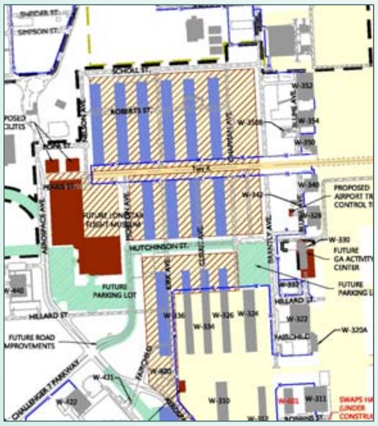
Phase 3 (2026-2030)

Year	Project Description	HAS Cost (000)	FAA Grant (000)	Tenant Cost (000)
2026	Construction of a Permanent Spacecraft Oxidizer Storage Area			✓
2026	Construction of a Rail Spur into The Southeast Quadrant	$2,200		$6,500
2026	Construction of a Roadway Flyover over the Train Tracks	$6,000		$17,800
2026	Construction of a Road into the Southeast Quadrant	$1,700		$5,200
2027	Construction of a Permanent Oxidizer Loading Area and Access Taxiway	$4,900		$4,900
2029	Construction of Rwy 17R-35L Parallel Taxiway on East Side	$11,500		$11,500
2029	Realignment of Twys B and D & Closure of Old Twys B & D		$8,500	
	Phase 3 Total	$26,300	$8,500	

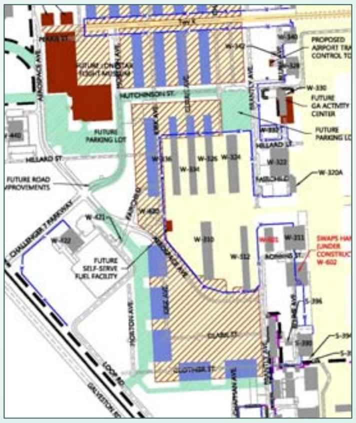
Note: Master Plan projects only.

General Aviation Hangars:
Numerous Alternatives

- T-Hangars

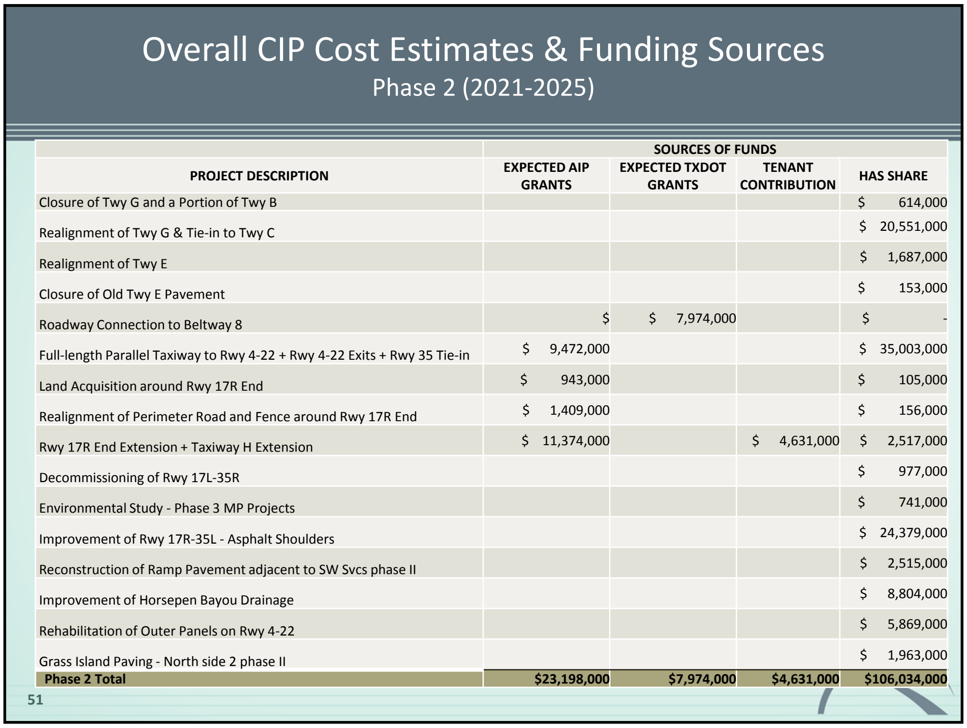


- Conventional Hangars



Overall CIP Cost Estimates & Funding Sources
Phase 1 (2016-2020)

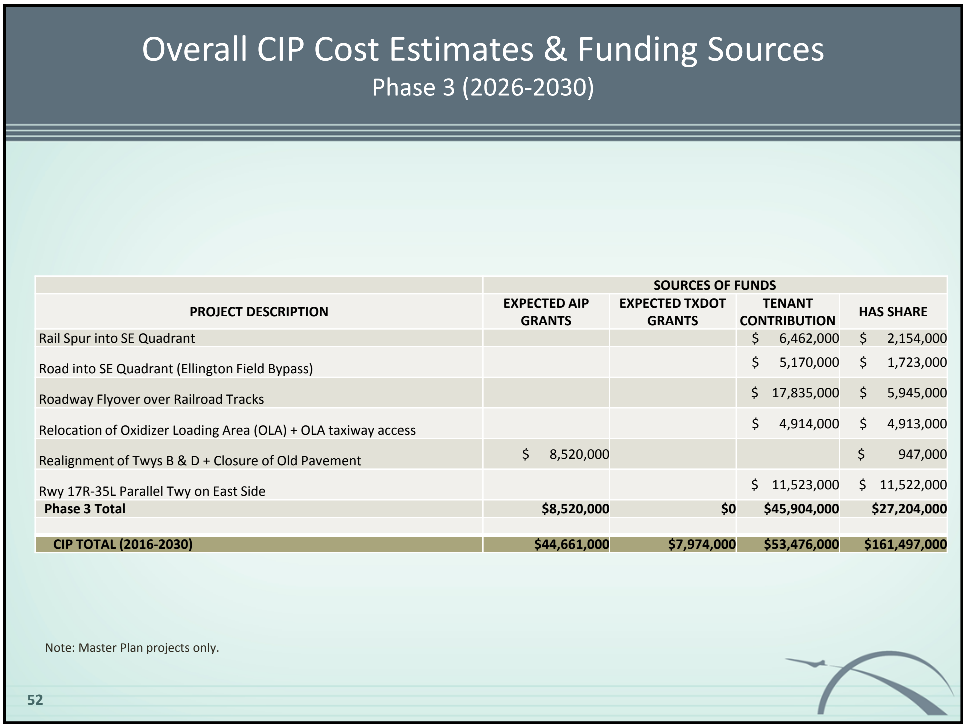
	SOURCES OF FUNDS			
PROJECT DESCRIPTION	EXPECTED AIP GRANTS	EXPECTED TXDOT GRANTS	TENANT CONTRIBUTION	HAS SHARE
Environmental Study - Phase 1 MP Projects				$ 614,000
Taxiway Connection Between First Spaceport Hangar and Rwy 4-22	$ 5,446,000			$ 605,000
General Aviation Activity Center			$ 2,941,000	$ 2,941,000
Environmental Study - Phase 2 MP Projects				$ 656,000
Cargo Lane to Cargo Ramp				$ 3,769,000
Grass Island Paving - North side 2 phase I				$ 188,000
Rehabilitation of Scholl St between Aerospace Av & Brantley Av				$ 3,392,000
Rehabilitation of Airfield Service Road				$ 687,000
Rehabilitation of T-hangar Ramp and Twy D Pavement				$ 1,617,000
Installation of Cat-IIIA ILS				$ 8,286,000
Replacement of the ATCT	$ 7,497,000			$ 833,000
FAA Engineering Agreement				$ 135,000
Replacement of Pavement (R&R) phase I				$ 328,000
New Electrical Vault at AOA				$ 3,610,000
Reconstruction of Ramp Pavement adjacent to SW Svcs phase I				$ 263,000
Replacement of Pavement (R&R) phase II				$ 335,000
Phase 1 Total	**$12,943,000**	**$0**	**$2,941,000**	**$28,259,000**



Overall CIP Cost Estimates & Funding Sources

Phase 2 (2021-2025)

	SOURCES OF FUNDS			
PROJECT DESCRIPTION	**EXPECTED AIP GRANTS**	**EXPECTED TXDOT GRANTS**	**TENANT CONTRIBUTION**	**HAS SHARE**
Closure of Twy G and a Portion of Twy B				$ 614,000
Realignment of Twy G & Tie-in to Twy C				$ 20,551,000
Realignment of Twy E				$ 1,687,000
Closure of Old Twy E Pavement				$ 153,000
Roadway Connection to Beltway 8	$	$ 7,974,000		$ -
Full-length Parallel Taxiway to Rwy 4-22 + Rwy 4-22 Exits + Rwy 35 Tie-in	$ 9,472,000			$ 35,003,000
Land Acquisition around Rwy 17R End	$ 943,000			$ 105,000
Realignment of Perimeter Road and Fence around Rwy 17R End	$ 1,409,000			$ 156,000
Rwy 17R End Extension + Taxiway H Extension	$ 11,374,000		$ 4,631,000	$ 2,517,000
Decommissioning of Rwy 17L-35R				$ 977,000
Environmental Study - Phase 3 MP Projects				$ 741,000
Improvement of Rwy 17R-35L - Asphalt Shoulders				$ 24,379,000
Reconstruction of Ramp Pavement adjacent to SW Svcs phase II				$ 2,515,000
Improvement of Horsepen Bayou Drainage				$ 8,804,000
Rehabilitation of Outer Panels on Rwy 4-22				$ 5,869,000
Grass Island Paving - North side 2 phase II				$ 1,963,000
Phase 2 Total	**$23,198,000**	**$7,974,000**	**$4,631,000**	**$106,034,000**



Overall CIP Cost Estimates & Funding Sources

Phase 3 (2026-2030)

	SOURCES OF FUNDS			
PROJECT DESCRIPTION	**EXPECTED AIP GRANTS**	**EXPECTED TXDOT GRANTS**	**TENANT CONTRIBUTION**	**HAS SHARE**
Rail Spur into SE Quadrant			$ 6,462,000	$ 2,154,000
Road into SE Quadrant (Ellington Field Bypass)			$ 5,170,000	$ 1,723,000
Roadway Flyover over Railroad Tracks			$ 17,835,000	$ 5,945,000
Relocation of Oxidizer Loading Area (OLA) + OLA taxiway access			$ 4,914,000	$ 4,913,000
Realignment of Twys B & D + Closure of Old Pavement	$ 8,520,000			$ 947,000
Rwy 17R-35L Parallel Twy on East Side			$ 11,523,000	$ 11,522,000
Phase 3 Total	**$8,520,000**	**$0**	**$45,904,000**	**$27,204,000**
CIP TOTAL (2016-2030)	**$44,661,000**	**$7,974,000**	**$53,476,000**	**$161,497,000**

Note: Master Plan projects only.

Appendix C

Public Meeting

Ellington Airport

Airport Master Plan Update
Public Meeting

March 31, 2015

PHOTOS COURTESY OF HOUSTON AIRPORT SYSTEM

Agenda

- ✈ Welcome and Introductions
- ✈ Role and Importance of Houston Airport System
- ✈ Airport Master Planning Process and Current Status
- ✈ Overview of Master Plan Update and Recommendations
- ✈ Questions and Answers

Ellington Airport

ROLE AND IMPORTANCE OF HOUSTON AIRPORT SYSTEM

The Role of Houston Airport System

- George Bush Intercontinental (IAH)
  - The City's largest airport and global gateway; 41 million passengers per year
- William P. Hobby (HOU)
  - Upcoming introduction of international flights; 12 million passengers per year
- Ellington Airport (EFD)
  - General Aviation center, with significant presence of U.S. military, Air National Guard, and NASA. Reliever airport for IAH and HOU.

"We exist to connect the people, the businesses, the cultures and the economies of the world to Houston."

Ellington Airport Impacts the Regional Economy

Total Economic Impact	Jobs Created	Earnings Generated
$640 Million	10,000 Jobs	$310 Million
“The total economic impact of Ellington Airport is over $640 million for the Houston Regional Economy.”	**“Ellington Airport is responsible for over 10,000 full time equivalent jobs.”**	**“Ellington Airport generates $310 million in employee and proprietor earnings.”**

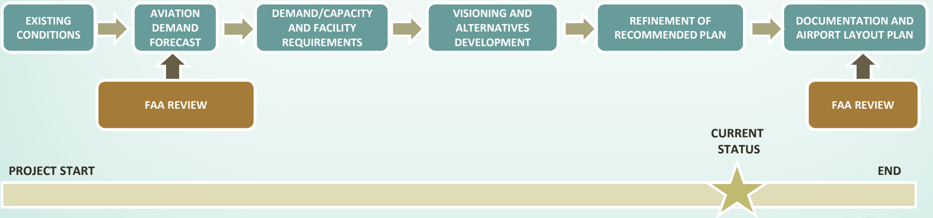
GRA, Incorporated; Economic Impact Study
June 30, 2011

Ellington Airport

AIRPORT MASTER PLANNING PROCESS AND CURRENT STATUS

FAA Requirements for Airport Master Plans

- An Airport Master Plan is a long-term development plan (15-20 year planning horizon), required by the FAA. The purpose of an Airport Master Plan is to facilitate long-term development at an airport.
- The main components are:
  - Documentation of the analyses and recommendations
  - An FAA-approved Airport Layout Plan, enabling the airport to receive federal funding for eligible improvements.



EXISTING CONDITIONS

AVIATION DEMAND FORECAST

DEMAND/CAPACITY AND FACILITY REQUIREMENTS

VISIONING AND ALTERNATIVES DEVELOPMENT

REFINEMENT OF RECOMMENDED PLAN

DOCUMENTATION AND AIRPORT LAYOUT PLAN

FAA REVIEW

FAA REVIEW

CURRENT STATUS

PROJECT START

END

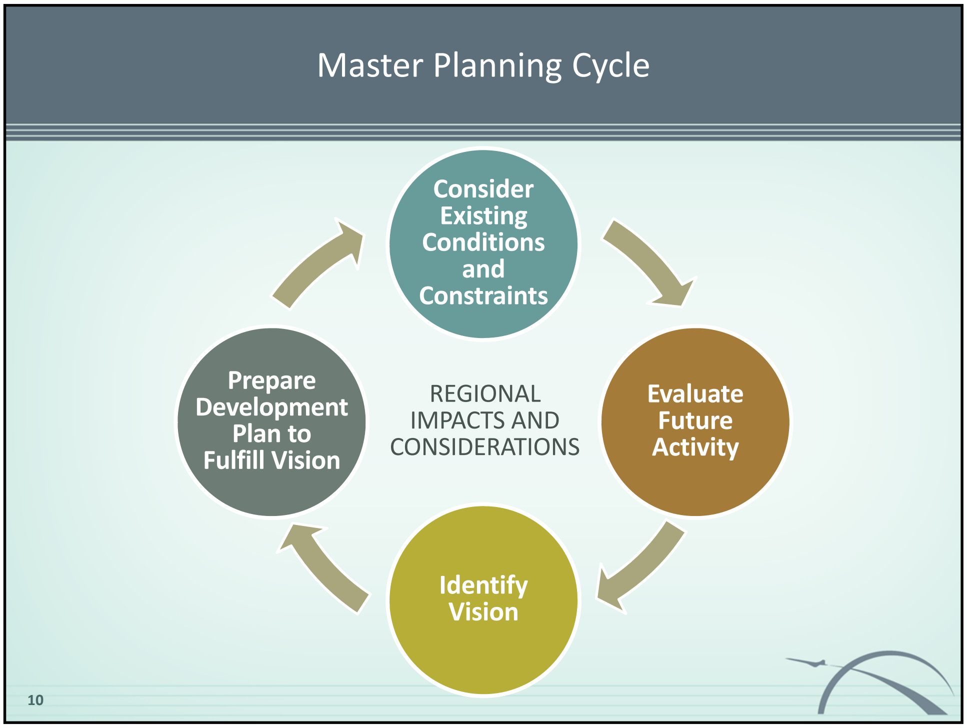
Ellington Airport Master Plan Update

- Prepare a master plan that synergizes with the certification, development and operation of EFD as a **Spaceport**
- Identify optimal land uses and prepare for future **revenue enhancement opportunities**
- Elevate **perception(s) of EFD**

- Key Elements to Address
  - Airfield
    - Short-term and long-term readiness for Spaceport operations
    - Maintain compliance with evolving FAA design criteria
    - Increase airfield efficiency and safety
  - Landside access
    - Additional Airport ingress/egress capability
    - Protect the ability to provide access to southeast quadrant (vehicular and potentially rail)
  - Land Use Development
    - Identify optimal land uses and key issues affecting potential on-Airport development
    - Storm water runoff and floodplain mitigation

Ellington Airport

OVERVIEW OF MASTER PLAN UPDATE AND RECOMMENDATIONS



Master Planning Cycle

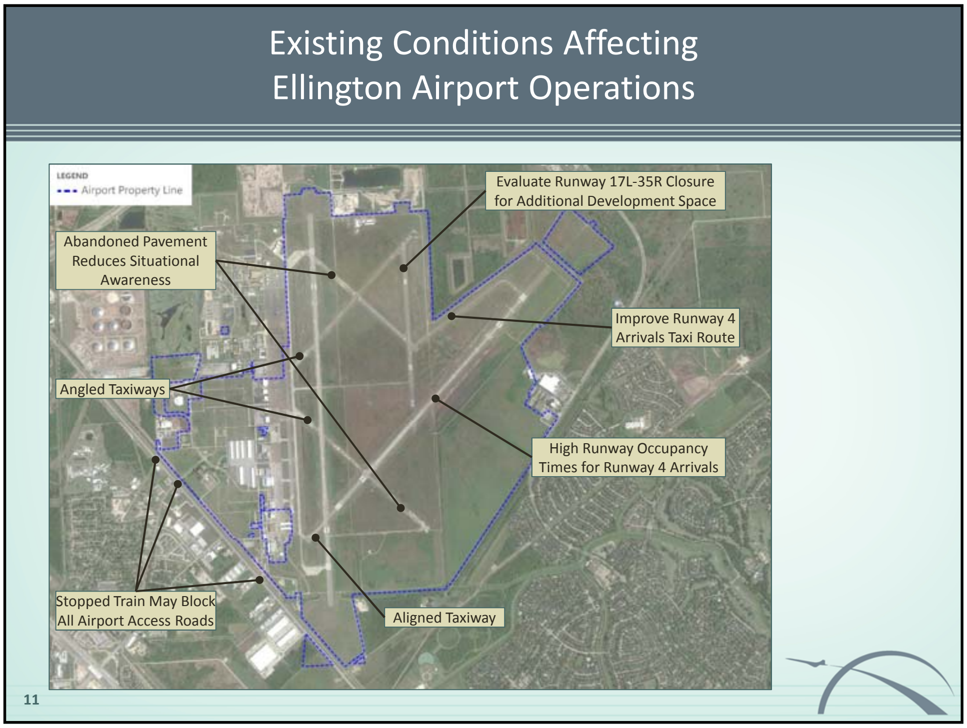
Consider Existing Conditions and Constraints

Evaluate Future Activity

Identify Vision

Prepare Development Plan to Fulfill Vision

REGIONAL IMPACTS AND CONSIDERATIONS



Existing Conditions Affecting Ellington Airport Operations

LEGEND
- - - Airport Property Line

Evaluate Runway 17L-35R Closure for Additional Development Space

Abandoned Pavement Reduces Situational Awareness

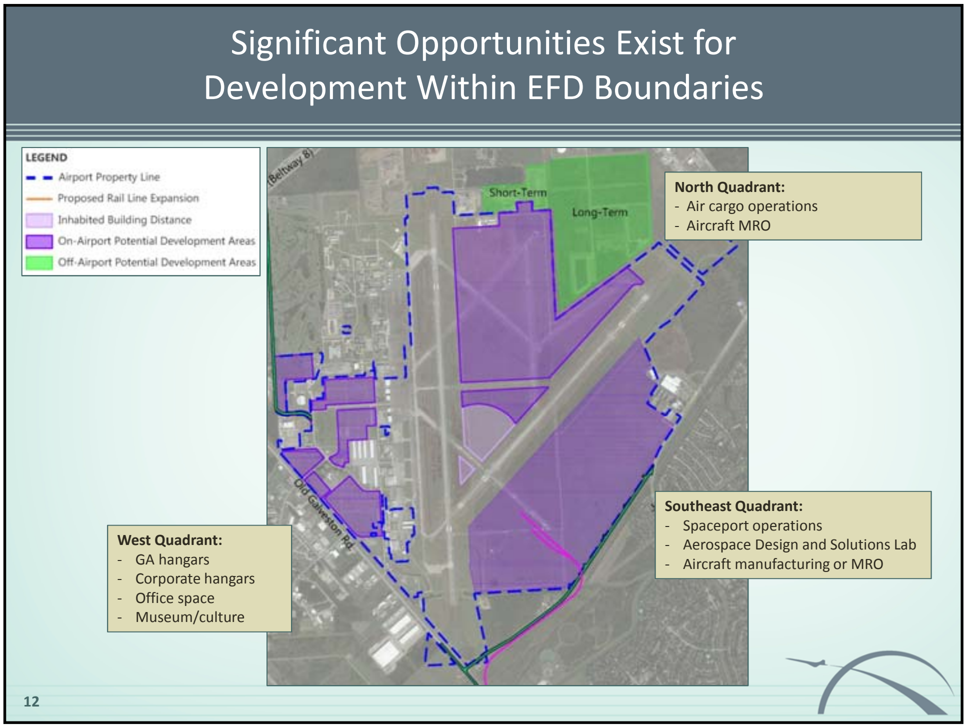
Improve Runway 4 Arrivals Taxi Route

Angled Taxiways

High Runway Occupancy Times for Runway 4 Arrivals

Stopped Train May Block All Airport Access Roads

Aligned Taxiway



Significant Opportunities Exist for Development Within EFD Boundaries

LEGEND
- - - Airport Property Line
— Proposed Rail Line Expansion
▨ Inhabited Building Distance
▨ On-Airport Potential Development Areas
🟩 Off-Airport Potential Development Areas

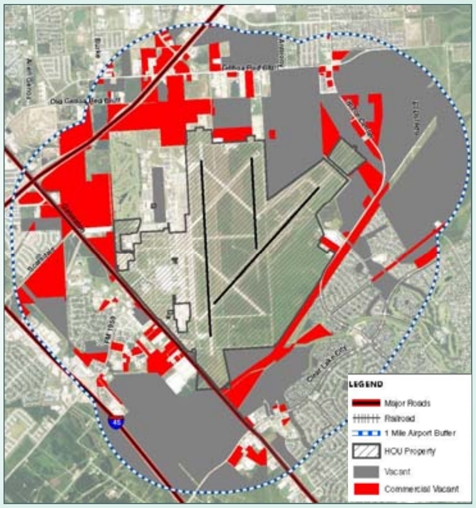
North Quadrant:
- Air cargo operations
- Aircraft MRO

Southeast Quadrant:
- Spaceport operations
- Aerospace Design and Solutions Lab
- Aircraft manufacturing or MRO

West Quadrant:
- GA hangars
- Corporate hangars
- Office space
- Museum/culture

Land is Available for Off-Airport Development

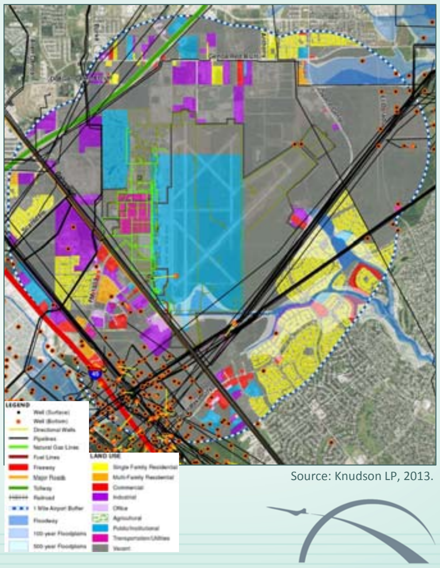
- Abundance of available land that is ready for development (hotels, retail centers, etc.)
- Excellent transportation connectivity to Beltway 8 and Interstate 45
- Flat topography
- Located in aerospace cluster with Boeing, NASA, and Johnson Space Center



Source: Knudson LP, 2014.

Constraints to Off-Airport Development

- Presence of many pipelines and railroad corridor
- Floodplains and wetlands which affect areas near EFD, and on EFD property
- Majority of agricultural lands are oil fields
- Lack of connectivity between land uses



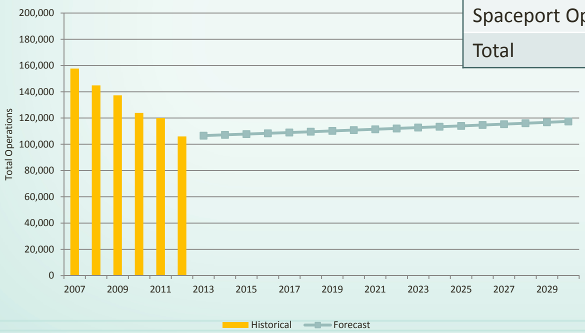
Source: Knudson LP, 2013.

Forecast of Future Aircraft Operations

No significant growth in aircraft operations is anticipated over the planning period

	2012	2030
Air Carrier	0	0
Air Taxi	8,827	12,607
General Aviation	61,683	69,313
Military	27,197	27,200
NASA	8,335	8,335
Spaceport Operations	0	200
Total	106,042	117,655

Source: Ricondo & Associates, Inc., 2014.



Ellington Airport's Rich Aviation Heritage

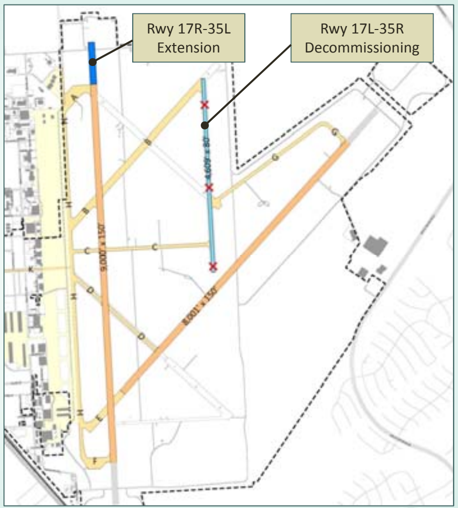
THE PAST
Ellington Field

THE FUTURE
Houston Spaceport at Ellington Airport

THE PRESENT
Ellington Airport

Recommended Runway Modifications

- Airfield recommendations will prepare EFD for spaceport operations while increasing the amount of land available for development
  - Extend Runway 17R-35L to support all future (horizontal-launch) spacecraft, with the exception of the Stratolauncher
  - Decommission Runway 17L-35R when the pavement fails, or if the land is needed for aeronautical development



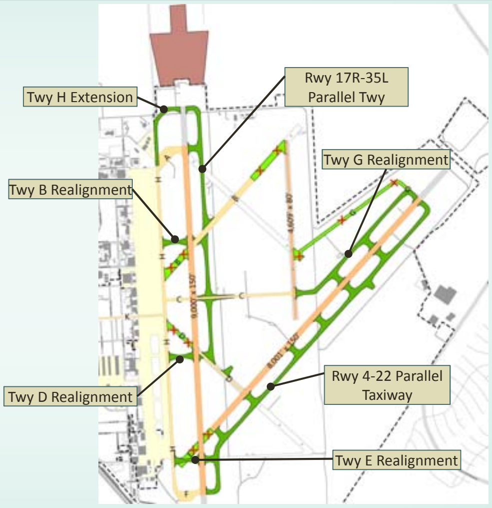
Recommended Taxiway Modifications

Near-Term Modifications:

- Construct taxiway parallel to Runway 4-22 to improve runway operations and allow full spaceport potential
- Realign Taxiways B, D, and E to meet current FAA design criteria and increase airfield safety
- Extend Taxiway H

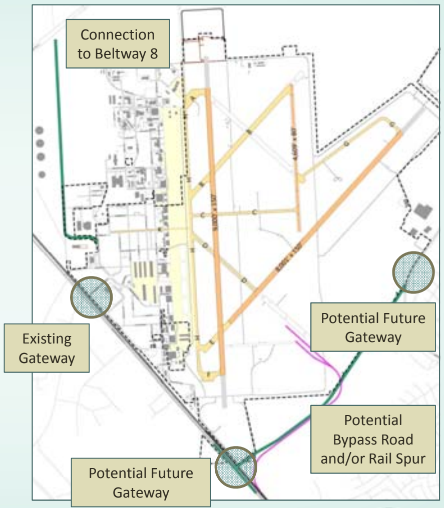
Long-Term Modifications:

- Realign Taxiway G for airfield efficiency and to increase availability of developable land
- Construct taxiway parallel to Runway 17R-35L



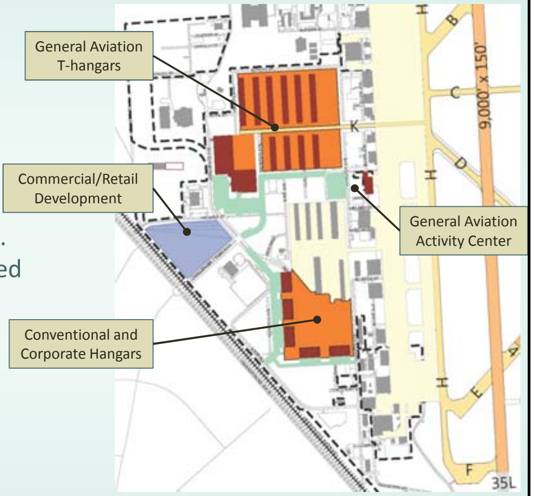
Access Improvements

- Construct bypass road when necessary to support future development in the southeast quadrant (note railroad crossing)
- Enhance and beautify Airport gateway(s)
- Preserve the ability to construct Beltway 8 connector
- Preserve the ability to construct a rail spur if needed to support future development



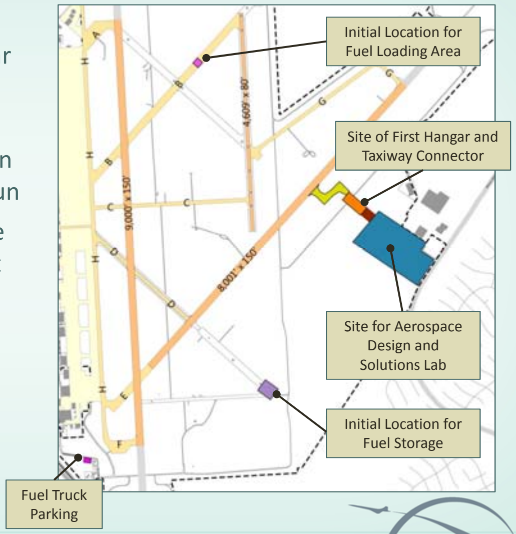
Accommodation of Expanding Tenant Needs

- Additional T-hangars can be constructed along Taxiway K
- Conventional (corporate) hangars can be constructed as demand materializes
- Airport Rescue and Fire Fighting operations were recently relocated. The previous site can be re-purposed as a General Aviation (GA) activity center to support future GA and corporate flight activity.

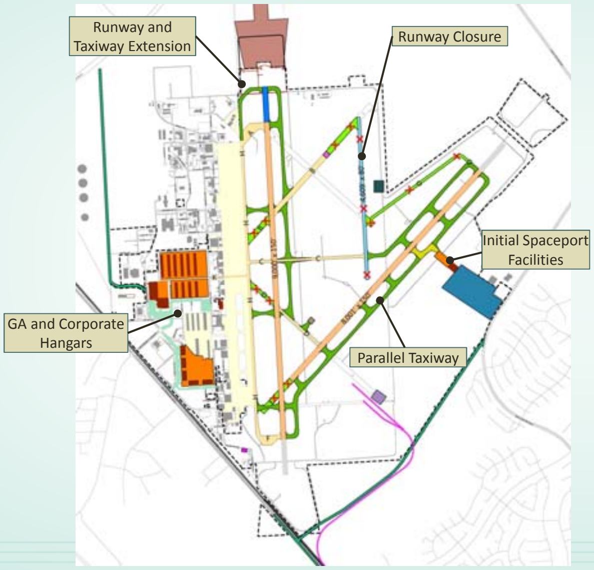


Initial Spaceport Facilities

- Recommended site for first spaceport hangar/apron will be near the existing Boeing and NASA facilities
- Initial planning for Aerospace Design and Solutions Lab facilities has begun
- Minor airfield improvements will be required to allow for first spaceport operations



Overview of Long-Term Airport Development Plan

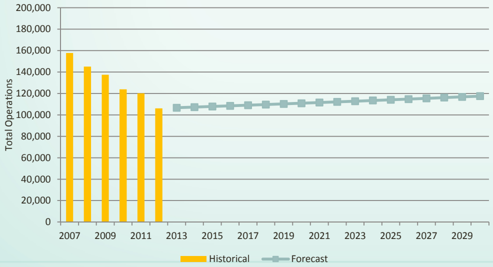


Ellington Airport

REGIONAL CONSIDERATIONS

Noise Impacts are Decreasing

- Noise contours shown were created during previous master plan in 2004
- Aircraft operations have decreased, thus reducing overall noise impact
- Proposed developments will generate minimal increases in aircraft operations



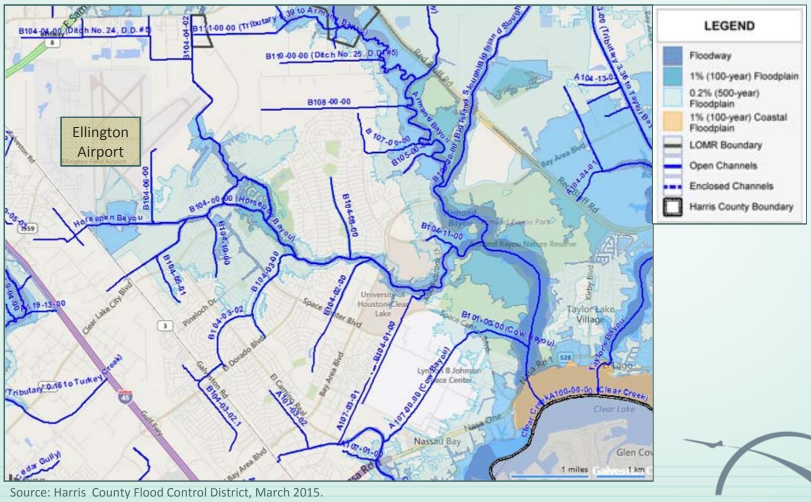
Noise contours prepared by LeighFisher Associates, 2004

Storm Water Runoff
Current Issues

Flooding at Ellington Airport:

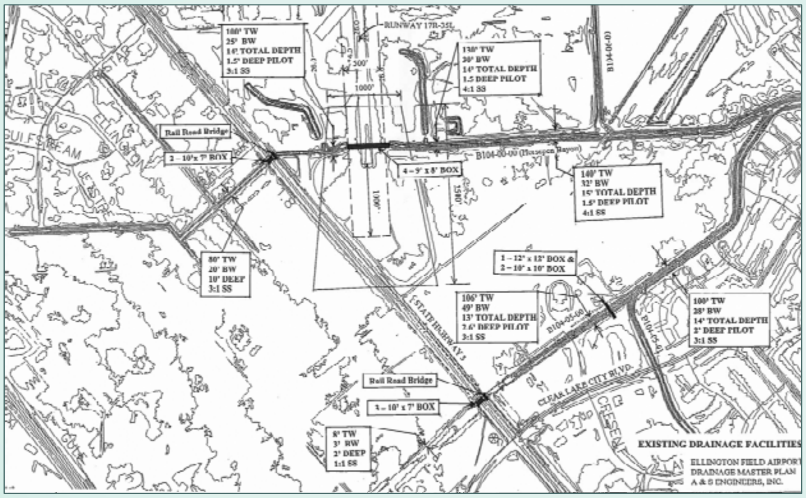
Storm Water Runoff
Current Issues

- Floodplain mitigation
- Runway 17R-35L is in the flood hazard way of Horsepen Bayou



Source: Harris County Flood Control District, March 2015.

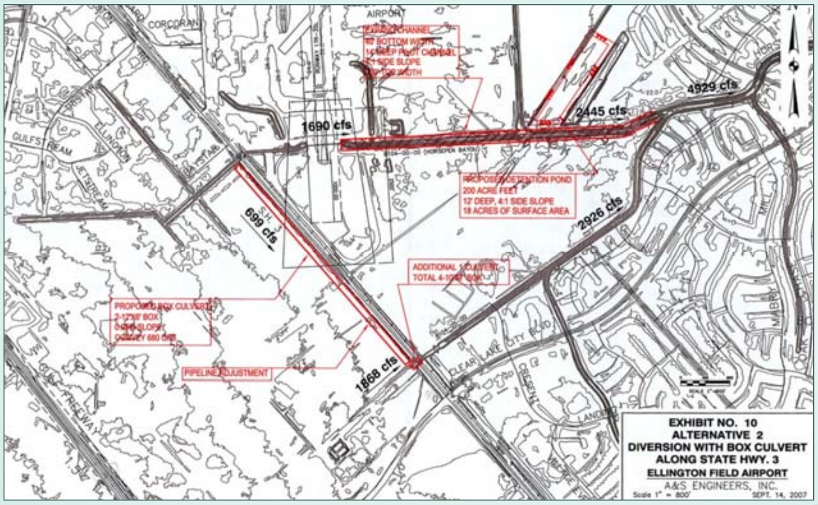
Storm Water Runoff
Existing Conditions



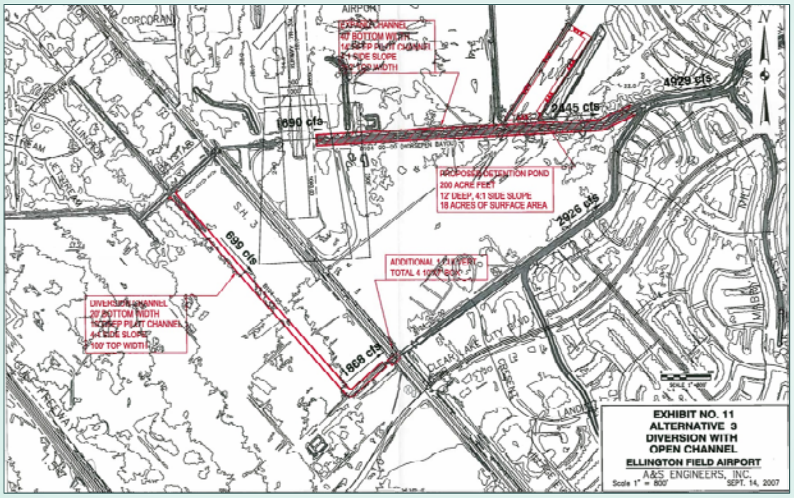
Storm Water Runoff
Proposed Improvements

- City of Houston is evaluating drainage improvements to improve storm water handling:
  - Horsepen Bayou expansion
  - New detention basin
- Future spaceport tenants/facilities will be required to have on-site detention.

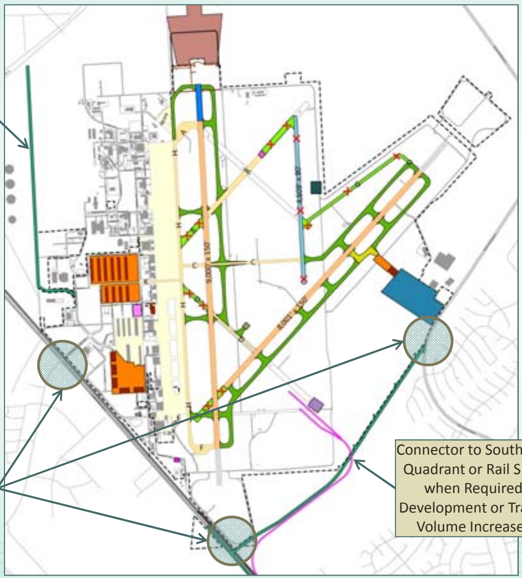
Storm Water Runoff
Box Culvert Alternative



Storm Water Runoff
Open Channel Alternative



Potential Long-Term Access and Image Improvements



Connector to Beltway 8 Remains a Possibility

Development of Gateway Entries to Houston Spaceport

Connector to Southeast Quadrant or Rail Spur when Required Development or Traffic Volume Increases

Next Steps

- Receive and review comments on the current recommendations
  - Modify recommendations, if necessary, based on comments received
  - Send comments to: **HAS.CommunityRelations@houstontx.gov**
- Prepare project reports
- Prepare Airport Layout Plan for FAA approval

Thank You for Attending and for Your Feedback!

Appendix D

Economics and Business Study

[Preliminary Draft for Discussion Purposes Only]

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1. Introduction

The Houston Airport System has a vision to create a commercial spaceport for aerospace innovation that allows support for horizontally launched spacecraft, known as Reusable Launch Vehicles (RLV's). This vision involves conversion of Ellington Airport (EFD) into a spaceport and a focal point for aerospace innovation – a regional center for a cluster of aerospace entities acting as incubators and accelerators for aerospace technology development. The proposed spaceport development is on 440 acres of greenfield land at the southeast section of the airport, shown in Figure 1-A.

Figure 1-A: Ellington Airport Spaceport Development Zone, SE Airside

SOURCE: HOUSTON AIRPORT SYSTEM

For Houston, this presents a tremendous opportunity for becoming a major contender in the rapidly growing commercial spaceflight industry. If planned correctly, for the next 10-20 years, Houston can use its position as a major metropolitan travel and business center, with proximity to the Gulf of Mexico, to lead the direction of growth for the commercial spaceflight industry. Houston is an ideal location for staging spacecraft launches over the Gulf with RLV's. Houston's "boom-town" economy leveraged with access to the NASA Johnson Space Center and coupled with a large subcontractor community of over 80 aerospace companies who currently provide significant access to an existing, robust aerospace community, has the potential to attract spaceport tenants, suppliers, vendors, entrepreneurs and developers. These distinct advantages positions Ellington Spaceport at the ground level of an emerging commercial spaceflight industry, to allow Houston to stake a claim that will keep its culture vibrant, and at the forefront of space exploration.

A successful Ellington Spaceport will be one that fits in and adds value to the local and regional economy. A competitive spaceport needs to offer far more than accessible airspace and a long runway to survive as a spaceport. The economic feasibility to ensure survivability of Ellington as a spaceport, and investment justifications, as well as the potential for growth and development of the surrounding community are vital questions addressed in this study.

1.1 Spaceport Location

Ellington Airport is one of three major airports run by the Houston Airport System (HAS), shown in Figure 1-C. It is located southeast of Houston, and currently, operates as the least active of the three airports managed by HAS. Ellington serves as the home base for several US Coast Guard and Texas National Guard units, as well as NASA training and research aircraft. The facility has hosted a strong NASA presence since the 1960's. The bulk of activity at Ellington Airport is devoted to private general aviation.

Ellington's advantages as a future hub of commercial spaceflight are due to its unique location, having proximity to one of the largest transportation hubs in the U.S. as well as one of the largest concentrations of space industry expertise in the country. Its convenient location to Bush Intercontinental Airport (IAH) and William P. Hobby Airport (HOU) provide a gateway with ease of access necessary to allow space tourist and spaceflight participants to travel to Houston by conventional flight for transition to a suborbital space flight.

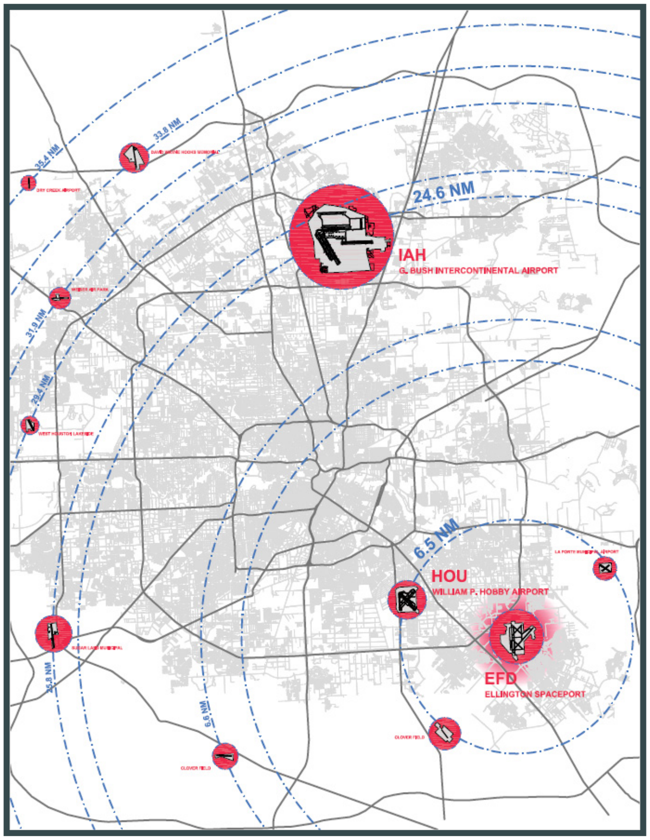

Figure 1-C: Houston Metro Airports

SOURCE: XSC, 2013

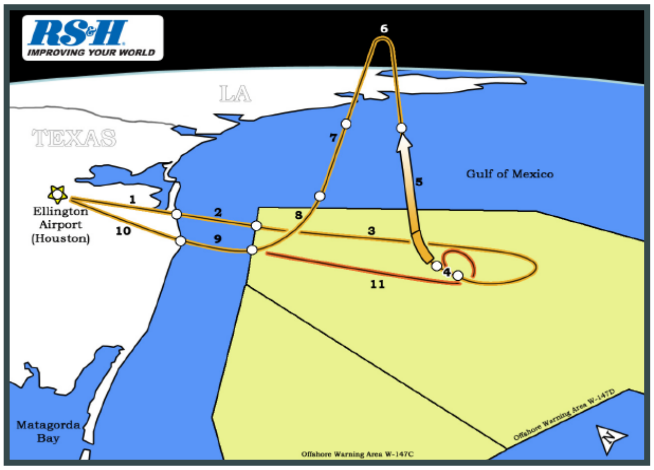

Figure 1-B: Sample RLV Flight Profile

SOURCE: RS&H, EFD TECHNICAL FEASIBILITY STUDY, 2012

As a spaceport, Ellington is an ideal location for a horizontal launch and landing spaceport because of its proximity to the Gulf of Mexico for staging launch operations (Figure 1-B). A Technical Feasibility Study conducted for HAS in 2012, by Reynolds, Smith & Hills, Inc. (RS&H) concluded "it is feasible to support space launch activities originating from Ellington" [1].

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[1] Houston Airport System: "Ellington Airport, Spaceport Feasibility Study", February 10, 2012, RS&H Project 212-2264-000

[Preliminary Draft for Discussion Purposes Only]

1.2 Study Context & Scope

The Ellington Spaceport Economics and Business Study addresses targeted markets, the anticipated activity level, and economic performance. The study identifies the competition within the national spaceport infrastructure network. It strategically assess market development, reasonable capture expectations, and time phasing to match expected timing of market developments. Illustrated in Figure 1-D, is a typical roadmap toward FAA commercial spaceport licensing, and identifies the components of this study within that process.

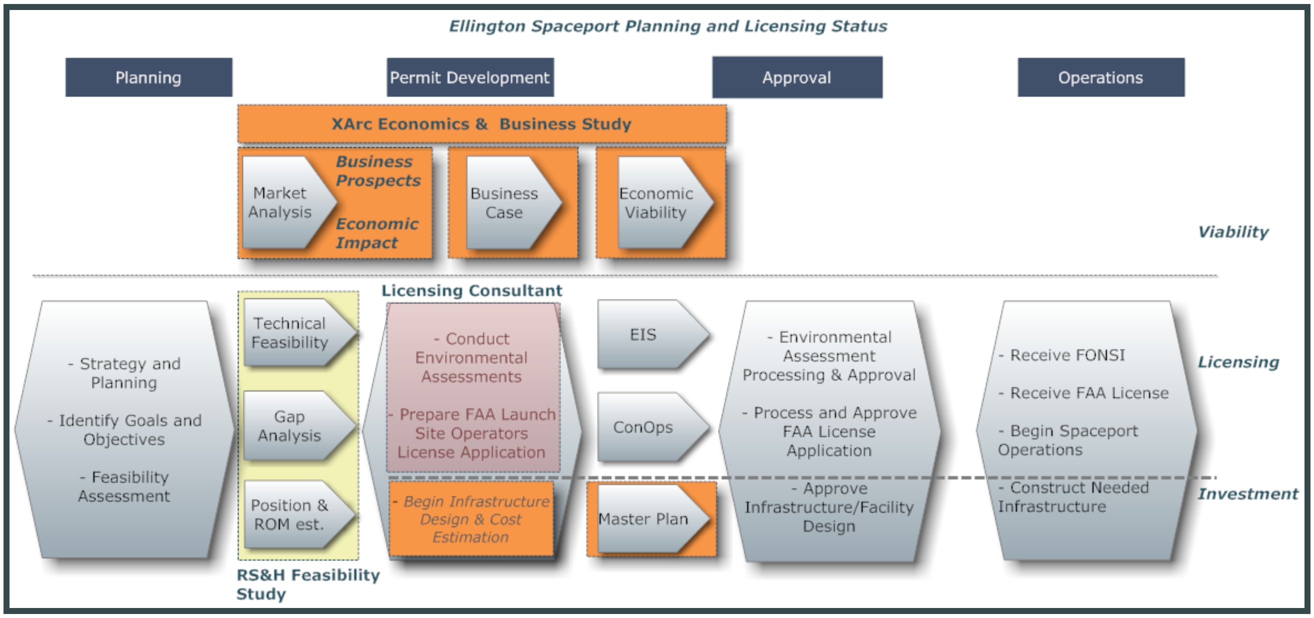

Figure 1-D: The Economics & Business Study establishes investment justification for spaceport licensing

SOURCE: XSC, 2013

1.2.1 STUDY COMPONENTS & PROCESS

The study is comprised of the six assessments shown in Table 1-A below. Each of these assessments builds upon each other as building blocks for developing and validating a spaceport business model. The Market Assessment serves as the foundation, identifying types of markets and spacecraft which can service those market segments available to EFD; while the Competitive Assessment shows how Ellington is positioned against competing commercial spaceports vying for these same markets. The User Needs Assessment surveyed potential operators/developers and related stakeholders to benchmark types of spacecraft and facility needs for operating from EFD to service the identified markets. The Demand Forecast Assessment then analyzed the potential for Ellington to capture a percentage of the addressable market size. The Business Case Assessment incorporated our understanding of the market environment to develop plausible operational scenarios for a business case with activity timelines for spaceport development. From the preceding assessments a spaceport business model was derived to reflect the reality of the market, and included an implementation plan for creating an environment at the spaceport for community collaboration in aerospace research and development. Three case studies of similar technology parks were also assessed to validate the proposed spaceport Research Park for lessons learned, or strengths and weaknesses of the three cases as applied to Ellington Spaceport of successful and not so successful technology park developments.

The analysis and data from the five assessment building blocks were then integrated to reflect the market activity timelines for spaceport operations in constrained and robust scenarios for identifying projections of spaceport infrastructure and facility growth patterns. Facility square footage estimates with associated costs were included. The spaceport growth pattern projections are used to inform EFD master planning activity, (Table 1-A). For visualization, marketing, and business development purposes, a spaceport design concept was created based on this market research driven design process. The sixth assessment, the Economic Impact Assessment was flowed into the process to describe the value to the Houston area, the economic benefit from the standpoint of HAS developing the spaceport.

Table 1-A: Study Elements and Relevance to EFD Master Plan

STUDY COMPONENT	INFORMS MASTER PLAN WITH:
Market Assessment Analysis of launch market segments that could utilize EFD	• **Spacecraft technology type** – Operational impacts to existing infrastructure
Competitive Assessment Identifies existing or potential competing spaceports and contrast their facilities and incentive policies with EFD	• **Infrastructure services** – Planned enhancements
User Needs Assessment Identifies operational & facility needs of operators and related stakeholders	• **Facility requirements** – New or re-purposed facilities needed
Demand Forecast Assessment Forecasts addressable launch demand at EFD (3 cases)	• **Phased development** – Implementation planning
Business Case Assessment Provides financial projections that quantify the potential business viability of the commercial entities utilizing EFD	• **Planning viability** – Growth scenarios
Economic Impact Assessment Assess impact of spaceport activity on the local economy	• **Commercial activities** – Ties revenue to growth scenarios

SOURCE: XSC, 2013

1.2.2 STUDY TEAM

XArc Spaceport Consultants (XSC)

Exploration Architecture Corporation (XArc) formed XArc Spaceport Consultants (XSC) in September of 2012, to lead a consortium of aerospace companies for providing full service consulting capabilities for capital projects endeavoring to seek commercial spaceport licensing and design. Core consortium members include Exploration Architecture Corporation (San Antonio, TX), Futron Corporation (Bethesda, MD), and The Aerospace Corporation (El Segundo, CA). Capabilities of the core XSC team serve as the basis for providing consulting services for initial phases of project development. Together with other specialized providers within the consortium as needed, a comprehensive set of spaceport development requirements can be serviced by

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the team, including: facility analysis; master planning; FAA licensing; operational planning; public relations; environmental assessments; economic analysis; business case planning; program management; and architecture, engineering and construction services. The combined capabilities of the XSC team has a successful history of demonstrated experience working on commercial spaceports worldwide, including Oklahoma Spaceport FAA licensing; Spaceport America programming and operational assessments; Spaceport Curacao economic impact assessment, and Texas commercial spaceports site assessments, (Table 1-B).

Table 1-B: XSC Spaceport Planning Consulting Experience

CONSORTIUM MEMBER	SPACEPORT PROJECT EXPERIENCE				CURRENT PROJECT
Exploration Architecture Corporation	Spaceport America	Kennedy Space Center	Cape Canaveral		Ellington Spaceport
The Aerospace Corporation	Oklahoma Spaceport	Vandenberg AFB	Texas Aerospace Commission Spaceports	Cape Canaveral	Ellington Spaceport
Futron Corporation	Spaceport America	Curacao Spaceport	Spaceport Florida Authority		Ellington Spaceport

SOURCE: XSC, 2013

Exploration Architecture Corporation's XArc Spaceport Consultants (XSC) team was competitively chosen by the Houston Airport System to conduct the Ellington Spaceport Economics and Business Study. The team is led by XArc Exploration Architecture Corporation with Futron Corporation, and The Aerospace Corporation providing subcontracted support. Figure 1-E identifies the team structure and team member responsibilities.

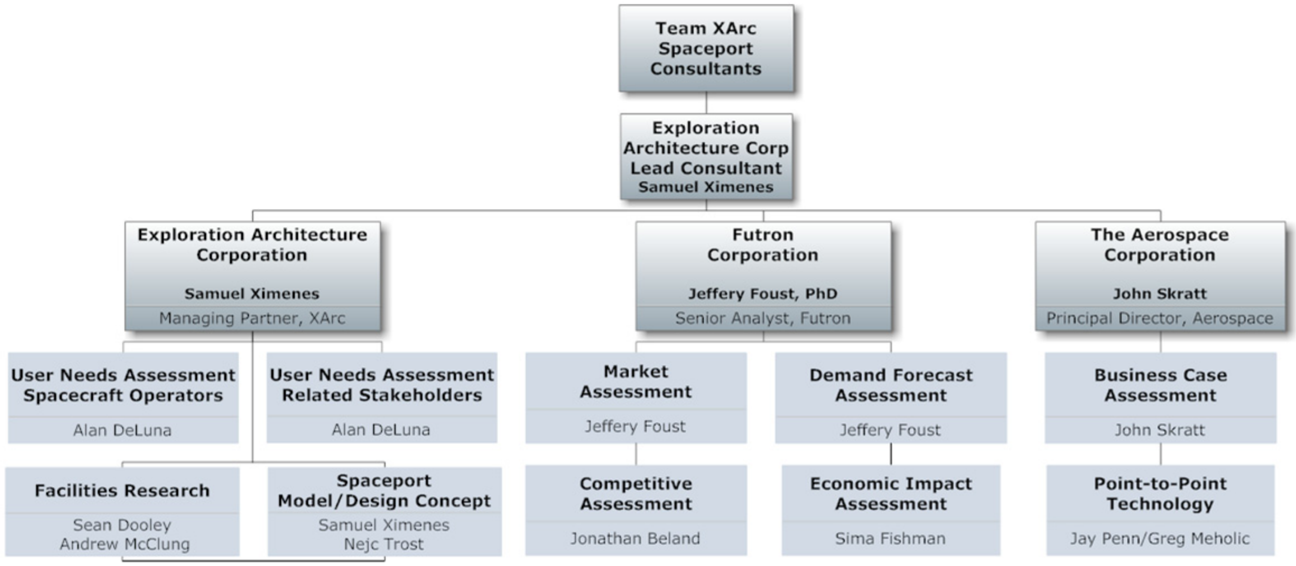

Figure 1-E: XSC Study Team for Ellington Spaceport Economics and Business Study

SOURCE: XSC, 2013

2. Market Segment Assessment

Objective: Provide an analysis of appropriate launch market segments that could utilize EFD (by customer type, orbit, and application) and market intelligence about those relevant segments.

2.1 Introduction

The market assessment task was designed to define and analyze appropriate launch market segments for a spaceport at Ellington Airport. It is a qualitative assessment that takes into account:

Vehicles capable of operating from EFD

Capabilities of these vehicles

Potential markets they can serve

This market assessment task is an essential first step in any overall analysis of the prospects of spaceport activity at Ellington Airport. The launch industry is a diverse one, with a wide range of vehicles supporting launches of tiny "nanosatellites" to large communications satellites to crew and cargo missions for the International Space Station. Moreover, new markets are emerging for launch activities, particularly in the field of commercial suborbital spaceflight. However, for technical and policy reasons, not all of these vehicles can launch from, and not all of these markets can be addressed by, Ellington.

The market assessment provides a top-level, qualitative assessment of the markets that could be served by launch vehicles that exist today or are under active development that could operate from Ellington. (More detailed launch forecast demand scenarios are provided in the Demand Forecast Assessment described in Section 5.) Given prohibitions on vertical launches from Ellington, the market is limited primarily to those served by emerging reusable suborbital vehicles, like SpaceShipTwo and Lynx, as well as small air-launched vehicles, like Pegasus. While launches of larger satellites and to orbits higher than low Earth orbit are not likely given these restrictions, the development of suborbital space tourism and research, as well as growing applications for small satellites, could offer potentially lucrative markets for launch companies that could fly from Ellington.

2.2 Approach

There are a wide range of launch vehicles in operation today or in various stages of development. These vehicles go from small suborbital vehicles designed to carry payloads briefly into space to powerful rockets used to launch large satellites and crewed spacecraft into Earth orbit and beyond. However, only a small fraction of these vehicles would be able to operate out of a spaceport at Ellington Airport, due to both policy considerations as well as the operational limitations of the facility. That reduces both the number of potential vehicles and the markets that they can serve.

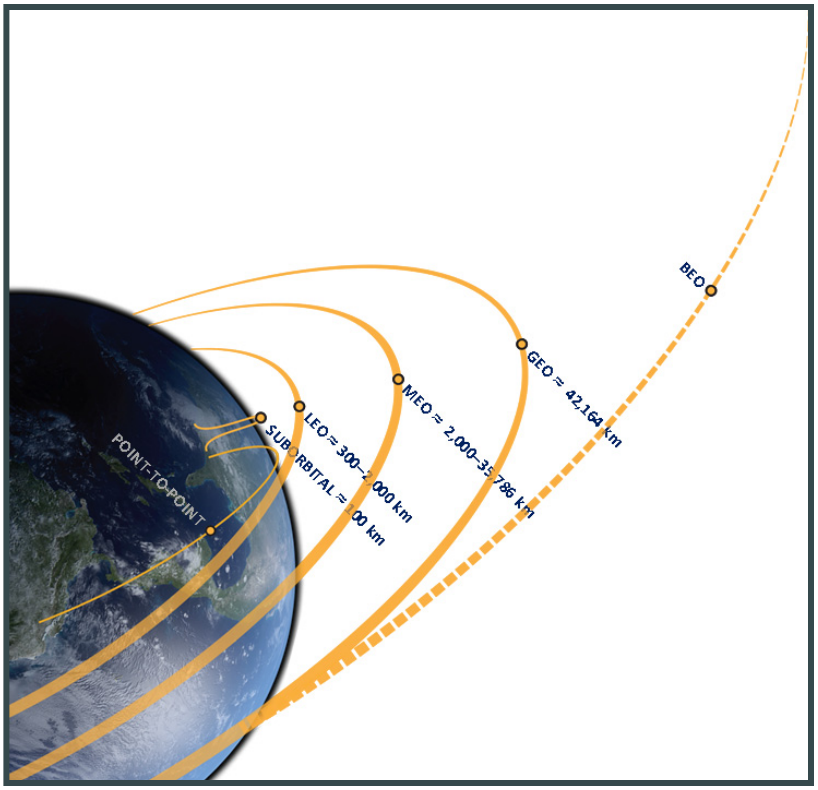

Figure 2-A: The XSC study examined potential markets based on orbit

SOURCE: XSC, 2013

For the purposes of this market assessment, we consider only those launch vehicles that can take off and land horizontally from runways at Ellington. This limits the available vehicles to some types of suborbital vehicles, like Virgin Galactic's SpaceShipTwo and XCOR Aerospace's Lynx, and orbital launch vehicles that use an aircraft as an initial stage, including Orbital Sciences Corporation's Pegasus XL and Stratolaunch System's Stratolauncher. (In some cases, including SpaceShipTwo and Stratolauncher, vehicles under development may require runways longer than those currently available at Ellington.) These vehicles are retained for this analysis in the event that either their technical requirements change or Ellington lengthens its runways to accommodate them. In addition, vehicles developed in other nations (e.g. China and Russia) that could not, for policy reasons, operate from a United States spaceport were excluded; although in practice there are no vehicles in operation or under development in other nations that would be excluded from operating out of Ellington on those grounds.

These operational restrictions place limits on the markets addressable from vehicles operating out of Ellington, particularly for launching satellites. Most air-launch systems—the only kind of satellite launch systems that could operate from Ellington, given the prohibition on vertical launch systems—are designed to launch small satellites, weighing no more than a few hundred kilograms, into low Earth orbit. By contrast, most communications satellites weigh several thousand kilograms and operate in geostationary orbit. There are however, a growing number of applications for small satellites in lower orbits that would be addressable by vehicles operating out of Ellington in the coming decade and beyond.

To identify markets that could be served by suborbital or orbital vehicles launching from Ellington, XSC examined the capabilities of those vehicles and compared them to satellite and suborbital payload requirements in a variety of markets, aggregated by orbit. Figure 2-A identifies the various orbits examined for serviceable markets. The most diverse markets are for Suborbital missions, as well as Low Earth Orbit (LEO) satellite launches. There is a limited market for Medium Earth Orbit (MEO) satellites, and little or none for satellite in Geosynchronous Earth Orbit (GEO), or missions Beyond Earth Orbit (BEO). A market for future hypersonic Point-to-Point (P2P) transportation capability was not forecasted as the maturity of this technology has yet to be realized.

Market segments identified in this analysis were taken from a study conducted by the Tauri Group and published in the "FAA Annual Compendium of Commercial Space transportation: 2012". Figure 2-B from the Tauri study summarizes and defines these markets. The color coded market segment icons from the Tauri Study are used throughout this report.

COMMERCIAL HUMAN SPACEFLIGHT
Human spaceflight experiences for tourism or training

BASIC AND APPLIED RESEARCH
Basic and applied research in a number of disciplines, leveraging the unique properties of and access to the space environment and microgravity

AEROSPACE TECHNOLOGY TEST AND DEMONSTRATION
Aerospace engineering to advance technology maturity or achieve space demonstration, qualification, or certification

MEDIA AND PUBLIC RELATIONS
Using space to promote products, increase brand awareness, or film space-related content

EDUCATION
Providing opportunities to K-12 schools, colleges, universities, and graduate programs to increase access to and awareness of space

SATELLITE DEPLOYMENT
The use of SRVs to launch small payloads into orbit

REMOTE SENSING
Acquisition of imagery of the Earth and Earth systems for commercial, civil government, or military applications

POINT-TO-POINT TRANSPORTATION
Future transportation of cargo or humans between different locations

Figure 2-B: Market Segments Definitions

SOURCE: FAA ANNUAL COMPENDIUM OF COMMERCIAL SPACE TRANSPORTATION: 2012 / SUBORBITAL REUSABLE VEHICLES: A 10-YEAR FORECAST OF MARKET DEMAND, THE TAURI GROUP

XSC's assessment of these markets, and the vehicles able to operate from Ellington that could serve them, are discussed in the following section.

2.2.1 AVAILABLE VEHICLES

As noted above, the space markets that can be directly served by launch operations from Ellington Airport will depend on the vehicles that can operate from a spaceport there given the restrictions on the types of vehicles it can support (i.e., no vertically-launched vehicles). The "Ellington Airport, Spaceport Feasibility Study", prepared by RS&H has defined three generic concepts for reusable launch vehicles (RLV) that are considered for operation at EFD and are referred to as Concept X, Concept Y, and Concept Z type vehicles. Table 2-A describes the respective vehicle concept characteristics.

Table 2-A: Reusable Launch Vehicle Concept X, Y, Z Summary

CHARACTERISTIC	CONCEPT X	CONCEPT Y	CONCEPT Z
Takeoff Orientation	Horizontal	Horizontal	Horizontal
Takeoff Method	Jet Powered	Rocket Powered	Jet Powered
Uses Carrier Aircraft	No	No	Yes
Landing Method	Glide or Jet Powered	Glide	Glide / Expendable
Suborbital or Orbital	Suborbital	Suborbital	Either
Manned or Unmanned	Manned	Manned	Either

SOURCE: HOUSTON AIRPORT SYSTEM: "ELLINGTON AIRPORT, SPACEPORT FEASIBILITY STUDY", FEBRUARY 10, 2012, RS&H PROJECT 212-2264-000

An XSC survey of global horizontal launch vehicle spaceship development efforts was conducted, cataloged, and mapped to a concept type X, Y, or Z operational scenario as shown in Table 2-B.

Table 2-B: Horizontal Launch Vehicles Spaceship Catalog Survey

	TYPE	SPACE SYSTEM	COMPANY	ORIGIN	RWY LENGTH (FT)	PROPULSION	MARKET	PAY LOAD (KG)	CREW	FLT ALTITUDE (KM) (EST)	TRL (EST)
1	Z	Pegasus XL	Orbital Space Corporation	US	10,000	SRB	Satellites	443	0	380	9
2	Z	WK2 / SS2	Virgin Galactic	Mojave, US	12,000	Hybrid; N2O	Space Tourists	0	6	100	8
3	Z	LauncherOne	Virgin Galactic	Mojave, US	10,000	Hybrid; N2O	Small Satellites	225	0	380	6
4		Pollux	CIRA	Italy	-	-	Satellites	-	-	380	5
5	X	Skylon	Reaction Engines	UK	18,000	LOX-LH2	Space Tourists	12000	25	380	5
6	Y Z	Lynx Mark III	XCOR	Mojave, US	7,900	LOX-Kerosene	Small Satellites	650	0	380	5
7	Y	Lynx Mark II	XCOR	Mojave, US	7,900	LOX-Kerosene	Space Tourists	0	2	100	5
8	X	LAPCAT A2	Reaction Engines	UK	18,000	LOX-LH2	Point2Point	-	300	28	5

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	TYPE	SPACE SYSTEM	COMPANY	ORIGIN	RWY LENGTH (FT)	PROPULSION	MARKET	PAY LOAD (KG)	CREW	FLT ALTITUDE (KM) (EST)	TRL (EST)
9	Z	Stratolaunch	Stratolaunch Systems	Mojave, US	12,000	SRB and Liquid Stages	Satellites	6100	-	380	4
10	X	Rocketplane XP	Rocketplane Global	Oklahoma City, US	10,000	LOX-Kerosene	Space Tourists, P2P	-	6	100	4
11		S3 Spaceplane	Swiss Space Systems	Switzerland	10,000	LOX-Kerosene	Satellites	250	0	380	3
12	X	Sidereus spaceplane	Rocket Crafters	Utah, US	-	Hybrid, LOX	Space Tourists	-	8	100	3
13		VEHRA	Dassault Aviation	France	10,000	LOX-Kerosene	Satellites	300	0	380	2
14	X Z	GO Launcher 2	Generation Orbit	Atlanta, GA	8,000	LOX-Paraffin	Satellites	30	0	380	2
15		Cosmopolis XXI	Space Adventures	RUS	-	SRB	Space Tourists	-	5	100	2
16		Ascender	Bristol Spaceplanes	UK	-	Hydrogen Peroxide	Space Tourists	-	4	100	2
17		Spaceplane	EADS Astrium	EU	10,000	Methane - Oxygen	Space Tourists	-	5	100	2
18		VSH	Dassault Aviation	France	10,000	LOX-Kerosene	Space Tourists, P2P	-	3	100	2
19	X Z	GO Launcher 1	Generation Orbit	Atlanta, GA	8,000	LOX-Paraffin	Satellites	100	0	100	2
20		Constellation	Marcus Aerospace	Atlanta, US	-	-	Satellites	75	0	500	1
21		Spacecab	Bristol Spaceplanes	UK	-	LOX/LH2	Satellites	750	-	380	1
22		Explorer	Marcus Aerospace	Atlanta, US	-	-	Space Tourists, Satellites	450	5	380	1
23		Talis Enterprise	Talis Enterprise	Germany	-	-	Space Tourists	-	8	125	1

SOURCE: XSC, 2013

Vehicles available for EFD operations were filtered by assessing for technology readiness (Figure 2-C), runway length required, and other criterion for operating out of EFD. This filtering limits the market to three reusable suborbital vehicles currently in various stages of development, and several air-launch orbital systems that are either in operation today or in early stages of development.

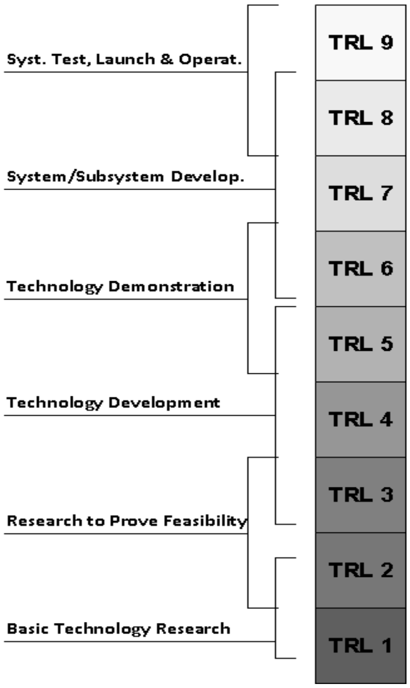


Figure 2-C: Definitions of NASA Technology Readiness Level (TRL)

SOURCE: NASA

Suborbital Vehicles Types Identified for EFD

Virgin Galactic plans to serve this emerging market through the use of its SpaceShipTwo suborbital vehicle. SpaceShipTwo will take off from a runway attached to a carrier aircraft, WhiteKnightTwo. At an altitude of about 15,000 meters, WhiteKnightTwo will release SpaceShipTwo, which will ignite its rocket engine to ascent to an altitude of at least 100 kilometers. SpaceShipTwo will then glide back to a runway landing at its takeoff site. The vehicle will have two pilots and room for six spaceflight participants or equivalent cargo.

XCOR Aerospace is also pursuing the suborbital spaceflight market with its Lynx spaceplane. The Lynx will takeoff from a runway under rocket power and immediately ascend towards space. The Mark I version of the Lynx will reach a peak altitude of about 60 kilometers, although the Mark II version that will shortly follow will reach altitudes of at least 100 kilometers. It will then land at the same runway it took off from. XCOR is offering lower prices for Lynx flights—$95,000, versus $200,000 for Virgin Galactic—each Lynx will carry only one customer, plus one pilot, and unlike SpaceShipTwo, there will be no room in the cabin to float around.

Another company planning a suborbital vehicle that takes off and lands horizontally is RocketCrafters. The company is working on an as-yet-unnamed suborbital spaceplane that will be capable of taking off and landing from runways under rocket power. The company has released few other details about their plans, including the number of people the vehicle can carry and the price for a flight. The company has indicated they expect flights to begin "sometime before the end of 2016," after the development of prototypes that have both jet and rocket engines for pilot training. Given the limited detailed revealed by the company, RocketCrafters is much more of a long shot to enter the suborbital spaceflight market than either Virgin Galactic or XCOR.

Orbital Vehicles Types Identified for EFD

As previously noted, operational restrictions at Ellington limit the population of possible orbital launch vehicles that could use the facility to air-launch systems that use an aircraft as their initial stage. Single stage to orbit launch vehicles that take off and land horizontally have been proposed in the past, but none are in operation today and none are expected to enter service in the next decade.

While air launch systems offer a great deal of operational flexibility, one drawback is that they have limited payload performance, given the restrictions on the size of a rocket that a plane can carry. This limits air launch systems to small satellites in low Earth orbit, leaving many existing space markets, requiring larger satellites and/or in higher orbits, un-addressable by these systems.

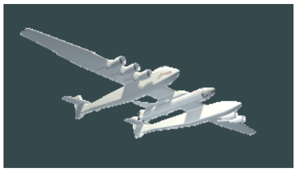
The one air launch system currently operating is Orbital Sciences Corporation's Pegasus XL rocket. The rocket is attached to the underside of an L-1011 aircraft, which carries the rocket to an altitude of about 12,000 meters before releasing it. The three solid-fuel stages of the Pegasus XL can place payloads of up to 450 kilograms into low Earth orbit, depending on the altitude and orbital inclination. The rocket has flown more than 40 times since its introduction in 1990, including 27 consecutive successful missions. However, Orbital has only one Pegasus mission on its manifest, and the long-term future of the vehicle is in doubt.

Several other air launch systems are currently under development devoted to launching even smaller satellites. Virgin Galactic announced plans in 2012 to develop LauncherOne, an air launch system that will use some technology already developed for its SpaceShipTwo suborbital system. LauncherOne will use the WhiteKnightTwo aircraft as a launch platform, but replace the SpaceShipTwo suborbital vehicle with a new two-stage liquid-propellant rocket. LauncherOne is slated to enter service in 2016, launching satellites for less than $10 million.

XCOR Aerospace is also planning to develop a small satellite launcher variant of its Lynx suborbital spaceplane. The Lynx Mark III is a variant of the Mark II with an external pod that can host an expendable upper stage and satellite. The company has previously discussed being able to launch satellites weighing up to 10 kilograms for approximately $500,000, beginning no earlier than 2016.

Generation Orbit is a small Georgia-based startup company developing a small air launch system. The Generation Orbit Launcher 2, (GO2), would use a modified business jet carrying a small launch vehicle on its underside. (The GO Launcher 1 is a suborbital prototype). GO2 would launch 20 to 30 kilograms into low Earth orbit. The company has not announced a service date or pricing for the GO2 system.

The Defense Advanced Research Projects Agency (DARPA) is supporting a project called the Airborne Launch Assist Space Access (ALASA) to develop an air launch system. ALASA would use an aircraft that would, like other air launch concepts, release a rocket to carry a satellite into orbit. DARPA has a goal of launching satellites weighing up to 45 kilograms into orbit for $1 million each, starting in the mid-2010s. Last year DARPA awarded system design study contracts to Boeing, Lockheed Martin, and Virgin Galactic to further concepts the companies were proposing (Virgin's being similar to its LauncherOne). In our discussion with Virgin Galactic, in was indicated they would consider evaluating potential of using Ellington as a candidate site for launches from the Gulf Coast region.



While these air launch systems are all designed for payloads weighing no more than a few hundred kilograms, one system in the early stages of development is planning to launch larger satellites. Stratolaunch Systems, a company backed by Paul Allen, unveiled plans in December 2011 for the largest air launch system proposed to date. Stratolauncher would use a custom-built aircraft that would be the largest (by wingspan) built to date, featuring twin fuselages and six jet engines. The aircraft would carry aloft and then release a rocket designed to carry satellites weighing up to 6,100 kilograms into low Earth orbit. The company originally planned to use a derivative of the SpaceX Falcon 9 for the rocket, but the companies parted ways in late 2012 and Stratolaunch is now in discussions with Orbital Sciences Corporation. The company, at the time of its original announcement, said it expected to begin flight tests in 2016.

One issue with Stratolaunch Systems with respect to Ellington is that the company's proposed aircraft requires a minimum of 12,000 feet (3,660 meters) of runway, about 3,000 feet (910 meters) more than the longest current runway at Ellington. Given the potential for technical modifications to the Stratolauncher design as the company switches launch vehicle providers, as well as the potential to increase the runway length at Ellington, we have retained this vehicle in our assessment of addressable markets.

2.3 Market Assessments

2.3.1 SUBORBITAL

Suborbital, for the purposes of this analysis, refers to launches where a payload (including people or experiments) is flown above the atmosphere, but does not go into orbit and immediately returns to Earth, either at the site of the launch or other locations. Altitudes attained by suborbital launches vary, but typically reach an altitude of at least 100 kilometers, known in the aerospace community as the Von Karman Line. To date the vehicles in this market have been expendable, un-crewed, vertically launched sounding rockets, but several reusable suborbital vehicles, some of which carry people and/or take off and land horizontally on runways, are under development as described above, and expected to enter service in the next few years, and thus provide an opportunity for Ellington Airport.

Tourism

COMMERCIAL HUMAN SPACEFLIGHT

Human spaceflight experiences for tourism or training

The largest market for these new suborbital vehicles is space tourism. Several companies are developing vehicles that will carry paying customers on suborbital flights, giving them views of the Earth from altitudes of 100 kilometers or higher and exposing them to approximately five minutes of weightlessness before returning to Earth. Virgin Galactic, the leader in this emerging industry, has signed up more than 560 customers as of February 2013, all of whom have paid at least a $20,000 deposit and some of whom have paid the full ticket price of $200,000. XCOR has also signed up customers for the Lynx vehicle though partners such as Space Experience Corporation (SXC). Space Adventures, the space tourism company that has arranged for several customers to fly to the International Space Station, also has customers who have paid deposits for suborbital flights, although it is partnered with Armadillo Aerospace, a company whose vertically-launched vehicle cannot operate from Ellington.

Studies indicate that tourism is likely to be the largest market for suborbital commercial spaceflight for the foreseeable future. Futron's Space Tourism Market Study, first published in 2002 and last updated (for suborbital spaceflight) in 2006, indicates growing demand for suborbital spaceflight, reaching 14,000 customers a year by 2021. A 2012 report prepared by The Tauri Group for the FAA Office of Commercial Space Transportation and Space Florida estimated lower, but still significant, numbers of potential space tourism customer, increasing to approximately 400 per year in the final year of their ten-year baseline forecast and more than 1,200 in the final year of their growth forecast. (The Futron forecast estimated the demand for flights, based on the population of people globally with the interest and willingness to pay for them; the Tauri forecast uses a somewhat different methodology.)

The number of flights will depend on the mix of vehicles used, as proposed vehicles can carry between one (Lynx) and six (SpaceShipTwo) people, in addition to crew; greater use of SpaceShipTwo, for example, would result in few overall flights. However, companies in the industry anticipate a large number of flights taking place from multiple spaceports around the world, starting with the Mojave Air and Space Port in California and Spaceport America in New Mexico and then expanding to facilities elsewhere in the United States and beyond. If successful, this market would provide many spaceports with regular suborbital launch activities.

Research

BASIC AND APPLIED RESEARCH

Basic and applied research in a number of disciplines, leveraging the unique properties of and access to the space environment and microgravity

While tourism appears to be the largest market for commercial suborbital vehicles, research is emerging as a significant market in its own right. There is growing interest in flying experiments, with or without people on board, to perform biomedical, materials science, space science, and other research, taking advantage of the high altitudes and several minutes of microgravity achievable on a suborbital flight. The low costs per flight and the potential for rapid re-flights—some companies are discussing flying on a daily, or even several times per day basis—adds to the attractiveness of these vehicles to the research community.

The size of this market is still difficult to gauge, since the full research capabilities of these vehicles have yet to be demonstrated. The Tauri Group suborbital forecast cited above estimates that, in its baseline model, research use of suborbital vehicles will grow from 19 to 78 seat equivalents (i.e., the amount of space equivalent to that used by a person on a tourism flight) per year over its ten-year forecast; a more optimistic growth forecast sees that rising from 21 to 171 seat equivalents over that same ten-year period. A single suborbital flight may be able to accommodate from one to several research seat equivalents, depending on the vehicle and the configuration, as is the case with suborbital tourism flights.

Technology Demonstration

AEROSPACE TECHNOLOGY TEST AND DEMONSTRATION
Aerospace engineering to advance technology maturity or achieve space demonstration, qualification, or certification

A third, smaller market for suborbital vehicles is in the arena of technology development. Similar to research, this involves flying technologies to demonstrate their performance in the space environment, advancing their technology readiness level to allow them to be used on orbital missions. Depending on its specific capabilities, a suborbital vehicle can test a technology in weightlessness, vacuum, and at near-hypersonic velocities. This can provide for a more effective and less expensive means of testing and qualifying technologies than other approaches.

The market for technology development flights appears to be small at this time, and likely would be ancillary to other markets, such as research and tourism. The Tauri Group forecast estimated the number of seat equivalents for suborbital technology development missions to grow only from two per year to nine per year over the course of its baseline ten-year forecast. In the growth forecast, there is more growth, but the market remains small: from four per year to 25 per year in the forecast period.

Other Markets

EDUCATION
Providing opportunities to K-12 schools, colleges, universities, and graduate programs to increase access to and awareness of space

REMOTE SENSING
Acquisition of imagery of the Earth and Earth systems for commercial, civil government, or military applications

MEDIA AND PUBLIC RELATIONS
Using space to promote products, increase brand awareness, or film space-related content

POINT-TO-POINT TRANSPORTATION
Future transportation of cargo or humans between different locations

Suborbital vehicles can serve a number of additional markets as well. Some applications that have been proposed include media and public relations, education, and remote sensing. Given the limited information available, these markets are not expected to be major drivers of commercial suborbital launch activity in the coming decade.

A potential large long-term suborbital market is point-to-point transportation. There have been numerous proposals to develop high-speed passenger transports that would fly suborbitally, going from one point on the globe to any other within one to two hours. This could greatly reduce the travel time for intercontinental flights. Ellington would be of particular interest to such vehicles, given its location as part of a major metropolitan area. However, the technology needed for such vehicles has yet to be developed, and the pricing of such flights, the corresponding size of the market, and the overall financial viability of such systems has yet to be demonstrated. This is a market worth watching over the long term (i.e., more than a decade), but is not one that provides any near-term demand for spaceport facilities at Ellington or elsewhere.

2.3.2 LOW EARTH ORBIT

Communications

SATELLITE DEPLOYMENT
The use of SRVs to launch small payloads into orbit

Most communications satellites are located in geostationary orbit and are quite large: it is not uncommon for such spacecraft to weigh in excess of six tons, in order to maximize the power and throughput capacity of the satellite's communications payload. These characteristics put these spacecraft far beyond the range of any vehicle that could operate from Ellington for the foreseeable future.

There are, however, another class of smaller communications satellite that operate in low Earth orbit. Three companies—Globalstar, Iridium, and ORBCOMM—operate fleets, or constellations, of communications satellites in LEO to provide data and telephone services globally. All three companies started in the 1990s and launched their constellations then. However, terrestrial competition caused each company to go through Chapter 11 bankruptcy reorganization at the end of the 1990s through the early 2000s. The companies are still in business today in reorganized form, and all three are in the process of launching next-generation satellites to replenish their constellations as the original satellites reach the end of their lives.

In some cases these spacecraft are small enough to be launched by vehicles that could operate from Ellington: the original ORBCOMM satellites weighed less than 50 kilograms each, and were launched several at a time on Pegasus rockets. Currently, there are no additional LEO communications satellite constellations planned for the next decade, and the three companies that have such systems have already made launch arrangements with other providers. However, there may be opportunities to launch one-off satellites to replace those that failed prematurely; this could provide a small number of launch opportunities for smaller vehicles that could operate from Ellington.

Remote Sensing

SATELLITE DEPLOYMENT
The use of SRVs to launch small payloads into orbit

REMOTE SENSING
Acquisition of imagery of the Earth and Earth systems for commercial, civil government, or military applications

LEO is commonly used for remote sensing satellites that take imagery of the Earth at visible and other wavelengths. Such images have many applications by government agencies and commercial entities alike, from monitoring land usage to urban planning to national defense. Traditionally, remote sensing has required the use of relatively large satellites, weighing many hundreds to thousands of kilograms, in order to accommodate all of the optics, sensors, and other equipment required to collect images and return them to Earth.

Advances in small satellite technology, though, enable smaller spacecraft weighing dozens of kilograms or less to perform many of the same missions. While smallsats can't provide the same extremely high-resolution imagery as larger commercial spacecraft, like DigitalGlobe's WorldView spacecraft, they can provide medium-resolution imagery at far lower costs than larger spacecraft. In addition, multiple small spacecraft can provide high temporal resolution (that is, shorter gaps between images of the same location) than a single larger spacecraft, something useful for activities where frequency imagery is desirable or required.

An example of companies in this market is Skybox Imaging, a company developing a constellation of small remote sensing satellites to provide frequent imagery coverage. The company is building its own satellites, weighing a few tens of kilograms, with the first two slated for launch as secondary payloads later this year. Skybox is also a customer of Virgin Galactic's LaucnherOne dedicated smallsat launch vehicle.

SpaceWorks Engineering, in a new (February 2013) forecast for smallsat launches, estimates that 56 satellites in what is classifies as reconnaissance, earth observation, and remote sensing will launch over the next three years, with potential for growth in the overall satellite market, including remote sensing and related applications, through the end of the decade. Since remote sensing satellites typically have specific orbit requirements (highly inclined "Sun-synchronous" orbits in order to observe different regions of the Earth at the same local time), dedicated smallsat launchers could find a niche here.

Science

SATELLITE DEPLOYMENT
The use of SRVs to launch small payloads into orbit

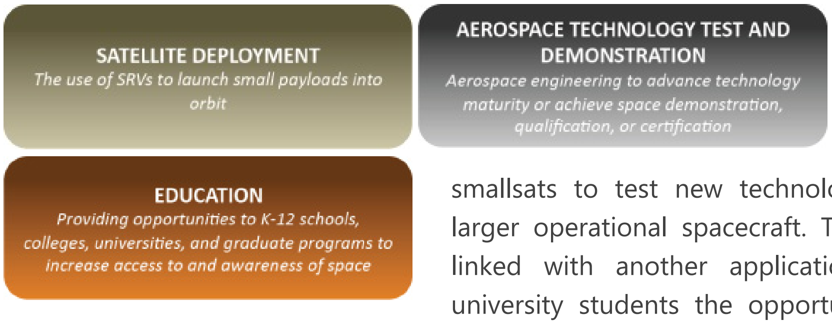
BASIC AND APPLIED RESEARCH
Basic and applied research in a number of disciplines, leveraging the unique properties of and access to the space environment and microgravity

Small satellites in LEO can be used for a variety of non-Earth science applications, in particular astronomy and space sciences. Studies of the Earth's magnetic field are a particularly good use of small satellites, since the requirements of the instruments needed are a good fit for smallsats. Several universities have already flown smallsats, some weighing only a few kilograms, to study the Earth's magnetic field and its interaction with the upper atmosphere or with the solar wind.

Small astronomy satellites can also be flown for specific missions. In February, an Indian rocket launched the Canadian NEOSSat (Near Earth Object Surveillance Satellite), a small space telescope weighing 75 kilograms designed specifically to search for near Earth objects. Canadian researchers also launched a small astronomy telescope called MOST in 2003 that remains in operation today.

The SpaceWorks forecast estimates 107 smallsats will launch over the next three years, constituting a third of the overall market for smallsats in that period. This could be another significant market for dedicated smallsat launch vehicles operating from Ellington, although in many cases these efforts are done on small budgets, electing for relatively inexpensive secondary payload launch opportunities, especially if there is flexibility in schedule or orbit.

Technology Demonstration and Education



The most common use for smallsats historically has been in technology demonstration. An example of this would be flying experimental smallsats to test new technologies before incorporating them into larger operational spacecraft. This use of smallsats has been closely linked with another application: supporting education by giving university students the opportunity build and fly smallsats. In both cases, the satellites are typically small and low cost, with short operating lives and little preference for a particular orbit.

The SpaceWorks forecast expects that technology development smallsats will have a similar market share to scientific satellites, with 110 forecast for launch over the next three years. The forecast does not separately identify education as a market, although many of the technology demonstration satellites are likely to be educational in nature as well. Because such spacecraft are often built on small budgets, without significant schedule or orbit constraints, they may not be major customers of dedicated small satellite launch vehicles, preferring instead to fly as secondary payloads on larger launch vehicles.

2.3.3 OTHER ORBITS

Medium Earth Orbit

Medium Earth orbit refers to the range of orbits above LEO (typically above 2,000 kilometers) and below geostationary Earth orbit (GEO, approximately 36,000 kilometers). These orbits are infrequently used, since they do not have the advantages of either LEO or GEO, and many of the Van Allen radiation belts lie in this zone. One exception is navigation satellites like the Global Positioning System (GPS), which operate in orbits at altitudes of about 20,000 kilometers.

In addition to the U.S., Russia, Europe, and China are deploying, or have plans to deploy, their own navigation satellite systems. These spacecraft, though, tend to be significantly larger than small satellites: Europe's Galileo spacecraft have a mass of about 700 kilograms, meaning they are too large for all but Stratolauncher. Moreover, the national nature of such systems, including their security implications, means that navigation satellites are typically launched by that country's own launch vehicles, further limiting the market for potential launches from Ellington to GPS. The Air Force, which operates the GPS system, is currently committed to launching those satellites on larger EELV-class launch vehicles that cannot operate from Ellington.

Geostationary Earth Orbit

One of the most commonly-used orbits for spacecraft is geostationary Earth orbit (GEO), where the orbital period is 24 hours, allowing a spacecraft to appear motionless from the ground. This orbit is used by hundreds of commercial and government communications satellites, as well as a smaller number of meteorology and intelligence satellites. Commercial communications satellites constitute the largest single market for commercial launch activity today.

However, the high orbits and large sizes of these spacecraft prevent these GEO markets from being accessible by any vehicle operating from Ellington. The smallest air-launch systems are unlikely to be able to place payloads of any mass in GEO. Even Stratolauncher is likely to be able to place only one to two tons in GEO, depending on the characteristics of the launch vehicle. GEO satellites, however, are typically much heavier, with some commercial communications satellites weighing in excess of six tons.

Beyond Earth Orbit

There are similar restrictions on spacecraft going beyond Earth orbit. Here the market is much smaller than GEO, limited primarily to science missions by NASA and other space agencies, although with the prospect of a handful of commercial missions, such as Google Lunar X PRIZE landers, later in the decade. The energy requirements to achieve these orbits are even higher than reaching GEO, again eliminating all the smaller air-launch systems with the exception of Stratolaunch. This makes it unlikely there would be significant launch activity involving missions beyond Earth orbit from Ellington.

2.4 Conclusions

Given the capabilities of the vehicles that exist today or are projected to enter service in the next decade, the markets most likely to be served by those capable of operating from Ellington Airport are in the suborbital and LEO segments. In suborbital spaceflight, space tourism is clearly the largest market, with the potential for hundreds of flights per year, depending on the capabilities of the vehicles in service and how quickly this market matures. Research and technology development are likely secondary markets, smaller in size than tourism but still accounting for dozens of flights per year. The LEO market is likely to comprise a mix of small satellites for remote sensing, technology development and education, science, and communications; these markets could all grow over the next decade as advances in smallsat technology advances, enhancing the capabilities of such spacecraft. Markets beyond LEO are unlikely to provide significant, if any, demand for launches from Ellington given the performance requirements for those missions and the limitations on launch activity from the spaceport.

While suborbital and LEO markets have the potential to generate significant launch activity for vehicles that could operate from Ellington, there are several caveats that should be considered. One is that many of these applications are just emerging, and their potential size has yet to be fully demonstrated in the market. Second, and perhaps more importantly for Ellington, there is and will continue to be significant competition for these launches among current and proposed spaceports in the United States and elsewhere. Ellington is not the only spaceport available for these vehicles, and many operators already have arrangements with other facilities. Ellington will have to demonstrate that not only does it have the capability to support vehicles serving these markets, but that it is also a better option than competing facilities from technical, economic, and other vantage points.

3. Competitive Assessment

Objective: Identify existing or potential competing spaceports and contrast their facilities and incentive policies with EFD.

3.1 Introduction

Any assessment of the feasibility of a spaceport at Ellington Airport must take into account the fact that such a facility would not operate in a vacuum. A number of other facilities in the United States are also interested in hosting commercial launches, from existing commercial airports to purpose-built spaceports. The number of such existing or proposed spaceports exceeds the number of companies currently able to use them, creating the potential for significant competition among these spaceports as they attempt to lure these companies to perform launches or establish manufacturing or research & development operations. Understanding this competitive landscape, and how Ellington matches up with these other facilities, can help HAS identify strengths it can emphasize to potential users as well as weaknesses it should address.

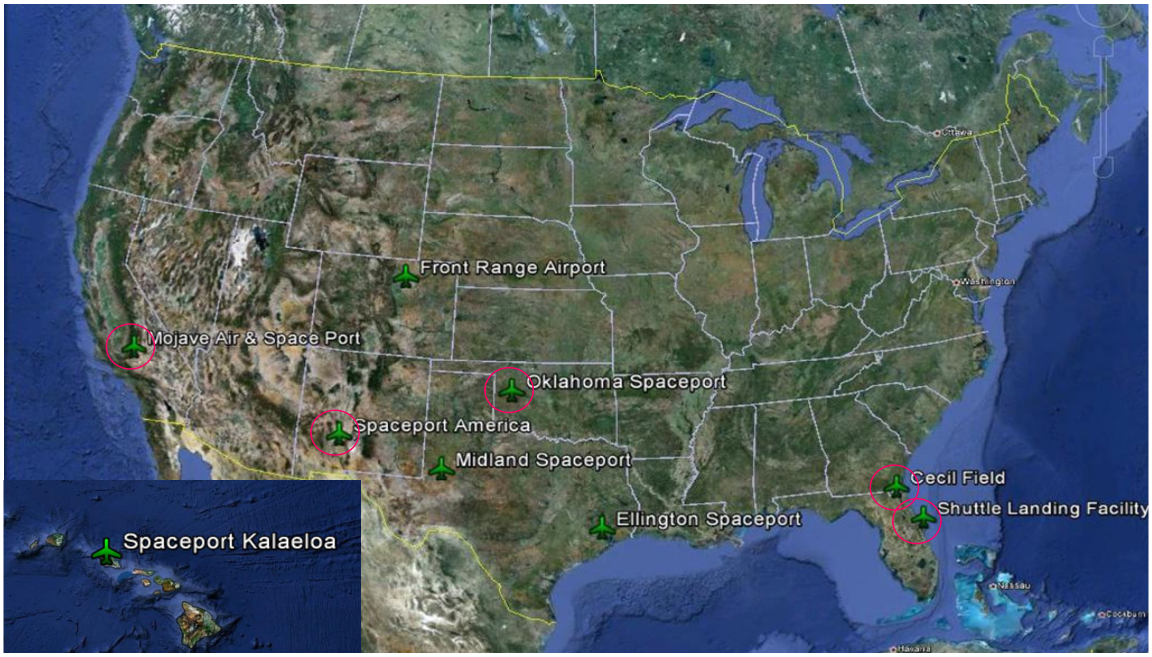
The follow section will compare several characteristics of Ellington's spaceport infrastructure and location to seven spaceports in the United States which intend to host horizontal takeoff and landing spacecraft with both suborbital and orbital trajectories.

Spaceports are compared on several technical, geographical, and economic/political criteria, and grouped by whether they are more, less, or similarly competitive to Ellington. The spaceport comparison study:

- Identified those spaceports that can support launches in markets addressable to EFD
- Analyzed the state of their development, existing and planned infrastructure, and proximity to major population centers and transportation hubs
- Identified any state incentives (tax credits, grants, regulatory policies) that can attract operators
    - Created a SWOT analysis for each spaceport comparing the strongest competing spaceports to EFD; (spaceport SWOT analyses are found in Appendix C)

The eight spaceports compared with Ellington in this study are show in Figure 3-A. All these facilities are designed to accommodate horizontal takeoff and landing vehicles for suborbital or orbital flights.

Each of these spaceports have been ranked on each aspect in relation to Ellington Spaceport, i.e. for each given characteristic, is each spaceport stronger than Ellington, weaker, or the same? Following the breakdown of these characteristics the spaceports most strongly in competition will be listed as well as those presenting the least competition.



○ = FAA-licensed Commercial Launch Sites

SOURCE: XSC, 2013

Figure 3-A: Ellington Spaceport Competitors

3.2 Methodology

This study compiled a list of 13 characteristics to compare the spaceports included in the survey. These characteristics are related to each spaceport's infrastructure, user base, regulatory status, and location. Using Ellington Spaceport as the baseline, this study ranked the other eight spaceports for each of the 13 characteristics, based on whether or not they were superior or inferior to Ellington.

When comparing these spaceports it is important to take account of the fact that every characteristic is not equally important. Thus, before any sort of quantitative assessment is made between the strengths of Ellington Spaceport versus its competitors, one must separate the characteristics being judged into different categories.

The first group of characteristics is the most important. Factors such as the operational status of the spaceport, its FAA license, and having an anchor client are primary criteria for a spaceport's competitive standing.

[Preliminary Draft for Discussion Purposes Only]

Table 3-A: Spaceport Comparison Characteristics & Weighting

CHARACTERISTIC	WEIGHT
Operational?	1
FAA Licensed?	1
Anchor Client?	1
Space Industry Presence?	1
State Funding?	1
State Incentives?	1
Near Metropolitan Area?	1
Orbital Flight Eligibility	1
State Spaceport Authority?	0.5
Federal Funding?	0.5
Room for Runway Extension?	0.5
Runway Composition?	0.5
Federal Incentives?	0

Other characteristics, such as the ability to construct runway extensions, the presence or absence of a state spaceport authority, or the composition of the runway, are less critical towards establishing a viable market presence.

Finally, since Federal indemnification laws apply countrywide, these were not a factor when comparing the spaceports in this survey.

Spaceports were ranked on each listed aspect in relation to Ellington Spaceport, i.e. for each given characteristic, is each spaceport stronger than Ellington, weaker, or the same?

Superior to Ellington	Same as Ellington	Inferior to Ellington

Figure 3-B: Ranking Matrix Key

3.3 Spaceport Comparisons

3.3.1 METRIC ANALYSIS

3.3.1.1 Operational Status

A spaceport's current operational status is an indicator of how far it has progressed towards regular commercial flights. As the market is a limited one, those facilities that open first have a better chance to capture what market share exists and retain that share as the commercial spaceport industry evolves. The metric rates the spaceports in the survey based on whether or not there are commercial space industry companies conducting research and development activities on-site.

- Ellington Spaceport's status
    - Currently not operational as a spaceport, as it is still in the planning stages
- Stronger candidates:
    - Midland Airport – Future development site of XCOR

- Mojave Air & Space Port – Development and construction site and several commercial space concerns
- Spaceport America – home base of Virgin Galactic and hosts other companies, such as Armadillo Aerospace, UP Aerospace, and SpaceX research and development activities.

Table 3-B: Comparative Operational Status

ELLINGTON SPACEPORT	CECIL FIELD	FRONT RANGE AIRPORT	KALAELOA SPACEPORT	MIDLAND AIRPORT	MOJAVE AIR & SPACE PORT	OKLAHOMA SPACEPORT	SHUTTLE LANDING FACILITY	SPACEPORT AMERICA
No	No	No	No	No	Yes	No	No	Yes

3.3.1.2 FAA License Status

A key step on the path towards conducting commercial spaceflights is being granted a license to conduct such flights from the Federal Aviation Administration's Office of Commercial Space Transportation. This metric indicates whether or not a spaceport has such a license.

- Ellington Spaceport's status
  - Currently not licensed by the FAA
- Stronger candidates:
  - Cecil Field
  - Mojave Air & Space Port
  - Oklahoma Spaceport
  - Spaceport America

Table 3-C: FAA License Status

ELLINGTON SPACEPORT	CECIL FIELD	FRONT RANGE AIRPORT	KALAELOA SPACEPORT	MIDLAND AIRPORT	MOJAVE AIR & SPACE PORT	OKLAHOMA SPACEPORT	SHUTTLE LANDING FACILITY	SPACEPORT AMERICA
No	Yes	No	No	No	Yes	Yes	No	Yes

3.3.1.3 State Space Industry Authority Status

Some states have space industry authorities, under the auspices of the state government or independent non-profit organizations, for the purpose of providing economic, legislative, and regulatory support for the commercial space industry within their state. These space industry authorities enjoy a highly visible role guiding their respective state commercial space industries and can ease the path of fledging spaceports looking for guidance and assistance. This metric itemizes the spaceports in this survey by the presence or absence of a space industry authority in their state.

- Ellington Spaceport's status
    - Currently no Texas state space industry authority
- Stronger candidates:
    - Cecil Field – Space Florida
    - Kalaeloa Spaceport – Office of Aerospace Development
    - Oklahoma Spaceport – Oklahoma Space Industry Development Authority
    - Shuttle Landing Facility – Space Florida
    - Spaceport America – New Mexico Spaceport Authority

Table 3-D: State Space Industry Association Status

ELLINGTON SPACEPORT	CECIL FIELD	FRONT RANGE AIRPORT	KALAELOA SPACEPORT	MIDLAND AIRPORT	MOJAVE AIR & SPACE PORT	OKLAHOMA SPACEPORT	SHUTTLE LANDING FACILITY	SPACEPORT AMERICA
No	Yes	No	Yes	No	No	Yes	Yes	Yes

3.3.1.4 Anchor Client Status

The presence of an anchor client at a spaceport is an indication of how close to operational a spaceport is. When facilities have commercial space clients onsite and using the facilities, adding their own improvements and employing staff, they are closer to becoming operational than those facilities whose spaceport status is still in the proposal stage. This metric rates spaceports based on whether or not they have an anchor client.

- Ellington Spaceport's status
    - Currently no anchor client
- Stronger candidates:
    - Front Range Airport – Rocket Crafters (currently only a Letter of Intent signed)
    - Midland Airport – XCOR Aerospace
    - Mojave Air & Space Port – Multiple clients including Stratolaunch and Virgin Galactic
    - Spaceport America – Virgin Galactic, as well as base of operations for Armadillo Aerospace and UP Aerospace.

Table 3-E: Anchor Client Status

ELLINGTON SPACEPORT	CECIL FIELD	FRONT RANGE AIRPORT	KALAELOA SPACEPORT	MIDLAND AIRPORT	MOJAVE AIR & SPACE PORT	OKLAHOMA SPACEPORT	SHUTTLE LANDING FACILITY	SPACEPORT AMERICA
No	No	Yes	No	Yes	Yes	No	No	Yes

3.3.1.5 Space Industry Presence

The presence of a pre-established space industry geographically close to a potential spaceport is a strong contributor to its feasibility. Having an already-established workforce and industry supply network means that a spaceport does not have to spent as much time and energy luring those resources to it.

- Ellington Spaceport's status
    - Large and robust space industry presence in Houston area. **This is one of Ellington's strongest points.**
- Weaker candidates:
    - Cecil Field – Well to the north of Florida's Space Coast.
    - Kalaeloa Spaceport – Hawai'i has little to no indigenous space industry.
    - Midland Airport – No local space industry presence
    - Oklahoma Spaceport – No local space industry presence

Table 3-F: Local Space Industry Status

ELLINGTON SPACEPORT	CECIL FIELD	FRONT RANGE AIRPORT	KALAELOA SPACEPORT	MIDLAND AIRPORT	MOJAVE AIR & SPACE PORT	OKLAHOMA SPACEPORT	SHUTTLE LANDING FACILITY	SPACEPORT AMERICA
Yes	No	Yes	No	No	Yes	No	Yes	Yes

3.3.1.6 Federal Funding/Incentives

The federal government has provided its support for commercial spaceports via legislation and the availability of spaceport infrastructure grants.

The federal government first introduced legislation to indemnify launch site operators from third-party claims due to accidents in the 1980s and has maintained this policy through the present. Thus, all spaceports in this survey enjoy this coverage and have no advantage over each other.

More recently, the federal government, through the FAA, has also awarded grants to several spaceports in this survey towards the acquisition of equipment or towards feasibility studies.

- Ellington Spaceport's status
    - No grant awarded as of yet
- Stronger candidates:
    - Cecil Field – $105,000 grant in 2010.
    - Front Range Airport - $200,000 grant in 2012 for feasibility study
    - Kalaeloa Spaceport – $250,000 grant in 2012 towards FAA License acquisition
    - Mojave Air & Space Port – 3 separate grants totaling $273,750 between 2010-2012
    - Oklahoma Spaceport – 2 grants totaling $980,000 in 2010-2011
    - Spaceport America – 2 grants totaling $292,400 in 2010-2011

Table 3-G: Federal Funding/Incentive Status

ELLINGTON SPACEPORT	CECIL FIELD	FRONT RANGE AIRPORT	KALAELOA SPACEPORT	MIDLAND AIRPORT	MOJAVE AIR & SPACE PORT	OKLAHOMA SPACEPORT	SHUTTLE LANDING FACILITY	SPACEPORT AMERICA
No	Yes	Yes	Yes	No	Yes	Yes	No	Yes

3.3.1.7 Local Funding

Several states or municipalities have provided funding towards the development of commercial spaceports. This metric indicates which of the spaceports in this survey have received such financial support.

- Ellington Spaceport's status
    - No grants awarded as of yet
- Stronger candidates:
    - Kalaeloa Spaceport – 2012 Hawai'i state government funding to support FAA license application
    - Midland Airport – Economic incentive agreement with Midland Development Corporation as part of XCOR Aerospace deal
    - Spaceport America – Approximately $212 million in construction bonds backed by state and county taxpayers, plus an annual operating budget of $4.3 million.

Table 3-H: Local Funding Status

ELLINGTON SPACEPORT	CECIL FIELD	FRONT RANGE AIRPORT	KALAELOA SPACEPORT	MIDLAND AIRPORT	MOJAVE AIR & SPACE PORT	OKLAHOMA SPACEPORT	SHUTTLE LANDING FACILITY	SPACEPORT AMERICA
No	No	No	Yes	Yes	No	No	No	Yes

3.3.1.8 Local Incentives

Some of the spaceports in this survey have benefited from incentives from state and local sources to support their development efforts.

- Ellington Spaceport's status
    - Texas has passed a local limited liability law, further protecting commercial space operators in Texas from legal repercussions of accidents.
- Weaker candidates include these spaceports that are not located within states with state limited liability or informed consent laws:
    - Kalaeloa Spaceport
    - Mojave Air & Space Port (partial limited liability law in place)

Table 3-I: Local Incentive Status

ELLINGTON SPACEPORT	CECIL FIELD	FRONT RANGE AIRPORT	KALAELOA SPACEPORT	MIDLAND AIRPORT	MOJAVE AIR & SPACE PORT	OKLAHOMA SPACEPORT	SHUTTLE LANDING FACILITY	SPACEPORT AMERICA
Yes	Yes	Yes	No	Yes	No	No	Yes	Yes

3.3.1.9 Proximity to International Airport

Accessibility for non-local, including international, customers will be a strong factor in encouraging growth for a commercial spaceport. For the purposes of this survey, the spaceports were judged based on their distance from a major international airport.

- Ellington Spaceport's status
    - Ellington is less than one hour's drive from Houston Intercontinental Airport and even closer to Hobby Airport making it very accessible to non-local customers. **This is one of Ellington's strongest points**
- Weaker candidates:

  - Midland Airport – More than four-hour drive from Dallas/Fort Worth International Airport
  - Mojave Air & Space Port – More than two-hour drive from Los Angeles International Airport
  - Oklahoma Spaceport – More than two-hour drive from Will Rogers World Airport (Oklahoma City)
  - Shuttle Landing Facility – Approximately one hour from Orlando International Airport, but little local infrastructure
  - Spaceport America – Up to a three-hour drive to airports in El Paso or Albuquerque.

Table 3-J: International Airport Status

ELLINGTON SPACEPORT	CECIL FIELD	FRONT RANGE AIRPORT	KALAELOA SPACEPORT	MIDLAND AIRPORT	MOJAVE AIR & SPACE PORT	OKLAHOMA SPACEPORT	SHUTTLE LANDING FACILITY	SPACEPORT AMERICA
Yes	Yes	Yes	Yes	No	No	No	Yes	No

3.3.1.10 Orbital Flight Eligibility

Though initial plans for commercial spaceflight operators requiring horizontal takeoff and landing are primarily associated with suborbital operations, the ability to expand operations into the orbital realm once the market and technology catch up will be a distinct advantage. A key aspect of any orbital launch facility is access to wide swaths of open, unpopulated area downrange of the launch, providing a place for spent lower stages to impact without endangering populated areas. In the United States, the only practical such areas are offshore ocean regions. Thus, facilities with easy access to the ocean will be able to engage in orbital flight.

- Ellington Spaceport's status
  - Ellington's location in the southeastern sector of Houston places it close to the Gulf of Mexico. **This is one of Ellington's strongest points**
- Weaker candidates:
  - All of these spaceports are far away from any coast, making them less desirable for use on orbital launches:
    - Front Range Airport; Oklahoma Spaceport; and Spaceport America

Table 3-K: Orbital Flight Eligibility Status

ELLINGTON SPACEPORT	CECIL FIELD	FRONT RANGE AIRPORT	KALAELOA SPACEPORT	MIDLAND AIRPORT	MOJAVE AIR & SPACE PORT	OKLAHOMA SPACEPORT	SHUTTLE LANDING FACILITY	SPACEPORT AMERICA
Yes	Yes	No	Yes	No	Yes	No	Yes	No

3.3.1.11 Runway Extension Feasibility

Early horizontal takeoff spacecraft will need long runways to provide pilots with enough length to safely take off and land. First generation commercial spacecraft like the Virgin Galactic SpaceShipTwo system and XCOR Lynx are based on a runway length of at least 10,000 feet. Some of the spaceports in this survey will require runway extensions to meet this standard. However, some of these spaceports lie within populated areas and have little to no room to extend their runways. This metric sorts spaceports into three categories: those currently with runways greater than 10,000 feet, those with shorter runways with room to extend, and those with shorter runways with no room to extend.

- Ellington Spaceport's status
  - Ellington's longest runaway is 9,500 feet, which means it could benefit from another 1,000 to 2,000 feet to place it in the same class as Spaceport America or Oklahoma Spaceport. Given its location, such an extension might be feasible but difficult and expensive.

Table 3-L: Runway Extension Feasibility

ELLINGTON SPACEPORT	CECIL FIELD	FRONT RANGE AIRPORT	KALAELOA SPACEPORT	MIDLAND AIRPORT	MOJAVE AIR & SPACE PORT	OKLAHOMA SPACEPORT	SHUTTLE LANDING FACILITY	SPACEPORT AMERICA
Existing space	Un-needed	Existing space	No space	Little space	Existing space	Un-needed	Un-needed	Un-needed

3.3.1.12 Runway Composition

This is a very specific but still important distinction among the spaceports in this survey. The composition of the runways in use at the various spaceports could be a restricting factor in determining which spacecraft could or could not use the facility. Runways made of asphalt would pose a danger to those spacecraft using liquid oxygen as their oxidizer. A spill of liquid oxygen on an asphalt surface would enable ordinarily stable petroleum-based asphalt to ignite if given an ignition source. As such, asphalt surfaces are not preferred for use with any propulsion unit using liquid oxygen. It should be noted that of the horizontal takeoff spacecraft currently in development, only XCOR's Lynx is slated to use liquid oxygen as its oxidizer.

Table 3-M: Runway Composition

ELLINGTON SPACEPORT	CECIL FIELD	FRONT RANGE AIRPORT	KALAELOA SPACEPORT	MIDLAND AIRPORT	MOJAVE AIR & SPACE PORT	OKLAHOMA SPACEPORT	SHUTTLE LANDING FACILITY	SPACEPORT AMERICA
C	C/A	A	A	A	C/A	C	C	C

C: Concrete A: Asphalt C/A: Concrete/Asphalt

3.4 Conclusions

3.4.1 SPACEPORT COMPARISON RESULTS

Table 3-N shows the cumulative scores of the competing spaceports in relation to Ellington Spaceport. In particular, the two strongest competitors and the two weakest competitors have been identified.

Table 3-N: Spaceport Metrics Comparison Results

	CECIL FIELD	FRONT RANGE AIRPORT	KALAELOA SPACEPORT	MIDLAND AIRPORT	MOJAVE AIR & SPACE PORT	OKLAHOMA SPACEPORT	SHUTTLE LANDING FACILITY	SPACEPORT AMERICA
Stronger than Ellington	2.5	2	2	2	4	2.5	1	5.5
Same as Ellington	6	6.5	5	4.5	3.5	3	9	2.5
Weaker than Ellington	1.5	1.5	3	3.5	2.5	4.5	0	2
Strengths vs. Weakness	**1**	**0.5**	**-1**	**-1.5**	**1.5**	**-2**	**1**	**3.5**

Mojave Air & Space Port and Spaceport America emerged as the most competitive spaceports for Ellington. They were mostly distinguished by the size of their facilities and their already-operational status as spaceflight research and development centers as well as strong local government support. Spaceport America in particular is the frontrunner in the competition to be a viable commercial spaceport.

Kalaeloa Spaceport, Midland Airport, and Oklahoma Spaceport emerged as the weakest competitors for Ellington spaceport, though they were hampered for different reasons. Kalaeloa Spaceport suffered from limited infrastructure as well as little activity to date at the site, while both Midland Airport and Oklahoma Spaceport suffered from little recent commercial activity (a factor that is changing for Midland) and remote geographic location. Midland Airport does have an anchor tenant (XCOR), and Cecil and Shuttle Landing Facility have potential to be strong competitors.

3.4.2 INCENTIVES

Listed below are types of incentives spaceports are using to lure tenants, (e.g. cash incentives were offered to XCOR, which received $10M from Midland, as well as a $3M offer from Space Florida):

• Cash incentives	• Tax credits
• New facilities construction or refurbishment of existing ones	• Friendly regulatory environment (liability indemnification)
• Reduced or nominal ($1/year) leases of facilities	• Workforce training and/or education programs

Note: some of these are typically done in conjunction with a local or state government

4. User Needs Assessment

Objective: Identify significant facility needs of the spacecraft operators and stakeholders and the related capacity of the spaceport

4.1 Introduction – Launch Operators and Related Stakeholders

This task identified and analyzed the needs of prospective launch system operators, developing an overview of their requirements and of their potential interest in locating at EFD. It addressed those spaceport facilities and operational attributes which affect the ability of a spaceport to attract and support a spaceflight operator. These items are:

Facility needs of the operator and capacity of the spaceport

Operational impacts and limitations by both the operator and spaceport

Schedule/timelines of the operator and spaceport

4.2 User Needs Assessment - Process

Inputs included the information within the RS&H study (Technical Feasibility Study)[2] for baseline data on facilities and capacity. It also used the results of the Market Assessment task to "define and analyze appropriate operator market segment(s)", to identify the most likely areas in which to pursue potential operators (tenants). Potential operators were researched and where possible interviewed to establish their

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[2] Houston Airport System: "Ellington Airport, Spaceport Feasibility Study", February 10, 2012, RS&H Project 212-2264-000

needs. Additionally, existing spaceports were visited and their senior management interviewed to determine how they addressed the needs of operators.

This and the similar task of analyzing the needs of related stakeholders were considered together because of the interrelationship between operator and stakeholder. A related stakeholder (such as R&D firms, manufacturers, fabricators, assemblers, laboratories, etc.) either provides a service to the operator or is enabled by the presence of an operator. The related stakeholder's task was to identify and analyze the needs and potential demand for facilities supporting these stakeholders.

Hereafter we will refer to the combined tasks as "task". This task had four components:

- Commercial Operators and Related Stakeholders Needs Assessment
- EFD Facilities Analysis
- Gap Analysis
- Future Facility Requirements

Performing these tasks were iterative with one set of information causing changes to products and those changes resulting in additional data requirements. All these activities were performed concurrently.

4.2.1 COMMERCIAL OPERATORS NEEDS ASSESSMENT

After the Market Assessment task of identifying target operator types for Ellington Spaceport described in Section 2, potential spaceflight operators were identified. This included United States and foreign suppliers. Potential operators were surveyed regarding their needs and expectations of spaceport services and capabilities. This was accomplished via:

- Research of public sources
- E-mail
- Phone calls
- Visits

Prior experience was that many operators consider such information proprietary. The survey was attempted without establishing non-disclosure or proprietary information agreements ensuring the data will be available for future activities. There was the option of some operators being referred to as an alias in the reports, none requested this. Two operators stated that they required non-disclosure agreements prior to release of information. We attempted to establish these NDA's under the auspices of XArc. The operators were confused by the inability to get NDAs from HAS and did not pursue the NDA or provide other than publically available data. Where operators declined to provide data, public source information was utilized and extrapolated as appropriate.

We also attempted to identify services the potential operators may require. These included such items as flight system maintenance services, fabrication services, and crew and passenger support services. We addressed the collateral services which may be required for each of the serviced market segments. These included such things as training for spaceflight participants, laboratory facilities for researchers, launch preparation facilities for satellites, etc.

4.2.2 EFD FACILITIES ANALYSIS

Facility analysis included identification of facility capabilities; planned changes, development, or construction; and timelines/schedules. This facility analysis was specific to the needs of potential users. The RS&H study was used as the baseline data. If support needs were identified not within the RS&H study, the needed information was sought, extrapolated or otherwise developed.

4.2.3 GAP ANALYSIS

It was expected that operators would be able to take advantage of existing pads, runways, hangars, and other facilities, allowing the spaceport to capture a portion of this market without the need to develop significant new infrastructure. Gap analysis was performed to identify those facility attributes requiring change in order to support or attract operators. This analysis identified those attributes which must be maintained as well as those requiring modification. Understanding those attributes already supporting the market allows HAS to avoid inadvertently changing these in the future. The gap analysis also identified “low-hanging fruit” for the spaceport where minimal changes can enhance attraction of candidate operators.

The analysis was performed at the micro and macro level. In the micro analysis, the requirements of each operator were evaluated individually. This resulted in a list of minimal changes for each. This allows HAS to specifically target individual candidate operators and understand the cost and operational impact of doing so. In the macro analysis, the requirements of the most likely operators were consolidated. In this case, the gap analysis identified actions necessary to attract the portfolio of operator types.

4.2.4 DETERMINE FUTURE FACILITY REQUIREMENTS

Because of the developing nature of the commercial space launch business, infrastructure improvements must be carefully planned and justified to ensure they are both necessary and affordable. The analysis of future facility requirements compared current facility capabilities with what will be needed to accommodate each different forecasted operator type. Several capability shortages were identified and are addressed in the Future Facilities section.

4.3 User Needs Assessment - Findings

It must be noted that in the User Needs Assessment, developer provided timelines, schedules, and future capabilities were accepted as presented (or research found). Where information was conflicting, the most likely is presented. We did not perform a market viability, business case, or technical assessment of any of the claims, systems, or corporations. That depth of analysis is out of scope for this project. Descriptions of these findings follow.

4.3.1 FINDINGS: POTENTIAL TYPES OF LAUNCH SERVICE OPERATORS

Based upon survey market information and the Market Assessment in Section 2, a set of potential launch service operators for Ellington Spaceport was identified.

The operational and technical challenges of a spaceport not directly located on the coast limited the viable systems. The strongest limitation is found in the area of vertical launch vs. horizontal flight. As previously noted, vertical launch is not appropriate for Ellington Spaceport. Horizontally initiated air launch is hoped to be a viable alternative to vertical launch. In air launch, the booster is carried to a high altitude and to an appropriate range via an aircraft. Once there, the booster is released and ignited sending the payload to its target altitude or orbit. There is one successful example of air launch, the Orbital Sciences Pegasus system.

There are several air launch orbital payload systems contemplated or in development. It is projected that air launching will reduce facility and range costs. Fewer hardened/blast proof facilities (e.g. pad, blockhouse, and associated equipment) are needed. This permits takeoff from a wide variety of sites, generally limited by the support and preparation requirements of the payload. The travel range of the aircraft allows launches nearer the equator, which increases performance and is a requirement for some mission orbits. Launching over oceans may also reduce insurance costs.

The Market Assessment identified markets for horizontal launch to include sub-orbital and orbital research, tourism, and point-to-point travel via fully reusable launch vehicles (RLV). It is hoped that RLVs will reduce the cost of operations by not expending and disposing of the launch vehicle with every use. These systems take off and land horizontally like conventional aircraft. Research and tourism operations would generally take off and land at the same facility. Point-to-point would operate between city pairs at speeds as high as Mach 6.

Corporations which have systems that were identified as candidates for Ellington operations are shown in Table 4-A.

Table 4-A: Benchmarked Potential Types of Launch Service Operators

SOURCE: XSC, 2013

The above have active hardware development tasks in work or are actively soliciting investors and/or customers. Others considered but not included were Rocketplane and EADS Astrium. The Rocketplane XP system was for suborbital tourism with the hopes of maturing it into a point-to-point transport system. Rocketplane went into bankruptcy several years ago. It is now out of bankruptcy but is not yet back into development still requiring additional new investors. Similarly, the EADS Astrium TBN system targeted suborbital tourism with hopes to mature into a point-to-point system. EADS corporate management determined that the near term market and its development costs did not support their return on investment requirements. Development is on hold until investors are found for the system.

All the systems examined have current commitments to sites for development and operations. Also, similar systems have been attempted by numerous others in the past. The business failure rate is 100% except for the Orbital Pegasus. Historically, those that fail will be replaced with others with similar target markets and similar spaceport needs. Some systems examined appear to have strong funding and some only can hope for adequate future funding. Some are testing hardware but schedules and cost are much longer and higher than initially projected. As previously noted, this study did not determine the viability of the systems identified. It cannot be considered as an endorsement of any system. Therefore, these systems were approached as benchmarks, useful in defining system characteristics and potential needs of future operators of the same vehicle class. Key characteristics of the benchmarked systems are found in 10.Appendix B Launch Vehicle Survey.

4.3.1.1 Findings: Benchmark - Stratolaunch Systems

Stratolaunch Systems – Overview

Stratolaunch Systems is developing an air launch system for large orbital payloads. The Stratolaunch system will consist of three primary components; a carrier aircraft to be built by Scaled Composites (The Spaceship Company), a multi-stage launch vehicle built by Orbital Sciences, and a mating and integration system to be built by Dynetics. The first test flight of the carrier aircraft expected in 2015. Development is estimated at $300M. Orbital testing of the launch vehicle was originally announced for 2016 but is now planned to start in 2017. A capacity of 13,500 lbs. to low earth orbit is targeted.

Stratolaunch Systems – Corporation

Stratolaunch is a private company founded in 2011 by Microsoft co-founder Paul G. Allen and Scaled Composites founder Burt Rutan. These individuals had previously collaborated on the creation of SpaceShip One, winner of the $10M Ansari X-Prize[3]. Paul Allen funded the Spaceship One X-Prize effort. Stratolaunch corporate headquarters is located in Huntsville, Alabama. Stratolaunch is held by Vulcan Inc., an investment and project management company founded in 1986 and owned by Paul Allen. It is headquartered in Seattle, Washington. Its subsidiaries include Charter Communications, Rose City Radio Corporation, Seattle Seahawks, Portland Trail Blazers, and Mojave Aerospace Ventures (among others).

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[3] The Ansari X Prize was a space competition in which the X Prize Foundation offered a $10M prize for the first non-government organization to launch a reusable manned spacecraft into space twice within two weeks. The prize was won on October 4, 2004, by the Tier One project designed by Burt Rutan and financed by Microsoft co-founder Paul Allen, using the experimental space plane SpaceShipOne.

[Preliminary Draft for Discussion Purposes Only]

Stratolaunch Systems – Details

Carrier Aircraft: The Stratolaunch carrier aircraft will have a wingspan of 385 ft., making it the largest airplane, by wingspan, to ever fly. It will weigh in at over 1,300,000 lb. including the fully fueled launch vehicle. The aircraft will be powered by six 46,000–66,500 lb. thrust-range jet engines from two used 747-400s that are being cannibalized for engines, avionics, flight deck, landing gear and other systems recycled to cut development costs. The carrier aircraft is expected to have a range of 1,200 nmi on air launch missions. It requires a 12,500 ft. x 200 ft. runway. The carrier aircraft is expected to make its first test flight in 2015.

Launch Vehicle: Orbital Sciences Corporation is developing the launch vehicle. Orbital replaces SpaceX which left the project in November of 2012. The three stage booster will be approximately 120 feet long. After release of the booster from the aircraft at approximately 30,000 feet, the first stage engines ignite and the spacecraft begins its journey into space. The booster's health and status during flight is monitored from the launch aircraft and on the ground.

The booster is expected to be a combination of solid fueled first and second stages similar to shortened space shuttle solid rocket booster in design, diameter (12.1 feet), and mass (275,000 lbs. each). The third stage may be a liquid oxygen/liquid hydrogen stage using RL-10 engines. There is potential that a hypergolic stage may be included (as an insertion stage or in place of LOX/LH2).

Facilities: Stratolaunch has a 20-year lease agreement with the Kern County Airport Authority, Mojave, California, for the lease of 20 acres at the Mojave Air and Space Port for facilities for the venture. Stratolaunch recently opened a new 103,257-square-foot hangar as one of the two Stratolaunch facilities built to accommodate construction of the system’s carrier aircraft. The other Mojave facility, an 88,000-square-foot fabrication facility, opened in October 2012 and is currently used to manufacture the aircraft’s wing and fuselage sections.

Operations will require the following from the launch site:

STRATOLAUNCH OPERATIONS REQUIREMENTS

- Hazardous launch vehicle processing facility approximately 140 ft. by 40 ft.; a computerized checkout and test system is necessary
- Liquid oxygen and liquid hydrogen fueling systems will be required near the flight line with the associated control systems
- Payload processing facility
- Telemetry system
- Range safety/flight termination system
- Rail service capable of handling oversized space booster transport containers and related handling and ordnance storage facilities

4.3.1.2 Findings: Benchmark - Virgin Galactic

Virgin Galactic, LLC Overview

Virgin Galactic is developing an air launch system for suborbital space tourism and research with a separate booster for orbital payload launch. The suborbital tourism system consists of a carrier aircraft (White Knight2) and a passenger vehicle (SpaceShip2). Both are currently under test, and built by Scaled Composites (The Spaceship Company). There are various reports of between 200 and 550 paid "spaceflight participants". The ticket price starts at $200,000 and is expected to be raised to $250,000 in 2013. Originally announced for service beginning in 2011, Virgin now promotes a "safety driven" schedule with manned sub-orbital testing in 2013. The first powered flight of Spaceship 2 occurred 29 April 2013. On May 14, 2013 in Abu Dhabi, Richard Branson announced that the first public passenger flight will be Christmas Day, December 25, 2013.

Virgin intends to run the first flights out of New Mexico at Spaceport America, before extending operations around the globe. Virgin Galactic has competitors but is likely to be the first-to-market, barring any problems arising in the test campaign. Virgin Galactic is planning to have a fleet of at least two WhiteKnight2 mother ships and five or more SpaceShip2 tourist suborbital spacecraft.

Their orbital payload system titled "Launcher One" uses the same carrier aircraft and an in-house designed multi-stage launch vehicle. Launcher One will carry up to 500 lb. to low earth orbit with an expected price of $10 million per launch. Launcher one is targeted to begin testing in 2015 with service beginning in 2017.

Virgin Galactic Corporation

Virgin Galactic is a limited liability company founded in 2004 by Richard Branson. Its headquarters is in Las Cruces, New Mexico. The parent corporation is Richard Branson's Virgin Group. Virgin Galactic is co-owned by Abu Dhabi's Aabar Investments. Aabar paid US$280 million for 31.8 per cent of Virgin Galactic's holding company in 2009, and later raised its stake to 37.8 per cent.

Virgin Galactic owns The Spaceship Company (TSC – formerly Scaled Composites), a builder of commercial specialty aircraft and spacecraft. TSC's initial customer is Virgin Galactic, which has contracted to purchase five SpaceShip2's and two White Knight2's.

Virgin Galactic Details

Carrier Aircraft: Virgin calls its carrier aircraft the "Mother ship" named White Knight2. White Knight2 is a custom built aircraft functioning as mother-ship and launch-platform for the spacecraft SpaceShip2. The aircraft has two hulls, linked together by a central wing. It can carry SpaceShip 2, Launcher One, or various research and payload hardware.

Spacecraft: SpaceShip2 was revealed to the public in December 7, 2009. Built from carbon composite materials and powered by a hybrid rocket motor developed by Sierra Nevada Corporation, SS2 is based on the Ansari X-Prize winning SpaceShip1 concept - a rocket plane that is lifted initially by a carrier vehicle before rocket powered flight. SS1 became the world's first private spaceship with a series of high-altitude flights in

2004. SS2 is twice as large as SS1 at 60 ft. in length. SS1 had a single pilot (and the ballast equivalent of two passengers); SS2 will have a crew of two and room for six passengers.

SpaceShip2 will be carried to 52,000 ft. by the carrier aircraft, WhiteKnight2. SS2 will then separate and continue to approximately 110km and a top speed of 2,400 miles per hour. The end-to- end flight time will be about 2.5 hours. The sub-orbital flight itself will only be a small fraction of that time. The weightlessness will last approximately 6 minutes. Passengers will be able float about the cabin during the weightless period.

To re-enter the atmosphere SpaceShip2 folds its wings upward. Part way through reentry it returns them to their original position for an unpowered descent (glide) flight back onto the runway. The craft has a very limited cross-range capability and has to land in the area where it started.

In addition to the sub-orbital passenger business, Virgin Galactic will market SpaceShip2 for sub-orbital space science missions. Science payloads may replace the mass of one or more passengers. The science equipment may be tended by passengers or may be automated.

Launcher One: Launcher One is an in-house developed orbital launch vehicle, announced by Virgin Galactic in July 2012. Launcher One is designed to launch “smallsat” payloads up to 100 lbs. (although there are references to 500 lbs.) into low earth orbit for under $10 million. Testing is projected to begin in 2015 with service in 2016. Several commercial customers are already reported to have contracted for launches, including GeoOptics, Skybox Imaging, Spaceflight Services, and Planetary Resources. Both Surrey Satellite Technology and Sierra Nevada Space Systems are developing satellite buses optimized to the design of Launcher One. Launcher One is looking to win development funding through competing in the DARPA ALASA (Airborne Launch Assist Space Access) program.

Launcher One configuration will be an expendable two-stage liquid-fueled (lox/hydrocarbon) rocket air-launched from a White Knight2. It is similar in concept to the existing solid fueled Orbital Sciences' Pegasus, or a smaller version of the Stratolaunch.

Facilities: Test launches are planned to take place from the Mojave Spaceport where the craft are manufactured. US operations will be managed out of Virgin Galactic’s custom built facility at Spaceport America near Las Cruces, New Mexico. Virgin Galactic has signed a 20-year (240-month) lease as the anchor tenant, agreeing to pay US$1 million per year for the first five years in addition to payments on a tiered scale based on the number of launches the company makes.

The New Mexico facility is purpose-built with $209 million in state (public) money establishing itself as Spaceport America. It was designed, built and is operated by the New Mexico Spaceport Authority (NMSA). Its current 10,000 ft. runway is being lengthened to 12,000 ft. to accommodate recently identified changes to Virgin’s operating requirements.

The terminal & hangar facility has a total area of 110,152 sq. ft. This is divided into three areas or zones. The western zone (25,597 sq. ft.), houses support and administrative facilities for Virgin Galactic and NMSA. The central zone (47,000 sq. ft.) contains the double-height hangar to store WhiteKnight2 and SpaceShip2 crafts.

The eastern zone (29,419 sq. ft.) encompasses the principal operational training area, departure lounge, spacesuit dressing rooms, and celebration areas. There is a separate mission control room which may be likened to an airport operations control center and tower.

Virgin Galactic announced in April, 2008 that in the future they will operate in Europe out of Spaceport Sweden and that the company was considering flying from a UK base, perhaps a RAF base in Scotland. A spaceport is also planned in Abu Dhabi where initial design and negations are in work. The Abu Dhabi site is more certain than others because of the local investment into Virgin Galactic. New Mexico will be Virgin's home until significant development costs are recovered. There is the possibility of occasional space tourist missions at other locations if there is such a market, others bring the passengers, and it can be satisfied with minimum Virgin investment. Similarly, suborbital research missions may be flown from other sites if there is a large, proven, local customer.

Operations of SpaceShip2 outside New Mexico may be expected to require a minimum hanger of 160 x 90 feet to accommodate White Knight storage and SpaceShip2 mating operations. Passenger facilities custom prepared to Virgin's "Spaceflight Experience" concept will be needed. This should be expected to be no less than the 29,419 sq. ft. available at Spaceport America. A test range and specialized telemetry is not required.

Operation of Launcher One will require a 160x90 ft. hanger where ever the booster is mated to the White Knight2. Payload processing support facilities will be needed where the payload is integrated with the booster. This is not necessarily where the White Knight and booster are mated but such would not be customary. Little is known about the booster but size equivalence to the XCOR Lynx indicates that a 10,000 sq. ft. assembly and test facility would be adequate. Also required would be the following for operations:

LAUNCHER ONE OPERATION REQUIREMENTS

- Liquid oxygen and hydrocarbon fueling systems will be required near the flight line with associated control systems
- Hypergolic support systems may be necessary depending upon the final selection of propellants
- Telemetry system
- Range safety/flight termination system
- Hazardous launch vehicle processing facility with a computerized checkout and test system is necessary

4.3.1.3 Findings: Benchmark - Orbital Sciences

Orbital Overview

Orbital Sciences is the operator of the air launch Pegasus system. Pegasus is the first totally commercially developed launch system and the only successful air launch system. The Pegasus rocket is launched from the company's "Stargazer" L-1011 carrier aircraft with 41 missions from six different launch sites worldwide since 1990.

The first successful Pegasus launch occurred on April 5, 1990 using a NASA-owned B-52 Stratofortress as the carrier aircraft. By 1994, Orbital had transitioned to their "Stargazer" L-1011, a converted airliner which was formerly owned by Air Canada.

Original launch price was $6 million. The cost per launch in 1994 was $11 million. Today the cost is approximately $30 million depending upon services used.

Orbital Corporation

Orbital Sciences Corporation (traded as NYSE: ORB) is the only public corporation engaged in the market addressed by this report. It is also the world's only successful provider of horizontal or air launch services. Headquartered in Dulles, Virginia, Orbital was founded in 1982 by David W. Thompson, Bruce W. Ferguson, and Scott L. Webster. Thompson remains as Chairman, President and CEO. Orbital's products include Space Launch Vehicles, Missile Defense Systems, Satellites and Related Systems, Advanced Space Systems, Space Technical Services. It has approximately 3,700 employees as of March, 2012.

Orbital also operates the Taurus and Minotaur ground-launched rockets combining Pegasus upper stages with either government-supplied or commercially available first-stage rocket motors to boost larger payloads to orbit. Minotaur IV combines decommissioned Peacekeeper rocket motors with proven Orbital avionics and fairings to provide increased lifting capacity for government-sponsored payloads.

With the development of the Antares space launch vehicle, Orbital is extending its capabilities to provide low-cost access to space for medium-class payloads. The inaugural launch of Antares occurred on April 21, 2013 from Wallops Island, Virginia.

Since its inception Orbital Sciences has built 569 launch vehicles with 82 more to be delivered by 2015. 174 satellites have been built by the company since 1982 with 24 more to be delivered by 2015. Orbital has a 40% share of the interceptor market, 55% share of the small communications satellite market, and a 60% share of the small launch vehicles market.

Orbital Sciences Details

Carrier Aircraft: The original carrier aircraft was a Boeing B-52 Stratofortress. In 1994 Orbital began using the Stargazer. "Stargazer" is an L-1011 commercial transport aircraft modified to serve as the launch platform as well as a platform for airborne research projects. The L-1011 has been used to launch 34 Pegasus rockets as well as the captive carry flights of the X-34 reusable launch vehicle demonstrator. The aircraft has also been used to conduct various airborne research projects including the NASA Adaptive Performance Optimization (APO) project.

Orbital's L-1011 airborne launch and research platform enhancements include:

- Fully equipped as an airborne platform providing power, data, video monitoring and telemetry transmission
- Efficient design for rapid test equipment installation and removal

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- The unique external payload hook system can support an externally mounted pallet for aerial research equipment or for external release
- Launch Panel Operator (LPO) station to monitor and control payload
- Launch vehicle and payload services such as conditioned air purge and nitrogen pressurization

Pegasus: The Pegasus effectively replaced the Scout vertically launched small launch vehicle.

Figure 4-A: Pegasus Launch Preparation

PHOTO SOURCE: NASA – RANDY BEAUDOIN, 2013

The Pegasus rocket is a winged space launch vehicle capable of carrying small, unmanned payloads of 980 lb. into low Earth orbit. It is air-launched, as part of an expendable launch system, with three main stages burning solid propellant.

Dual payloads can be launched, with a canister that encloses the lower spacecraft and mounts the upper spacecraft. The upper spacecraft deploys, the canister opens, and then the lower spacecraft separates from the third-stage adapter. Since the fairing is unchanged for cost and aerodynamic reasons, each of the two payloads must be relatively compact.

A fourth stage is sometimes added for a higher altitude, finer altitude accuracy, or more complex maneuvers. The HAPS (Hydrazine Auxiliary Propulsion System) is powered by three restartable, monopropellant hydrazine thrusters. As with dual launches, the HAPS cuts into the fixed volume available for payload. In at least one instance, the spacecraft was built around the HAPS.

The Pegasus is carried aloft below a carrier aircraft and launched at approximately 40,000 ft. The carrier aircraft provides flexibility to launch the rocket from anywhere rather than just a fixed pad. A high-altitude, winged flight launch also allows the rocket to avoid flight in the densest part of the atmosphere where a larger launch vehicle, carrying more fuel, would be needed to overcome air friction and gravity.

In a Pegasus launch, the carrier aircraft takes off from a runway with support and checkout facilities. Such locations have included Kennedy Space Center / Cape Canaveral Air Force Station, Florida; Vandenberg Air Force Base and Dryden Flight Research Center, California; Wallops Flight Facility, Virginia; Kwajalein Range in the Pacific Ocean, and the Canary Islands in the Atlantic. Orbital offers launches from Alcântara, Brazil, but no customers are known to have performed any launches. Launching Pegasus from equatorial launch sites can put spacecraft in orbits avoiding the South Atlantic Anomaly (a high radiation region over the South Atlantic Ocean) which is desirable for many scientific spacecraft.

For launches which do not originate from Vandenberg Air Force Base, the carrier aircraft is also used to ferry the assembled launch vehicle to the launch site. For such missions, the payload can either be installed at the base and ferried by the launch vehicle or be installed at the launch site.

The NASA X-43A hypersonic test vehicles were boosted by Pegasus first stages. The upper stages were replaced by exposed models of a scramjet-powered vehicle. The Orion stages boosted the X-43 to its ignition speed and altitude, and were discarded. After firing the scramjet and gathering flight data, the test vehicles also fell into the Pacific.

Facility Requirements: Orbital Pegasus operations are based out of California. The Stargazer is stored outdoors at Mojave Airport. Environmental conditions there allow this without a hanger. Significant aircraft maintenance or modification is best done inside a commercial aircraft hangar of approximately 34,000 sq. ft. The Pegasus rocket is integrated and the payload installed at Orbital's vehicle assembly building at Vandenberg Air Force Base, California. This specialized building is approximately 27,000 square feet.

Launch operations require a telemetry system and range safety/flight termination system at the air drop area.

Operations Models: The Pegasus launch system accommodates two distinctly different launch processing and operations approaches for non-VAFB launches. One approach (used by the majority of payload customers) is to integrate the Pegasus and payload at the VAB and then ferry the integrated Pegasus and payload to another location for launch. This approach is referred to as a "ferry mission."

The second approach is referred to as a "campaign mission." A campaign mission starts with the buildup of the Pegasus at the Vandenberg facility. The Pegasus is then mated to the OCA at VAFB and ferried to the integration site where the Pegasus and payload are fully integrated and tested. At this point, the launch may either occur at the integration site, or the integrated Pegasus and payload may be ferried to another location for launch.

4.3.1.4 Findings: Benchmark – XCOR Aerospace

XCOR Overview

The Lynx is XCOR's entry into the commercial reusable launch vehicle (RLV) market. This two-seat, piloted space transport vehicle will take humans and payloads on a suborbital flight to 100 km (330,000 feet) and then return safely to a landing at the takeoff runway. XCOR projects a maximum of 110 km (68 mi) altitude in flights of 30 to 45 minutes duration, while carrying up to 140 kg (310 lb.) internal—or 650 kg (1,400 lb.) external—of research payload. Flights will provide up to three minutes of microgravity below 0.01 g.

Like an aircraft, Lynx is a horizontal takeoff and horizontal landing vehicle using a fully reusable rocket propulsion system to depart a runway and return safely. This approach is unique compared to most other RLVs in development, such as conventional vertical rocket launches and air-launched winged rocket vehicles "dropped" at altitude from a jet powered mother ship.

XCOR currently plans to have the Lynx's initial flights from the Mojave Air and Spaceport in Mojave, California. Shortly thereafter they will move their development and test site along with their corporate offices to Midland, Texas.

XCOR offers a "Wet-lease" arrangement where it will transport the Lynx and operate it from any licensed spaceport with a 2,400 meter (7900 ft.) runway. Beginning in the first quarter of 2015 the Lynx is expected to be flying suborbital space tourism flights and scientific research missions from a new spaceport on the Caribbean island of Curacao. XCOR has held similar discussions with organizations in South Korea.

XCOR Aerospace, Inc.

XCOR Aerospace is a privately-held rocket engine and spaceflight development California C Corporation founded in 1999. Founders Jeff Greason, Dan DeLong, Aleta Jackson and Doug Jones each previously worked at the Rotary Rocket Company. XCOR currently has approximately 50 employees.

XCOR announced a move to Midland, Texas in July 2012. XCOR considered a number of locations before announcing that they would be moving their company headquarters and R&D activities to Texas, in part due to a significant set of financial incentives (including $10,000,000 cash) offered to XCOR by the Midland Development Corporation (MDC) and the Midland City Council. XCOR has committed to a future production facility near Kennedy Space Center, Florida for a $3 million incentive.

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XCOR's research and development funding has come from targeted commercial development programs, government research contracts, investment capital from angel investors and consulting services. These programs and contracts have led to breakthrough development of pump systems and a non-flammable composite tank material which are critical to XCOR's spaceflight goals.

As of July 2012, XCOR has presold 175 Lynx flights at $95,000 each.

XCOR Details

Lynx: The Lynx rocket plane is a suborbital horizontal-takeoff, horizontal-landing (HTHL), rocket-powered, human flown, space plane. According to XCOR, the Lynx will fly four or more times a day and eventually have the capacity to deliver orbital payloads (serving as a very high altitude carrier for a released booster).

Lynx is a continuation of XCOR's small rocket space plane program. This started in 2001 with EZ-Rocket, a Rutan Long-EZ homebuilt aircraft fitted with two 400 lb. thrust rocket engines replacing the normal propeller engine. EZ-Rocket has been flown at numerous airshows including the 2005 Oshkosh Airshow. In 2008, Rocket Racer was built (for the failed Rocket Racing League) on a Velocity SE airframe and later became known as the Mark-I X-Racer. It was powered by an XCOR designed rocket engine. This rocket-powered aircraft flew several demonstration flights at the 2008 EAA AirVenture Oshkosh air show. Through this development, the firm has developed and built thirteen different rocket engines and built and flown two manned rocket-powered aircraft. Between the two, XCOR has a history of 66 flights.

The Lynx will carry one pilot along with a ticketed passenger and/or a sub-orbital payload in the cabin. The Lynx was initially announced on March 26, 2008, with plans for an operational vehicle by the end of 2010. The initial test date has since slipped to 2013. Initial flights will be with the prototype, Mark 1 vehicle. The production model Mark II would fly nine to eighteen months afterwards depending on how fast the prototype moves through the test program.

Lynx has an all-composite airframe with an added thermal protection system (TPS) on the nose and leading edges to handle the heat of sub-orbital re-entry. The wing area is sized for landing at moderate touchdown speeds near 90 knots. Lynx is about 30 feet long with a double-delta wing with span of 24 feet.

XCOR has developed Nonburnite™, a cryo-compatible, inherently non-combustible composite material based on a thermoplastic fluorpolymer resin. Low coefficient of thermal expansion and inherent resistance to micro cracking make it well suited to cryogenic tank use and also part of the vehicle structure. Nonburnite™ will be used in the tanks of the Lynx rocket plane.

The Lynx will have four liquid rocket engines at the rear of the fuselage burning a mixture of LOX-Kerosene and each of them will produce 2,900 pounds-force of thrust.

Because it lacks any propulsion system other than its rocket engines, the Lynx will have to be towed to the end of the runway. Once positioned on the runway, the pilot will ignite the four rocket engines and begin a steep climb. The engines will be shut off at approximately 138,000 feet at a speed of Mach 2. The space plane will continue to climb, unpowered until it reaches an apogee of approximately 200,000 feet. The spacecraft will experience a little over four minutes of weightlessness before experiencing up to four gravities during re-entry. Once it has completed re-entry, the Lynx will then glide to an unpowered landing. The total flight time is projected to last about 30 minutes. The occupants will wear pressure suits.

The Lynx is planned to perform 40 flights before maintenance is required.

Lynx Mark I: The Lynx Mark I is the initial flight test vehicle now under development. This prototype vehicle will be used to characterize and flight test the various sub-systems of the craft including life support, propulsion, tanks, structure, aero shell, aerodynamics, re-entry heating and other design elements. The flight test program consists of a traditional envelope expansion regime in which the vehicle is gradually tested to its full flight profile. The Lynx Mark I will also be used to train pilots and crew for the Lynx Mark II. The Lynx Mark I is designed to achieve an altitude of 200,000 feet (approximately 61 km). Mark 1 production is planned to cost $10 million.

The Mark I will be placed into commercial service after being licensed as a launch vehicle under Federal Aviation Administration rules.

Lynx Mark II: The Lynx Mark II will begin construction and assembly in Midland, Texas after initial flight of the Mark I. The Mark II is the production version of the Lynx, servicing both the suborbital tourism market and all markets that make use of the Lynx's internal payload volumes, such as microgravity and biotechnology experiments. The Lynx Mark II uses the same propulsion and avionics systems as the Lynx Mark I, but has a lower dry weight and hence higher performance than the Mark I. The Mark II incorporates a lightweight composite LOX tank integral with the aero shell and several other key innovations that are proprietary to XCOR. Designed to fly to 328,000 feet (approximately 100 km), assuming certain payload weight conditions are met, the Mark II will take payloads and spaceflight participants to the edge of space and back.

Development of the Mark II is expected to cost $12 million.

Lynx Mark III: The Lynx Mark III is a highly modified derivative of the Lynx Mark II that features the ability to carry an external dorsal pod with either a payload experiment or upper stage capable of launching a small satellite into low earth orbit. Total payload capacity for the external dorsal pod is 650kg. The Lynx Mark III is a different vehicle from the Mark II, featuring upgraded landing gear, aerodynamics, core structural enhancements, and features a more powerful propulsion package and other modifications needed to carry the extra weight aloft.

The Mark III will be manufactured at a Space Florida facility near Kennedy Space Center in Florida. This will occur after sales justify the development costs.

Facilities: XCOR has done all its development and will perform its test flights out of a 10,375 square foot hangar on the Mojave Air & Space Port in Mojave, California.

XCOR promotes that it has a very austere operation. It can truck or fly all support necessary to operate the Lynx out of any appropriate licensed facility with at least a 7900 foot runway. There it would need a source of industrial liquid oxygen and a large private aircraft size hanger. No range or telemetry system is required.

The details of the new facility in Midland Texas or future facility at Space Florida are unknown.

4.3.1.5 Findings: Benchmark - Generation Orbit

Generation Orbit Overview

GOLAUNCHER is an air-launched system for small payloads (nanosat) into low earth orbit. The company's initial demonstrator, GO Launcher 1, would use existing solid-fueled upper stages to provide sub-orbital capability. Go Launcher 1 could mature into an operational capability capable of delivering up to 20 lb. to low earth orbit. GO Launcher 2 would be a larger system capable of placing 100 lb. into orbit.

Generation Orbit Corporation

Generation Orbit is subsidiary of SpaceWorks Enterprises. Space Works Enterprises, Inc. is a private aerospace engineering company best recognized for software and modeling, but which is also developing advanced space transportation concepts. SEI was founded in 2000 by Dr. John R. Olds, then a professor in the School of Aerospace Engineering at the Georgia Institute of Technology in Atlanta, Georgia. The firm was previously known as SpaceWorks Engineering, Inc. (SEI) and officially changed its name in 2011.

The FastForward Project, hosted by SpaceWorks, is a pre-competitive working group of industry, government, and academic professionals trying to understand the technical, economic, and regulatory challenges facing high-speed or suborbital flight between key city pairs such as point-to-point flight.

SpaceWorks employs approximately 15 people.

Generation Orbit Details

Carrier Aircraft: The carrier aircraft has been variously described as based upon existing US or Russian fighter jets but company personnel now report they are planning to use a Gulfstream G-III as the base vehicle. The modifications required, timeline, and costs are not available.

GO Launcher 1: GOLauncher 1 is an air launched single stage hybrid rocket capable of serving microgravity, astrophysics, and hypersonic researchers. GO1 can fly a range of suborbital trajectories including high altitude and suppressed. The hybrid motor thrust profile may be tailored to specific customer requirements. Trajectories may include:

- High Altitude/Microgravity: Optimized for maximum altitudes ranging up to 200 km and microgravity times up to 4 minutes

- Suppressed: Optimized for sustained high Mach, high dynamic pressure, offering captive carry and free-flyer hypersonic flight testing

Payload configurations can accommodate both integrated and recoverable experiments, as well as deployable hardware.

- Recoverable: payload modules similar to traditional sounding rocket configurations.
- Deployable: similar to traditional launch vehicle configuration with a deployable fairing, and separation system for the payload

The hybrid engine is being developed by California based Spacecraft Propulsion Group. SPG's new technology LOX/Paraffin hybrid motor provides the capabilities to air light, throttle, and restart. If the hybrid development is delayed, GO Launcher 1 may utilize existing solid rocket boosters with a result in loss of flexibility.

GO Launcher 2: GOLauncher 2 is an air launched two stage rocket system capable of placing payloads of up to 100 pounds into Low Earth Orbit. GO2 offers a range of dedicated and rideshare launch opportunities to customer defined orbits for payloads up to 100 lb.

Payloads can be accommodated in three configurations:

- Single Microsatellite
- Multiple Nano satellites
- Cubesats

A wide range of orbital parameters are capable:

- LEO altitudes up to 400 nautical miles
- Inclinations ranging from 0 deg to 98.7 deg

Facilities: Generation Orbit does not currently have any facilities. It may be anticipated that a 10,000 sq. hangar would be adequate for modifications to the G-III carrier. Development and manufacturing of the booster may be accommodated in a similar size facility.

Commercial liquid oxygen service in commercial quantities will be necessary. And a launch range capability will be necessary for the orbital launch operations.

The safety of the new technology rocket engine is unknown. It may be assumed at this point that a 1,250 foot safety zone around the fueled vehicle will be necessary. A dedicated airspace corridor will be necessary. Over flight of populated areas may not be allowed until the booster can be proven as no more dangerous than existing commercial aircraft and until the carrier aircraft is licensed for commercial work.

4.3.1.6 Findings: Benchmark - Rocket Crafters

Rocket Crafters Overview

Rocket Crafters goal is to manufacture rocket propulsion and suborbital spacecraft for the emerging point-to-point suborbital space transport market. Rocket Crafters plans to develop and commercialize a new hybrid rocket propulsion technology and leverage an ultra-lightweight, advanced composite material to manufacture dual-propulsion suborbital space planes. Rocket Crafters is focused on spaceflight training and commercializing the enabling technologies required for the future suborbital new space opportunities for both commercial and military applications.

Rocket Crafters Corporation

Rocket Crafters, Inc. is a privately held Utah company founded in November 2010 to develop, manufacture, and distribute rocket propulsion and dual-propulsion (jet/rocket) flight vehicle products and services to the space exploration, commercial space, and defense markets.

The company will move its headquarters, research and development laboratories, and manufacturing and assembly operations to Space Coast Regional Airport in Titusville, Florida. Rocket Crafters reports that it will invest $72 million to support operations. The source of these funds is unknown. It reports that it will bring up to 1,300 full-time jobs. At full employment, the company reports that its total economic impact is estimated to be over $48 million

The Front Range Airport and Rocket Crafters have entered into a letter of intent to operate out of Spaceport Colorado which is to be co-located at Front Range Airport located a few miles east of Denver International Airport.

There appears to be an overlap of management between Rocket Crafters, Generation Orbit, and Space Works. This makes determining the current size of Rocket Crafters difficult but it appears to be less than 10 employees.

Rocket Crafters Details

Firehawk: Rocket crafters development program will begin with development of dual propulsion – jet and hybrid rocket powered trainers. They plan to introduce a primary level trainer capable of teaching conventional-to-rocket powered flight transition before the end of 2014. It will deliver these aircraft to flight schools and aviation colleges beginning in 2015. These trainers will support training programs for what Rocket Crafters sees as the large number of pilots necessary to support the fleet of Rocket Crafters vehicles (described below). These trainers will operate out of Front Range Airport/Spaceport under FAA Experimental Aircraft License.

Sidereus: Sidereus is a suborbital space plane in development. It will be capable of making suborbital flights of up to 1,500 nautical miles at maximum altitude of 100 km. Sidereus uses two propulsion systems - fan jets and hybrid rockets, also referred to as "dual-propulsion". Sidereus will be able to take-off, land, and operate seamlessly under power within the global air traffic system. Sidereus will operate as an advanced trainer.

Additionally, it will feature a small cargo bay in which it can carry scientific experiments and ultra-priority cargo. Much of the design/engineering has been completed. First flight will occur sometime before the end of 2016.

Sidereus-2A: Sidereus-2A is a more advanced model of the vehicle. It will have a range of up to 4,500 nautical miles and travel at speeds approaching Mach 6. Sidereus 2A will have the ability to release micro-satellites.

Cosmos Clipper: Targeted to be the world's first passenger/cargo carrying hypersonic suborbital transport. Its passenger capacity and operating characteristics are unknown.

Propulsion Systems: Rocket Crafters is developing a range of rocket boosters and upper stages for sub-orbital and orbital use. They use a new hybrid technology of a proprietary solid fuel and liquid oxygen. Much of the development is being done by the Florida Institute of Technology in Melbourne, Florida.

Facilities: Rocket Crafters reports that they will operate out of a 27,000 sq. ft. interim HQ/R&D/Pilot Production/Assembly Building in Titusville, Florida beginning the summer of 2013. In 2014 it will develop a 33 acre campus (15 acre expansion option) of 400,000 sq. ft. (total). This will house Rocket Crafters' World Headquarters and R&D Center, Rocket Propulsion Products Production Plant, Rocket Propellants Production Plant and Distribution Center, Flight Vehicle Development and Assembly Center, and Atmospheric and Suborbital Flight Testing Center. Reports are that the company is looking for a development firm to construct the buildings using the development company's own funds then lease them to Rocket Crafters to recover their investment.

The safety requirements for Rocket Crafters are unknown. Until details of the propulsion system are understood, a 1250 foot interline distance should be assumed around the fueled vehicle. The interline distances for the Propulsion Production Plant are unknown.

4.3.1.7 Findings: Benchmark - The Spaceship Company (Scaled Composites)

The Spaceship Company is unique in the industry. It is not listed as an operator above because it does not operate any system directly. The Spaceship Company was a developer and tester of unique high capability and high technology aircraft (including White Knight and Spaceship 1) which was subsequently acquired by a spaceflight operator to build its craft. It is also an example of how a small independent aircraft maker can grow into a major company in the entrepreneurial space arena. Growth of such a company at Ellington may be an example of the upper end expectations for the spaceport in this arena.

TCS has its roots in Scaled Composites. Scaled Composites was founded in 1982 by Burt Rutan. Scaled Composites performed air vehicle design, tooling and manufacturing, specialty composite structure design, analysis and fabrication, and developmental flight tests of air and space vehicles. Scaled was originally located at Mojave Airport in California, as is TCS today.

Scaled Composites was purchased by the Beech Aircraft Corporation in 1985 after collaboration on the Starship project. In 1988, Beech's parent company, Raytheon, sold Scaled back to Burt Rutan, who then sold it

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to Wyman-Gordon. After Wyman-Gordon was acquired by Precision Castparts Corp., Rutan and ten investors re-acquired the company as Scaled Composites, LLC. Northrop Grumman, a major shareholder in the company with a 40% stake, acquired the full company in 2007. Burt Rutan retired in April 2011. Table 4-B lists the progression of the company's project experience toward development of commercial spacecraft. It is listed here to show the progression of growth of an entrepreneurial enterprise within the aerospace industry.

Table 4-B: History of Scaled Composites Aircraft Projects

PROJECT NAME	PROJECT NAME
1. Model 115 Starship: 85% scale prototype, went into production as the Beechcraft Model 2000 Starship (1982)	2. B-2 Spirit: Scale model pole-mounted B-2 for radar cross section tests
3. Model 133 ATTT (1987) tandem-wing STOL transport	4. Model 143 Triumph: Built for Beechcraft (1988)
5. IAI Searcher: longer-winged version of Pioneer UAV (1988)	6. Model TRA324 Scarab: Developed for Teledyne Ryan, now Northrop Grumman (1988)
7. DC-X: Constructed the structural aeroshell and control surfaces under contract to McDonnell Douglas	8. Model 151 ARES (1990)
9. Orbital Sciences Pegasus rocket: Wings, fins for air launch rocket (1990)	10. Model 158 Pond Racer: Built for air racer Bob Pond (1990)
11. Bell Eagle Eye: Tilt-rotor demonstrator aircraft for Bell Helicopter (1993)	12. Model 202 Boomerang: Asymmetric 5 seat aircraft
13. Model 205, first preliminary design for air launch of a booster rocket heavier than 500,000 pounds (230,000 kg) (1991)	14. Model 206, second preliminary design for heavy air launch (1991)
15. Model 247 Vantage: Developed for VisionAire (1996)	16. Model 271 V-Jet II: Developed for Williams International (1997)
17. Model 276 NASA X-38: fuselage of drop test vehicle (1998)	18. Model 281 Proteus (1998)
19. Roton ATV (1999)	20. Model 287 NASA ERAST: R/C model for proof of concept of 85,000 ft. (26,000 m) UAV
21. Model 309 Adam M-309: Prototype for the Adam A500 (2000)	22. Model 326 Northrop Grumman X-47A (2001)
23. Model 302 Toyota TAA-1 (2002)	24. Tier One (2003) i. Model 316 SpaceShipOne: The first privately built spacecraft ii. - Model 318 White Knight: Launch vehicle for SpaceShip1
25. Model 311 Virgin Atlantic GlobalFlyer: Same mission as Voyager, except a solo flight using a jet engine (2004)	26. Tier 1b (2008) i. Model 339 SpaceShipTwo: The successor to SpaceShipOne ii. Model 348 WhiteKnightTwo: The successor to White Knight
27. Stratolaunch carrier aircraft (Model 351), world's largest wingspan aircraft	28. Model 367 BiPod (2011) A hybrid electric roadable aircraft.
29. USAF Hunter-Killer project (2007) in cooperation with Northrop Grumman i. Model 395: Proposed unmanned version of Model 281, equipped with armament ii. Model 396: Smaller version of the RQ-4 Global Hawk, equipped with armament	30. what next ????

SOURCE: ????

At this point, Scaled (parent Northrop Grumman) was a recognized expert in air vehicle design, tooling, and manufacturing, specialty composite structure design, analysis and fabrication and developmental flight test. Its revenue was $20-30 million per year with slightly over 200 employees.

Table 4-C: Sample Skill Types Used by TCS

Drafting
Metals Fabrication Technicians
Aircraft Composites Production Technicians
Aircraft Assemblers
Airframe and propulsion technicians
Quality Assurance Technician
Supply Chain Management
Composite Aircraft Manufacturing Engineers
Flight Sciences Engineers
Structural Engineers
Systems Engineers

SOURCE: ????

In 2005 Sir Richard Branson and Burt Rutan formed The Spaceship Company (TSC) jointly owned by Virgin Group (70%) and Scaled Composites (30%). The new aerospace production company announced purpose was to build a fleet of commercial sub-orbital spaceships and carrier aircraft. Additionally, TSC was formed to own the technology created by Scaled for Virgin Galactic's SpaceShip program. This includes developments on the care-free reentry system and cantilevered-hybrid rocket motor, licensed from Paul Allen and Rotan's Mojave Aerospace. The company is a spacecraft manufacturing company and will sell spacecraft to all buyers.

With Branson's company, Virgin Galactic, The Spaceship Company (TCS) contracted Scaled Composites to develop a spaceflight system to Virgin Galactic's specifications. In parallel it focused on building its team, operations, supply chain and capabilities at Mojave Air & Space Port. In October 2012, Virgin Galactic announced that it had acquired full ownership of The Spaceship Company (thereby absorbing Scaled Composites).

TCS is now well into manufacturing the second SpaceShipTwo and second WhiteKnightTwo. Until recently, TSC's operations stretched over 130,000 square feet in three separate facilities. In 2013 TCS opened its 103,000 square foot assembly hanger for the Stratolaunch Systems carrier aircraft. The Spaceship Company has approximately 145 employees.

4.3.2 FINDINGS: RELATED STAKEHOLDERS

As seen above in the benchmarks, there is extreme vertical integration within and between an operator and a developer. The business models used by the operators tend to exclude and minimize the role of "related stakeholders". Certainly, there is a shortage of stakeholders catering to the operators. But since there are no operators having yet commenced their operational phase for serving their respective markets, there is no one with revenue to who related stakeholders might market.

We found that services (to operators and the markets) are not supplier driven, therefore we did not perform a structured survey of potential suppliers – they will move to where there is a profitable market for them. Instead, we developed the demand driven needs via research, targeted interviews, and discussions with other spaceport operators.

Operators will generally not ask for or desire related stakeholder support. The spaceport must prove the value of its resident (potential) stakeholders to the operator. It should be expected that if the Spaceport is successful in this value presentation, the operator may expect the support to be provided as part of the spaceport incentives to locate there.

At this point in industry development it is not possible to define related stakeholders (to launch operators) in other than general terms. There were several items of interest.

Related Stakeholders: Orbital Research Support: One of the general areas of related stakeholder and facility support requirements that can be projected is those needed to support sub-orbital research. NASA and CASIS analysis has determined that life science research is the market or discipline most likely to be commercially viable in orbital space research. The same follows considering sub-orbital research as the precursor to orbital research. Much of the current work in support of sub-orbital research has been in the area of life sciences. To be fully actualized, this life sciences research requires ground based support facilities near the launch site. This support is identified in Future Facility Requirements (below).

Related Stakeholders: Payload Processing Support: One of the general areas of related stakeholder and facility support requirements that can be projected is that which is needed to support payload processing. Payload processing includes receiving the payload from the vendor, verifying that it is flight ready (testing, servicing commodities, etc.), packaging for flight integration into the vehicle, and shipping to the payload integrator. This will be necessary for payloads installed into launch adapters, canisters, and fairings at Ellington. Some payloads attempt to use the ship and shoot philosophy where there is little more than bolting the payload to an adapter at the launch site. Historically this proves to be generally impractical for a variety of reasons; even the smallest cube sat often requires some sort of activation or post transport functional verification.

Payload processing support requires a facility and support systems. This support is identified in Future Facility Requirements (below).

4.3.3 FINDINGS: EFD FACILITIES ANALYSIS/GAP ANALYSIS

The vertical integration and self-sufficiency drive within service operators made a detailed EFD Facilities analysis and a gap analysis not useful. The general attitude within the operators is “give me space (and incentives), get out of my way, and I will build everything else I need”. As with related stakeholders, this analysis was only possible at the general level. Detailed analysis will be possible in the future when a specific operator is targeted for support and detailed proprietary information protected negotiations can be held. There are some major gaps depending upon the class of service operators at Ellington. These gaps are addressed in Future Facility Requirements section (below).

4.3.4 FINDINGS: KEY SITE SELECTION CRITERIA

We addressed the characteristics which developers stated they required and upon which existing spaceports base their marketing. We found them to be the items listed in Table 4-D below in no particular order:

[Preliminary Draft for Discussion Purposes Only]

Table 4-D: Spacecraft System Developers Spaceport Selection Criteria

Qualified Workforce
FAA Horizontal Licensed Spaceport (e.g. the spaceport has absorbed the effort and cost of site licensing or is committed to do so)
Commercial Space Operator/Manufacturer Liability Shielding Legislation
Strong Financial Incentives
Favorable Business Climate (Commercial Space Industry and Manufacturing)
Weather favorable to Flight Testing
Access to restricted airspace or over-water airspace to support spaceflight operations
Access to rocket motor test facilities
Strong Community Support and a Can-Do Attitude

SOURCE: XSC, 2013

Through discussion with spaceport operators and system developers we find consensus that the two overriding selection criteria are: 1) Significant Financial Incentives, and 2) Elimination of red tape, regulation, and operational restrictions.

4.3.5 FINDINGS: WORKFORCE PROFILE

The following workforce profile was identified as examples of types of jobs one developer early in his system definition cycle stated would be required to support development and operation of a vehicle fleet. He stated the average annual salary would be $46,000.

Table 4-E: Spacecraft System Developer Workforce Profile

Management	Finance-Accounting	Human Resources
Engineering Management	Production Mgmt. Engineering and Scientific	Mechanical and Aeronautical Engineering
Aero-Structural Engineering	Rocket Propulsion Scientists and Engineers	Electrical Engineers
Computer Scientists Production	Machinists-CNC Operators	Tool Makers
Airframe Assemblers	Advanced Composite Technicians	Administrative
Accountants	Secretaries and Admin. Assistants	Schedulers and Planners
Marketing Support Marketing and Sales	Rocket Propulsion Product Sales	Flight Vehicle Sales
Propellant Sales	Aerospace Marketers	Graphic Artists
Web Developers	Test Pilots	Jet Engine-Avionics Maintainers
Spaceflight Medicine	Ground Simulator Operators	

SOURCE: ?????

[Preliminary Draft for Discussion Purposes Only]

4.3.6 FINDINGS: RANGE SAFETY

Even for air launch over open ocean, FAA licensing requires some range system support to ensure the safety of people and property, to communicate with the carrier aircraft, and to provide data collection and display. In the past, this support was usually provided by a federal Major Range and Test Facility Base (MRTFB) such as the Eastern Range, Patrick AFB, Florida; Western Range, Vandenberg AFB, California; and Wallops Flight Facility, Virginia.

The Wallops Mobile Range (equipment) allows launch outside a MRTFB. Pegasus has used it for launch from foreign soil such as from the Canary Islands, Spain. Alaska Aerospace used it to support launches from Kodiak prior to building their own certified system. The use of a certified mobile range satisfies requirements of the Department of Transportation to enable a licensed commercial launch.

Table 4-F summarizes the range system capabilities needed. It is generally written for application to unmanned launch vehicles/spacecraft. Manned systems may not require such systems depending upon the FAA licensing requirements. Sub-orbital may not require such support if it can be shown that at maximum performance and total loss of trajectory control of the launch vehicle could not impact any populated areas.

Table 4-F: Facility Requirements for Providing Range Support

Trajectory Analysis: The planned trajectory must be analyzed to determine if any populated areas will be overflown and if the risk is acceptable. Impact limit lines must be developed to ensure that the instantaneous impact point (IIP) of any stage or debris does not impact inhabited land. Reference the Eastern and Western Range, Range Safety Requirements Document (EWR 127-1) for detailed requirements and risk limitations.	**Area Clearance and Control:** The airspace surrounding the launch area must be cleared and controlled during the mission. Notices to airmen and mariners must be sent to clear the airspace and the predicted impact points of the spent stages and known debris.
Range Safety Displays: Visual display of the present position and IIPs must be available to the safety personnel to verify that no safety criteria are violated. This requires redundant tracking sources such as radar or telemetry guidance data. Existing launch vehicles are equipped with tracking transponders and provide position data in the telemetry downlink (providing one of the redundant systems).	**Flight Termination System:** The flight vehicle must be equipped with command receivers that operate at acceptable frequencies. They must be capable of receiving commands utilizing the standard four tone alphabet. The command transmitter system must meet federal standards as described in EWR 127-1.
Control Center: The launch team requires a control center to conduct the launch countdown. This center requires consoles with voice nets and network computer displays. The consoles must have the capability to remote key the radios for communications with the carrier and chase aircraft.	**Telemetry:** Downlink telemetry data is usually in the S-band and upper S-band frequency range (2,200-2,300and 2,300-2,400 MHz). A telemetry system must be capable of tracking, receiving, and recording this data. The carrier aircraft may haves on-board video cameras and this data is transmitted via a telemetry system that operates in the upper S-band range. A chase aircraft may be necessary to downlink telemetry.
Air-to-Ground Communications: Air to ground communications is required to communicate with the carrier aircraft during the launch operations. This can be in the HF, VHF, or UHF frequency range.	**Voice Nets:** Voice nets are required for communications between the various controllers involved in the operation. Four to eight nets are required.
FTS Controllers: Certified FTS Controllers must meet the federal standards described in EWR 127-1.	**Data Recording:** Recording of all the telemetry downlinks is required.
IRIG Timing: Inter-range Instrumentation Group timing rqmt.	**Weather Forecasts:** Weather forecasts are required.

SOURCE: ?????

[Preliminary Draft for Discussion Purposes Only]

4.3.7 FINDINGS: NESSESARY FACILITIES

All systems examined require facility support. The location of the facilities (or combination of facilities) depends upon the operations model used by the operator/developer:

- Manufacturing Site: the hardware is built at the spaceport
- Ferry Mission: all hardware is integrated at the spaceport and ferried to the release site
- Campaign Mission: all hardware is integrated elsewhere and ferried to the spaceport. At the spaceport the payload is installed (if not already) or tourists embarked

Table 4-G lists the types of facilities needed by the operator/developer.

Table 4-G: Facility Support Types

Aircraft manufacture	Spacecraft manufacture
Spacecraft processing	Launch vehicle mate to carrier
Booster manufacture	Booster build up and testing
Payload processing and testing	Payload mate to booster
Oxidizer storage (hybrid propulsion)	Oxidizer loading on booster near flight line (hybrid propulsion)
Ordnance storage for solid propellant and small operational pyrotechnics	Operations and Mission management/control
Space tourist preparation and support	Runway sized to aircraft/spacecraft
Transportation access (oversized rail and highway)	Research support laboratories

SOURCE: XSC, 2013

Some facilities may serve multiple purposes (e.g. spacecraft manufacturing and processing in same site). We do not address flight test support because that is very system dependent.

4.4 User Needs Assessment - Conclusions

4.4.1 DEVELOPERS

Conclusion: Developers Must Be Attracted

The study was to address those spaceport facilities and operational attributes which affect the ability of a spaceport to attract and support a spaceflight operator. In today's market environment this requires the spaceport to attract a spaceflight system developer.

Unlike aviation where you have separate builders and operators, here the operators design, prototype, build, test, and fly the systems. All do it with as little reliance on outside suppliers as possible. Part of this is due to the model set by SpaceX in its development of the Falcon launch vehicle and Dragon spacecraft. Part is due to unstable funding and revenue streams making normal supplier relationships and timeline/schedule management impossible. Part is due to the bad experiences and financial losses suppliers had associated with the Kistler-Rocketplane bankruptcies (among others). And, part is due to the ingrained mistrust of "big aerospace" by the entrepreneurs. Finally, the largest reason there are not the normal industry segments of supplier base, system builder, and system operator is that there is only a postulated market for the expansion of space launch significantly beyond its current requirements. This is the reason none of the major aerospace or aircraft companies are developing systems. The economic reality is that the current market does not support buying from a manufacturer then operating for profit.

Conclusion: New Developers Must Be Attracted – Existing Launch System Developers Unlikely to Move

All existing, credible, developer/operators are committed to their current sites. Getting them to relocate is unlikely. For maximum positive economic impact, the spaceport must attract developers early in their cycle before another site captures them with better incentives. A developer/operator has longer business life and more economic impact if it is self-funding (e.g. Stratolaunch).

4.4.2 OPERATOR/DEVELOPER SITE SELECTION

Conclusions: Key Site Selection Criteria Are Financial Incentives, and Freedom to Operate

The list of attributes favored in spaceport selection is provided in the findings section (above). We looked into this more deeply with several spaceport managers and developer management and determined that there were two overriding factors in spaceport selection. They were:

- Cash incentives
- Freedom from interference by spaceport, local, and state government

It will be necessary for Ellington to develop a significant incentives package and hands off operations model to attract this market. The Houston Airport System should determine its sources and limits for financial incentives (to a single recipient and to multiple).

Conclusions: Availability of Composite, Plastics, and Propulsion Skills Enhance Attractiveness

Assessment of the workforce profile and examination of the companies actually working with hardware currently finds there are three key capabilities needed:

- Composite design and development specialists
- Advanced plastics design and development specialists
- Rocket propulsion design and testing specialists

Having personnel with these specific skills in the local area would be useful in attracting developers. A successful, world class airframe manufacturer and a world class propulsion company could be seen as a future supplier of the skills or necessary products. Other skills listed in the findings are also needed but are more generally available than these.

Conclusions: Range Safety System Is Required (But May Be Already Available)

Examination of the market and developing systems finds that it is not necessary that Ellington develop a range safety system. It should verify that the Wallops portable range system identified in section 4.3.6 will remain available for the foreseeable future. A preliminary application study should be done to identify where on the coastal area (Texas/Louisiana) the system should be located. If land basing does not give proper coverage then shipboard options should be examined.

4.4.3 OPERATOR LICENSING

Conclusion: Operator Licensing Restrictions will Limit Future Operations at Ellington

Ellington Spaceport will become a FAA licensed spaceport, however, the ability for operator licensing must be taken into consideration when determining which types of systems it would like to have as tenants. There are significant safety and licensing issues with Ellington operations for most of the systems in development or testing today. These include:

- Air corridor clearing for departure from and return to the launch site. Even air launch orbital systems may need the return corridor clearance for the return with a loaded vehicle after an aborted launch.
- Air tourism spacecraft glide back over populated areas is currently not expected to be permitted by FAA regulations until there is significant experience with this type operation.
- For hybrid propulsion systems, carrier flight over populated areas may not be allowed until an accident with the booster attached can be proven as no more dangerous to population and property than that of existing commercial aircraft operations.
- Carrier aircraft operations over populated areas may not be allowed until the carrier aircraft is licensed for commercial work.
- Carrier operations over populated areas with attached liquid propulsion systems are not expected to be licensed.
- Horizontal launch operations of liquid fueled systems over populated areas are not expected to be licensed. Note: Operational safety clears for liquid systems can be as large as 3 miles. This depends upon the quantities of oxidizer and fuel. None of the developers are willing to release this information.
- Early phase developmental flight testing of carrier aircraft or point to point systems over populated areas may be significantly restricted (experimental classification).

- Initial flight of newly manufactured aircraft or point-to-point system craft may be restricted until a type certification regimen is established for that craft and there are craft with those certifications in licensed operation.
- Point-to-point systems will have the same sonic boom limitations as Concord had when it was operating.

It may be expected that the following will be licensed after significant analysis and testing and after an operations experience base is established:

- Air tourism spacecraft glide back over populated areas
- For hybrid propulsion systems, carrier flight over populated areas
- Carrier aircraft operations over populated areas

Mapping the above limitations to the benchmarked suppliers' operation plans reveals that the following types horizontal launch systems may be licensed to operate out of Ellington Spaceport at some future date:

- Large carrier aircraft (not manufactured at Ellington)
- Large boosters with solid propulsion systems (none currently in development)
- Medium size boosters with hybrid propulsion systems
- Small boosters with solid propulsion systems
- Space tourism spacecraft with hybrid propulsion systems

These systems support the following type launch services:

- Large Orbital Cargo
- Large Space Tourism/Sub-orbital research
- Small Orbital Cargo
- Small Space Tourism/Sub-orbital research

The Houston Airport System should determine which types systems it would like to have as tenants and focus its actions on those systems.

4.4.4 FUTURE FACILITIES

Conclusions: Future Facility Requirements Must Be Protected

Future facility requirements depend upon which type system is being developed or used by the developer/ operator Ellington Spaceport attracts. Due to market uncertainties and licensing concerns, it is not recommended that facility changes be made at present. However, certain future changes should be protected (not precluded by other Ellington modifications) to enable the future spaceport. It may not be possible to protect all these capabilities and the list may be prioritized based upon the systems Ellington focuses upon (reference above). These changes are listed below:

- Runway expansion for large systems: Runways 12,500 feet long, 200 feet wide, and capable of carrying 1.3 million pounds (large carrier aircraft)
- Hangar to support an aircraft 285 ft. L x 385 ft. W x 50 ft. H (large carrier aircraft)
- Rail cargo service (large booster)
- Small booster assembly and payload integration facility 30,000 sq. ft. (small booster)
- Liquid oxygen storage area (hybrid propulsion)
- Liquid oxygen transfer to spacecraft (mounted on carrier) area (hybrid propulsion)
- Nitrous Oxide storage area (hybrid propulsion)
- Nitrous Oxide transfer to spacecraft (mounted on carrier) area (hybrid propulsion)
- Clear zone of 1250 foot around spacecraft/booster fueling area and travel paths (or ability to operationally clear area) (hybrid propulsion)
- Space tourist support facility of 30,000 sq. ft. facility (space tourism)
- Hanger for spacecraft processing and testing 10,000 sq. (space tourism)
- Life sciences research laboratory of 120,000 square feet capable of performing BSL-2 (Biological safety level – 2) activity (cargo/research)
- Payload processing facility of 10,000 sq. ft. capable of hazardous spacecraft fueling (1250 foot clearance) (orbital cargo)
- Operations and mission control 10,000 sq. ft. facility (all)

Absent from the above list is a storage facility for solid booster segments. The size and clear zones for this would be dependent upon the system, the specific propellant, and the time of storage.

[Preliminary Draft for Discussion Purposes Only]

5. Demand Forecast Assessment

Objective: Develop a forecast of addressable launch demand for EFD and three scenarios of launch activity to help determine the potential level of suborbital and orbital launch activity at Ellington Spaceport.

5.1 Introduction

An essential element in the analysis of the economic feasibility of a proposed spaceport is the level of launch activity that spaceport could host. The type and quantity of launches that could take place from Ellington Spaceport will have a significant effect on the overall economic activity the spaceport can generate for the greater Houston area, including the ability to attract ancillary businesses to the facility and surrounding community. Exact predictions of launch activity are exceedingly difficult to perform, given the large number of variables involved in determining launch activity and the uncertainties associated with each.

This section provides a set of forecasts for suborbital and orbital launches that could take place from Ellington Spaceport over the next decade. This analysis builds upon the Market Assessment task, which provided a qualitative analysis of potential markets and vehicles that could serve them by operating from Ellington. This analysis provides forecasts of addressable launches—those that are technically able to take place from Ellington—as well as scenarios of actual launch activity from Ellington, based on the market share that vehicle operators using Ellington are able to capture. The results provide a range of potential scenarios for launch activity that serve as the basis for further economic analysis.

5.2 Methodology

The Market Assessment task of this study identified several markets that vehicles capable of operating from Ellington Spaceport could serve. The definitions for each of these markets are described in the Market Assessment, Section 2. For the Demand Forecast Assessment, market segment groupings of Tourism, Research, Other, and SmallSat were used, and applied to the two categories of Suborbital and Orbital markets. In the suborbital market, tourism is the largest market, followed by research, and then technology and miscellaneous applications such as education and media. In the orbital market, launches of small satellites to low Earth orbit is the primary addressable market for vehicles operating from Ellington since the spaceport can accommodate only those vehicles that can take off and land horizontally with air launch systems whose capacities are much smaller than more conventional vertically launched expendable launch vehicles. Figure 5-A shows the market segment groupings used for the Demand Forecast Assessment.

[Preliminary Draft for Discussion Purposes Only]

Figure 5-A: Market Groupings

This study makes use of a number of existing forecasts for launch demand for these markets. In 2012, the FAA and Space Florida published a forecast of suborbital launch demand prepared by The Tauri Group.[4] That study was based on extensive research into likely demand for commercial suborbital spaceflight in selected markets. That report included three forecasts for commercial suborbital launch activity, based on “seat equivalents”, (a person of equivalent experimental payload) over a ten-year period. The report does not link the forecast to specific years (instead using “Year 1,” “Year 2,” etc.), but for the purposes of this study Year 1 of that forecast is assumed to be 2014, when commercial suborbital vehicles under development by Virgin Galactic and XCOR Aerospace are expected to enter revenue service.

For the suborbital space tourism market, the forecasts from the FAA/Space Florida report are synthesized with independently developed projections of the market by the Futron Corporation, based on updated versions of its Space Tourism Market Study from 2002. The Futron data predicts smaller initial demand than the FAA/Space Florida study, but faster growth over the ten-year forecast period.

The orbital forecast, restricted to smallsats, utilizes a forecast published in February 2013 by SpaceWorks Engineering, Inc. (SEI) of microsatellite and nanosatellite demand.[5] The SEI forecast is based in the initial years of the forecast on announced missions, and in later years provides two projections of growth in demand for such spacecraft. This forecast is focused on satellites with masses of 50 kilograms or less. It may thus exclude some satellites larger than 50 kilograms, but most vehicles that operate today or are under development that could operate from Ellington Spaceport in the future are focused on the small end of this market, where there has been the most growth given the low cost and expanding capabilities of such small spacecraft.

These reports are used to generate forecasts of addressable launches for Ellington. As these reports provide forecasts based on payloads (people, experiments, or satellites), they are converted to launches using separate methodologies. For suborbital markets, seat equivalents are translated to seats using a factor of 3.5 seat equivalents per launch. This is based on the average between Virgin Galactic’s SpaceShipTwo, with a capacity of six seats; and XCOR Aerospace’s Lynx, with a capacity of one seat (excluding pilots in both cases.) For smallsat launches, a “multi-manifesting factor” is used, as today smallsats are typically launched in clusters of

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[4] FAA Office of Commercial Space Transportation, *Suborbital Reusable Vehicles: A 10-Year Forecast of Market Demand*, August 2012, http://www.faa.gov/about/office_org/headquarters_offices/ast/media/Suborbital_Reusable_Vehicles_Report_Full.pdf (accessed June 25, 2013).

[5] SpaceWorks Engineering, Inc., *Nano/Microsatellite Market Assessment*, February 2013, http://www.sei.aero/eng/papers/uploads/archive/SpaceWorks_NanoMicrosat_Market_Feb2013.pdf (accessed June 25, 2013).

several to dozens at a time. This multi-manifesting factor declines over the forecast period, from 12 in 2014 to 4 in 2023, to reflect the projected introduction of more dedicated smallsat launch systems.

This study makes three different forecasts of the addressable market. The baseline addressable forecast uses the data from the baseline forecasts of the FAA/Space Florida suborbital report, with the exception that, for the tourism market, the projected seats from that study are averages with Futron's projections for that market; the baseline forecast from the SpaceWorks forecast is used for the orbital forecast. A high addressable forecast, representing the upper end of likely launch activity over the next decade, uses the "growth" forecast from the FAA/Space Florida report for suborbital markets and the growth forecast from the SpaceWorks report for the orbital market. A low addressable forecast, representing the lower end of likely launch activity over the next decade, used the "constrained" forecast from the FAA/Space Florida report for suborbital markets and the baseline forecast, reduced by 50%, from the SpaceWorks report for the orbital market (the SpaceWorks forecast provided only baseline and growth projections.)

The addressable forecasts also estimated revenues for the launches included in them. The forecasts assume that prices for individual launches, or seats on those vehicles, will decline over time because of vehicle improvements as well as competition. For smallsat launches, the forecast assumes an initial per-launch price of $5 million, declining over time to $2.5 million by the end of the forecast period. Suborbital revenue projections are more complex because of the mix of vehicles and prices currently offered: Virgin Galactic is, as of June 2013, charging $250,000 per seat, while XCOR Aerospace is charging only $95,000 per seat. Because of the mix of vehicles operating at any time in the forecast period is unclear, the forecast assumes that half the flights will be made by SpaceShipTwo-class vehicles (carrying six people or equivalent payloads) and its corresponding ticket prices, and half are made by Lynx-class vehicles (carrying one person or equivalent payload) and its corresponding ticket price. Those ticket prices are also projected to decline during the forecast period, to $50,000 each for XCOR and $90,000 each for Virgin Galactic, by the end of the forecast period.

Table 5-A: Revenue per Flight (in millions of dollars)

VEHICLE TYPE	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Suborbital (Lynx-class)	$0.095	$0.095	$0.080	$0.080	$0.080	$0.070	$0.070	$0.060	$0.050	$0.050
Suborbital (SS2-class)	$1.500	$1.500	$1.320	$1.140	$0.960	$0.900	$0.840	$0.720	$0.600	$0.540
Orbital	$5.000	$5.000	$5.000	$4.500	$4.500	$4.000	$4.000	$3.500	$3.000	$2.500

SOURCE: XSC, 2013 ???

Once the addressable market forecasts are complete, this study then generates scenarios for the level of activity captured by vehicles operating from Ellington Spaceport. For the sake of simplicity, the scenarios are all based on the baseline addressable market forecast described above. The scenarios make different estimates of the share of the three suborbital markets (tourism, research, and other) and the smallsat launch market captured by vehicles operating from Ellington. Those shares change over time during the ten-year forecast period. In the baseline scenario, flights begin at Ellington in 2016 with 10% of the suborbital tourism market, growing to 20-25% of all four markets by 2023. In the robust scenario, flights begin at Ellington in 2015 with 5% of each of the three suborbital markets, growing to 25-35% of the overall addressable market by 2023. In the constrained scenario, launches from Ellington begin on 2019 with 5% of the suborbital tourism market and 10% of the suborbital research and other markets, growing to 10-15% of all four markets by 2023.

Table 5-B: Ellington Market Shares in Constrained Scenario

MARKET	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Tourism	0%	0%	0%	0%	0%	5%	5%	10%	10%	10%
Research	0%	0%	0%	0%	0%	10%	10%	15%	15%	15%
Other	0%	0%	0%	0%	0%	10%	10%	15%	15%	15%
Smallsat Launches	0%	0%	0%	0%	0%	0%	10%	10%	10%	10%

SOURCE: XSC, 2013

Table 5-C: Ellington Market Shares in Baseline Scenario

MARKET	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Tourism	0%	0%	10%	15%	15%	15%	20%	20%	20%	20%
Research	0%	0%	0%	10%	10%	15%	15%	20%	20%	25%
Other	0%	0%	0%	10%	10%	15%	15%	20%	20%	20%
Smallsat Launches	0%	0%	0%	10%	10%	10%	15%	15%	15%	20%

SOURCE: XSC, 2013

Table 5-D: Ellington Market Shares in Robust Scenario

MARKET	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Tourism	0%	5%	10%	15%	20%	25%	25%	25%	25%	25%
Research	0%	5%	10%	15%	20%	25%	25%	25%	35%	35%
Other	0%	5%	10%	15%	20%	25%	25%	25%	25%	25%
Smallsat Launches	0%	0%	0%	10%	15%	20%	20%	20%	25%	25%

SOURCE XSC, 2013

These three scenarios provide a range of potential suborbital and orbital launch activity by, and corresponding revenues from, vehicles flying from Ellington Spaceport. It should be noted that the revenues calculated in these forecasts are those captured by the vehicle operator, and only a fraction of those revenues would actually be spent in operations at Ellington. Those calculations will be discussed in greater detail in later sections of this report.

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5.3 Results

The Table 5-E and Figure 5-B summarizes the total launches (suborbital and orbital) and revenue from the three addressable market forecasts, labeled "low," "baseline," and "high." In the low addressable market forecast, launches grow from 64 per year in 2014 to 89 per year in 2023, with revenue going from $69.3 million in 2014 to $65.5 million in 2023 (revenue does not grow at the same pace of launches because launch prices are projected to decline during the forecast period, as discussed the methodology section above.) In the baseline forecast, launches go from 104 in 2014 to 266 in 2023, with annual revenue going from $118.3 million in 2014 to $156.7 million in 2023. In the high forecast, launches go from 317 in 2014 to 499 in 2023, with revenue going from $290.2 million in 2014 to $271.6 million in 2023.

Table 5-E: Total Launches & Revenue ($M) in Three Addressable Market Forecasts

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
LAUNCHES										
Low	64	41	71	70	73	76	77	80	88	89
Baseline	104	112	110	120	125	143	167	194	233	266
High	317	327	340	356	367	384	412	436	479	499
REVENUE ($M)										
Low	$69.33	$55.53	$70.80	$61.89	$58.91	$61.90	$61.57	$64.30	$73.94	$65.45
Baseline	$118.26	$135.60	$119.93	$112.38	$107.43	$119.29	$129.99	$142.30	$165.97	$156.73
High	$290.17	$310.27	$299.20	$274.52	$256.09	$263.57	$270.67	$274.06	$298.23	$271.60

SOURCE: XSC, 2013

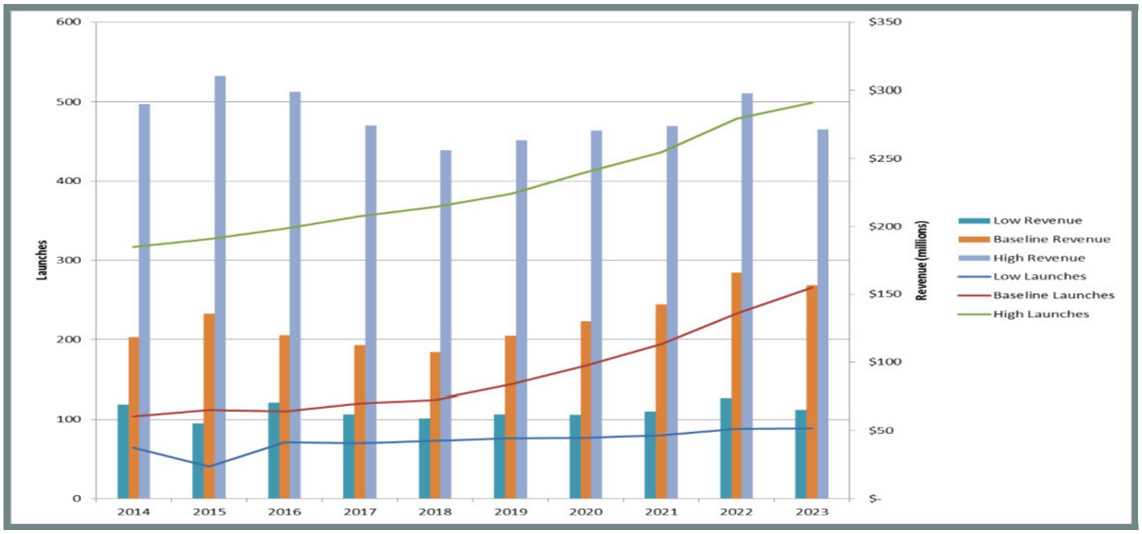

Figure 5-B: Graph of Total Launches & Revenue ($M) in Three Addressable Market Forecasts

SOURCE: XSC, 2013

[Preliminary Draft for Discussion Purposes Only]

The three scenarios for launch activity at Ellington, based on the baseline addressable market forecast, offer a range of outcomes, illustrated the tables below. In the constrained scenario (Table 5-F), activity grows to only 25 suborbital and 4 orbital launches by 2023, with revenue of $16.1 million. In the robust scenario (Table 5-H), however, activity grows to 60 suborbital and 9 orbital launches by 2023, with revenue of $39.8 million.

Table 5-F: Launches and Revenue ($M) from Ellington - Constrained Scenario

LAUNCHES	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Tourism	0	0	0	0	0	5	6	14	17	20
Research	0	0	0	0	0	1	2	3	3	3
Other	0	0	0	0	0	1	1	1	2	2
Smallsat Launches	0	0	0	0	0	0	2	2	3	4
Revenue	$-	$-	$-	$-	$-	$3.61	$10.12	$14.78	$17.10	$16.15

SOURCE: XSC, 2013

Table 5-G: Launches and Revenue ($M) from Ellington - Baseline Scenario

LAUNCHES	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Tourism	0	0	9	14	15	16	25	29	34	39
Research	0	0	0	1	1	2	3	4	4	6
Other	0	0	0	1	1	1	1	2	2	2
Smallsat Launches	0	0	0	1	1	1	2	3	5	7
Revenue	$-	$-	$6.16	$14.14	$13.27	$15.08	$22.29	$24.69	$28.12	$31.64

SOURCE: XSC, 2013

Table 5-H: Launches and Revenue ($M) from Ellington - Robust Scenario

LAUNCHES	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Tourism	0	5	9	14	19	27	31	36	42	49
Research	0	0	1	1	2	3	5	5	7	8
Other	0	0	1	1	1	2	2	2	3	3
Smallsat Launches	0	0	0	1	2	3	3	4	8	9
Revenue	$-	$4.03	$7.00	$14.57	$19.08	$27.04	$29.39	$31.80	$42.16	$39.80

SOURCE: XSC, 2013

5.4 Conclusions

The addressable market included in this study is only a small part of the overall global launch market. The rest of the market—launches of much larger satellites—remains unavailable to vehicles that can operate from Ellington, since these satellites require larger, vertically-launched rockets. However, the unaddressable markets remain relatively stable, with little or no growth during the coming decade. By contrast, the markets that can be served by vehicles able to fly out of Ellington are those that show the greatest prospects for growth in the coming decade, including commercial suborbital human spaceflight and the growing interest in low-cost but capable small satellites.

The forecasts of overall addressable activity show, in the baseline case, growth in the size of the addressable market from a little more than 100 launches per year to more than 250 over the next decade, with suborbital space tourism the largest market. Most of those launches will take place at other spaceports, but various scenarios for an Ellington Spaceport show that it could host, in the most robust case, as many as 60 suborbital and 9 orbital launches a year by 2023. This level of activity is small compared to aviation, but far more active than most existing spaceports today, thanks to the growth in the emerging suborbital market. Those flight activities alone could generate up to $40 million per year in revenue, although only a fraction of that revenue will actually be spent on Ellington, depending on where the operator is based and their mode of operation at the spaceport. The economic impact of those flights and other spaceport activities are discussed in a later section of this report.

6. Business Case Assessment

Objective: Assess the financial reasonableness of commercial entities that would make up the EFD Spaceport

6.1 Introduction

In the pursuit of an objective as large and complex as the establishment of a new spaceport all sectors of the space community must be considered in terms of how they can contribute to the success of the overall effort. The interrelationship in terms of finding mechanisms of mutual benefit between the federal, state and local governments along with the commercial sector is a challenge. For the past decade, as commercial development opportunities and space entrepreneurs have attained varying levels of maturity and success, each one has been faced with the task of evaluating the financial viability of corporate entities that make up a spaceport so that long term plans and budgets could reflect an appropriate partnering and risk sharing with each industrial and governmental element. The financial evaluation of these opportunities is an important part of developing a workable and saleable spaceport proposal. All of these opportunities need to be represented in a business case format that can be examined for its assumptions and assessed as to its risk by its spaceport partner. To do this the spaceport needs to apply technically based financial expertise and capable models to provide a consistent evaluation of the validity and risk associated with commercial opportunities offered by entrepreneurs and existing companies who wish to find a way to create a win-win situation wherein the spaceport is "helped" and they realize their financial rewards.

The financial implications of private enterprises based on or near EFD engaged in the development, operations, and/or support of space launch and landing systems is estimated based on projections of future demand as described in the Demand Forecast Assessment. Space access by systems operating out of EFD would support:

Local development of new systems based at EFD

Local support to systems based at other sites that would frequently operate out of EFD

Local support to systems based at other sites that would infrequently operate out of EFD

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6.2 Industry Context

The original intent of providing Pro Forma projections for the study were meant to focus on the local development of new RLV systems based at EFD. This type of activity would represent a new and growing high tech firm that would design, develop, test and operate out of EFD.

The study's original approach to developing a business scenario was to describe some high tech enterprise that would base itself at EFD, work in conjunction with NASA and other surrounding tech organizations and build a company that would bring a system through design, development, and test to operational status. In that manner a kind of top level pro forma assessment for that kind of a company would be run, and assessed for its net worth and whatever needed financial characteristics to draw out, that would then serve as a part of the value to the Houston area. This would be the economic benefit from the standpoint of HAS developing the spaceport.

The aerospace industry periodically goes through cycles of entrepreneurial development of new technology launch systems with the goal of attaining cheaper access to space. Historically, commercial companies attempting to fly reusable systems, whether or not they were suborbital or orbital, had to get to flight rates that began to approach several a day at some point in order to be able to look at actually sustaining profitability. Even when that was possible, the development cycle by the time the program went from the beginning of design through all the testing that it would have to go through, was starting approaching the equivalent kinds of timeframes that drug companies have to spend in being able to develop a drug and bring it to market where they start to produce some revenue. Those are long development times.

A design, development and operational spacecraft firm would take, depending on the specifics of the systems design that could fly out of EFD and based on prior analyses, 5 to 7 years to bring a system to full scale test. It appears that the current market conditions make an estimate for the initiation of such an enterprise at least several years in the future. It is probable that the start of such an enterprise would be a few years after other first-to-market operators prove the safety and efficiency of their systems and the size of the market.

If first-to-market operators commence operational flights in 2015, the start of a new development system based at EFD would not start before 2017 or 2018. An additional 5 to 7 years of development and test would mean an initial operational capability in 2022 to 2025 – well downstream of a time frame of financial significance to current decisions.

The commercial spaceflight industry now has a new breed of entrepreneurs like Elon Musk and Scaled Composites and others significantly shortening these development timelines, but even when looking at what they are doing, it is still a matter of 5 to 7 years, especially when considering getting these new types of vehicles through some kind of test regime, which the industry really doesn't quite understand yet, e.g. levels of safety or mission assurance for these systems.

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As mentioned in Section 4 User Needs Assessment, all existing, credible, developer/operators are committed to their current sites. So the time dimension relative to looking who are viable candidates for when Ellington will see the start of a new development company appears limited today. There are people and companies who have been studying these new technologies and have technology concept proposals ready to begin development, and if they were given the money they could probably start. But they are not being given the money; they're hanging on by angel investors and other atypical sort of investments.

What we have seen and found during the course of this study, is there is no investing in any of these companies through traditional Wall Street or going public type of investments. They are essentially self-funded or angel investors. Table 6-A identifies typical investments of the leading first-to-market developers.

Table 6-A: First-to-Market Commercial RLV Development Costs and Investment Sources

COMPANY	DEVELOPMENT COST PROJECTION	FUNDING SOURCES
XCOR	The XCOR system is going to cost between $50M and $100M to build	XCOR is funded by angel investors and what they call targeted investors
Virgin Galactic	The Virgin system is somewhere between $300M and $600M to build, and getting closer to the $600M	Virgin is being funded by Richard Branson and a Saudi Arabian investment company who gave him almost $400M on top of the $350M that Branson put into it
Stratolaunch	The Stratolaunch system, they are saying they going to spend $300M just to build the airplane side of it. If you look at airframe development of that size that's going to be more in the $1B to $2B	Stratolaunch is being funded directly by Paul Allen

SOURCE: ???? ALAN ???

To suggest there will be a future candidate viable growing company ready to base operations out of EFD for development of a new system, it would first be necessary to have the first-to-market developers, whether its Virgin Galactic, an XCOR or whomever, demonstrate the safety of their systems; the efficiency from the standpoint vies-a-vie what ticket prices the market will bear; and that the market is actually there that is being projected. For someone to come in from Wall Street or a going public kind of investment to come in and lay the kind of money needed on a new system development that could start at Ellington, you would have to have a year or two at least of time from first-to-market operations to be able to demonstrate to the investment community that this is a viable industry. In that sense, if the projections for business capture at Ellington start anywhere from 2015 to 2017, it will likely be the later part of the decade for when a completely new business might be initiated at Ellington in the sense of an entity that was going to design, develop, test and operate.

6.2.1 ALTERNATIVE OPERATING SCENARIOS

If the initiation of space launch activities at EFD is based on support to operators not based at EFD, the direct financial benefit to the local community is greatly reduced. The Pro Forma derived financial implications for operators based elsewhere is irrelevant to EFD operations except to the extent that such first-to-market operators will exist and when they will seek alternative points of operations other then their own base.

In the first years of these initial visiting operators, it is likely they will provide their own support equipment and personnel. There will be a requirement for local shelter and access to utilities. If the launch and landing market share for Ellington grows, there will be at some level activity for transitioning to a local base of operations with local staff, equipment and facilities, but the enterprise will still maintain its main base of operations at its home base. Thus, two scenarios for spaceport launch and landing operations are envisioned for EFD during its early years:

Scenario 1

For launch event frequencies of once or twice a year the operational scenario for any new spaceport will be to provide shelter and utilities for an outside operator crew and support equipment.

Scenario 2

For launch event frequencies equal to or less then once a week the operational scenario for any new spaceport will be to have locally stationed crew, equipment, offices, hangar space and access to consumables and utilities.

6.3 Launch Market Capture Projections

Using the baseline addressable market forecast (Table 5-E); a launch frequency estimate for EFD begins with converting “seat equivalents” to launches for each market segment grouping using the methodologies for suborbital and orbital flights as described in Section 5. The conversion graph is shown in Figure 6-A.

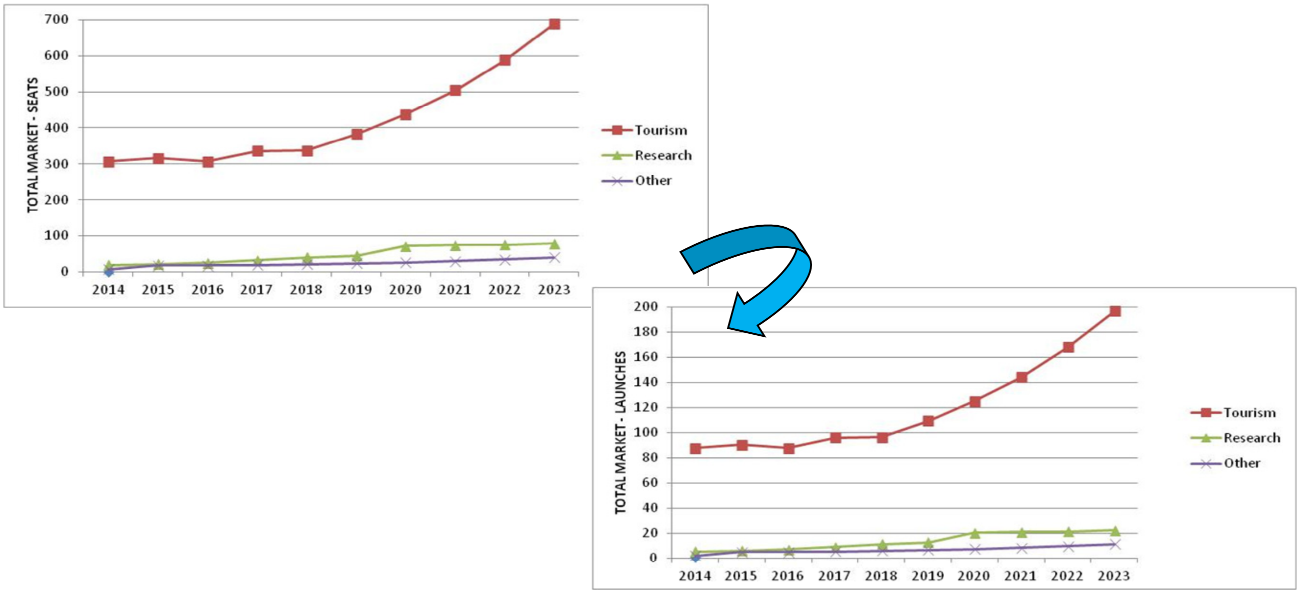

Figure 6-A: Estimate of Total Baseline Launch Market, Converting Seats to Launches

SOURCE: XSC, 2013

A high and low estimate of EFD's share of the total addressable launch market for each market grouping is shown in Figure 6-B.

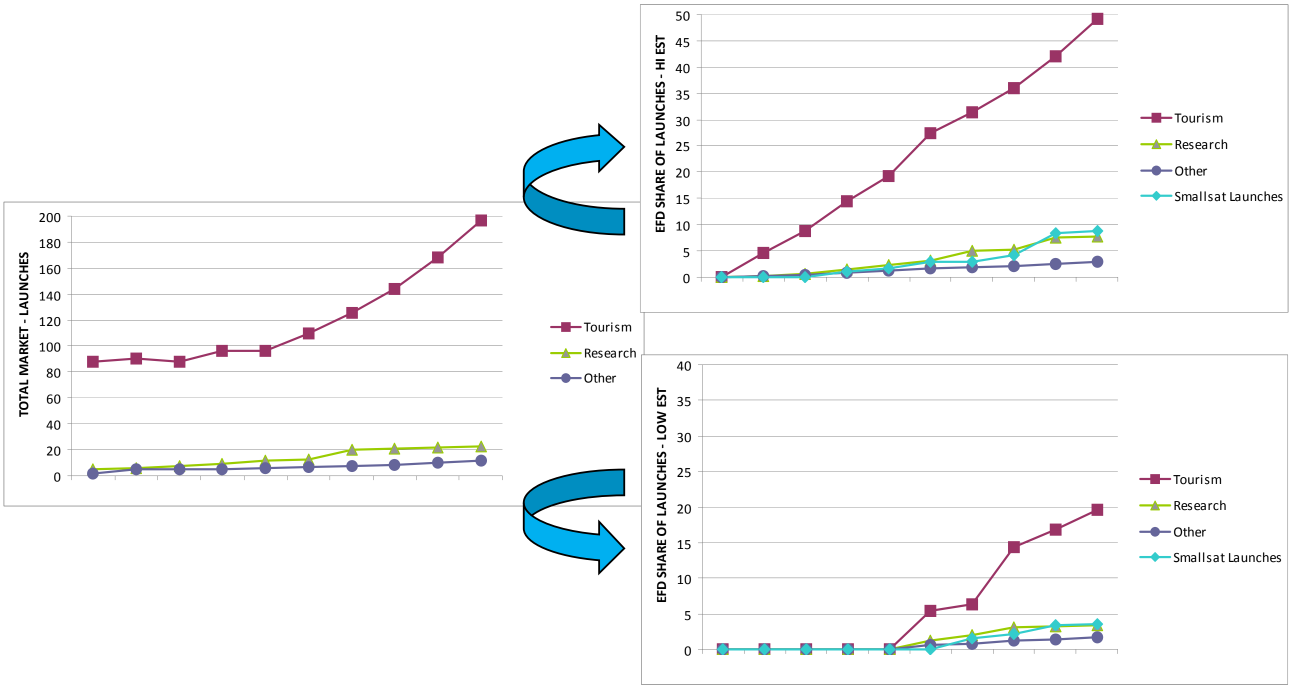

Figure 6-B: EFD Share of Total Launch Market – High & Low Estimate

SOURCE: XSC 2013

6.3.1 FREQUENCY BASED PROJECTIONS

EFD's projected ***high*** estimate for its share of the market for each market grouping is then calculated for the average number of days between launches, shown in Figure 6-C:

- Tourism
  - High Estimate
    - Drops below 1 launch event per month in 2016 to 2017
    - Drops below 2 launch events per week in 2020 to 2023
- Research and Smallsat
  - High Estimate
    - 1 launch event every 3 months starting in 2020
    - Gets to 1 launch event every 2 months by 2022 to 2023

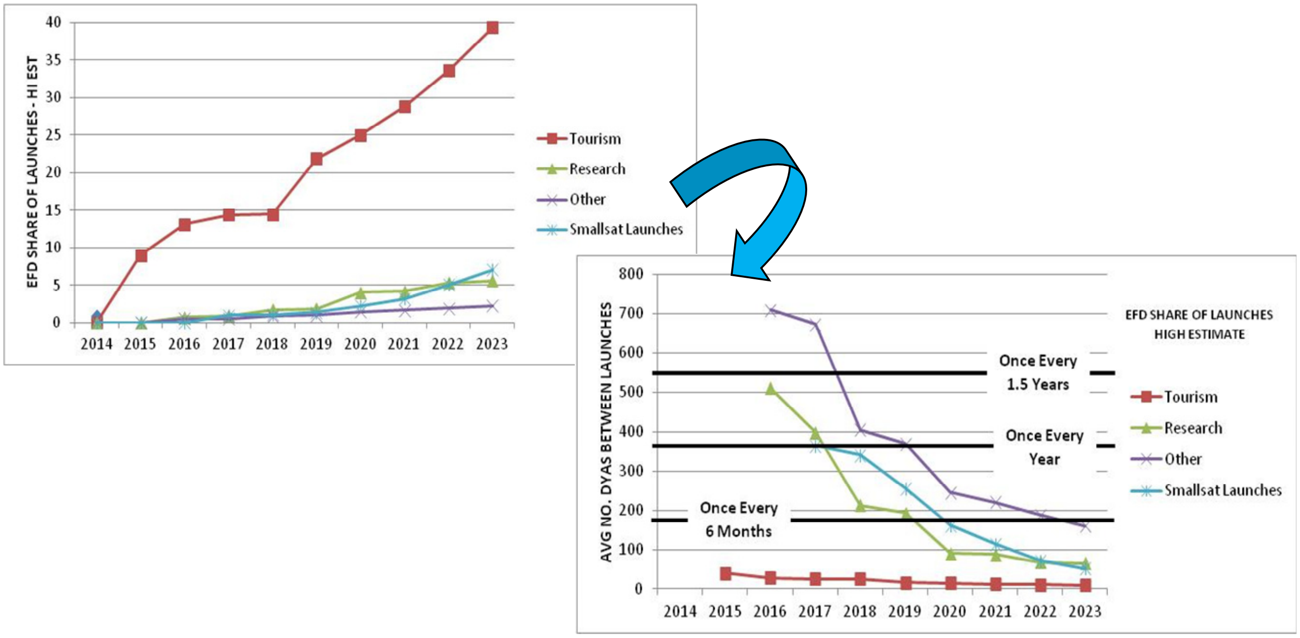

Figure 6-C: Average Number of Days between Launches – High Estimate

SOURCE: XSC, 2013

EFD’s projected ***low*** estimate for its share of the market for each market grouping is calculated for the average number of days between launches, shown in Figure 6-D below:

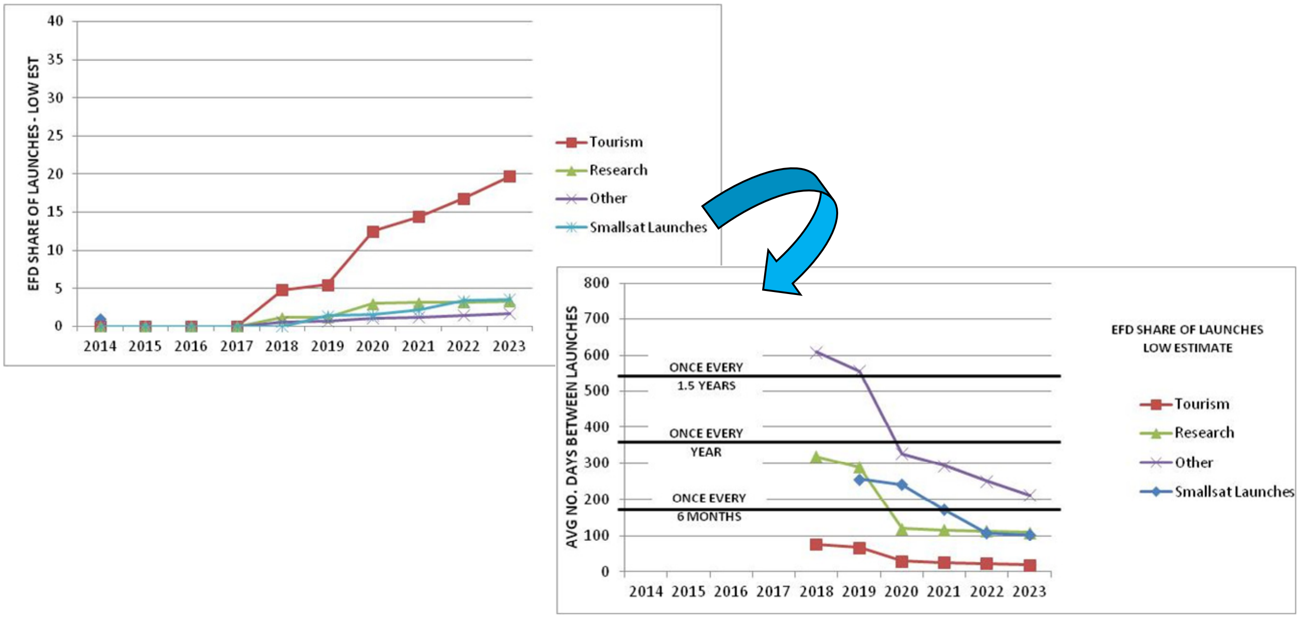

Figure 6-D: Average Number of Days between Launches – Low Estimate

SOURCE: XSC, 2013

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- Tourism
  - Low Estimate
    - Drops below 1 launch event per month by 2020
    - Might drop below 2 launch events per month in 2023
- Research and Smallsat
  - Low Estimate
    - Approximately once a year starting in 2018 or 2019
    - Gets to 2 launch events by 2020 or 2021

When considering the average days between launch events, tourism is the only market segment in the early years of operations in the demand forecast projections that achieve flight rates that get close to one a month, or one every couple of months, or even one every three or four months. Flight details are shown in Figure 6-E.

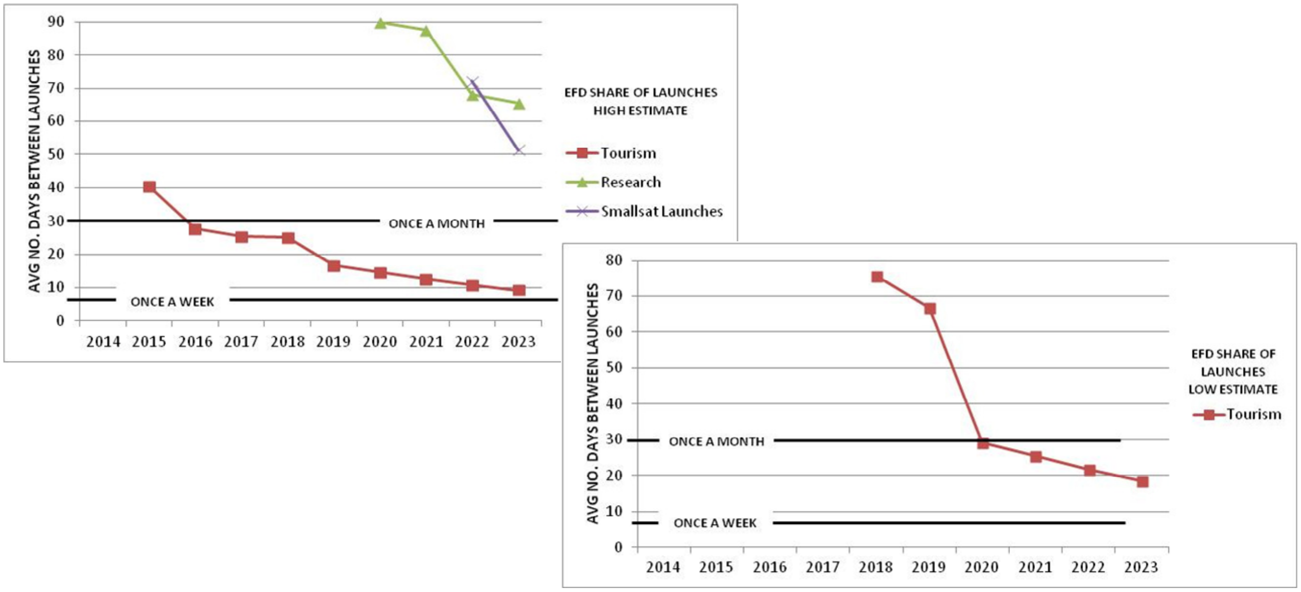

Figure 6-E: Average Number of Days between Launches – High and Low Estimates

SOURCE: XSC, 2013

6.3.2 EARLIEST FLIGHTS

It is only toward the very end of the 2023 time period in the high estimate that additional market segments in the projections begin to achieve higher flight rates. So the question then becomes what would the likely scenario be at the earliest time that EFD could see the beginnings of flight or launch events occurring at the spaceport? If this is at the beginning of the market, then consideration must be given to the number of spaceports around the country that are also in contention, and would like to see a first-to-market visiting operator capability being flown out of their position for whatever publicity and other kinds of things that would accrue as a result of those flight events. It is likely in the beginning year, or maybe first four or five launch opportunities, EFD might have to be in a position to actually pay for visiting operators to fly from Ellington; or figure out how to incentivize better than other competing spaceports for how to get a limited fleet of White Knight's and Spaceship Two's or whatever first-to-market system is flying at the time, because there will be more spaceports than there are providers. It will be highly competitive in the beginning.

It is anticipated that the earliest flights out of EFD would occur as a result of being more attractive a site then other spaceports. It is therefore likely that EFD would have to pay for the privilege of hosting early flights as opposed to receiving fees in order to establish the Houston area market. It could be that this condition lasts for the first 2 or 3 visits by first-to-market operators.

Based on market share projections for frequency of tourism flights of more than once a month, earliest flights would occur sometime starting between 2017 and 2020.

- Before that period of time and beginning either when EFD is licensed as a Spaceport or low estimates of market expansion prevail, Scenario 1 is the most likely operating scheme

- After the period of more then a flight a month (2017 to 2020), Scenario 2 is the most likely operating scheme

The launch frequency milestone of a visiting operator flying less that once a month was somewhat arbitrarily chosen as a notional "line in the sand" in order to apply context to the various flying scenarios in this study. If a visiting first-to-market operator is flying out of a spaceport whether it is Ellington or anywhere else that is not their home base, and doing it less frequently than once a month, it would seem that the parent company that owns the first-to-market operation would have figured out how to transport their crew and specialized equipment and even consumables with them, as opposed to trying to set up some kind of fixed base operation at other spaceports.

So for some period of time Scenario 1 would prevail, which basically says what the spaceport could provide is going to be a certain amount of shelter, access to utilities, and other sort of minimal interfaces with the airport/spaceport as well as to the surrounding community.

After some period of time EFD could switch to an operational capability when those first-to-market operators become convinced that operating out of the EFD facility is either: inexpensive, has access to specialized markets or to passengers willing to pay prevailing ticket prices, has other things to do in the general area, has nice facilities, hotels, etc. Maybe then EFD begins to see more frequent occurrence of launch events. At some point, whether it is the once a month marker, or somewhere in that time frequency that the flight rate increases such that the first-to-market operators are visiting a spaceport like Ellington two, three, even four times a month and getting closer to once every other week, clearly then they are probably getting to the point of setting up some kind of base of operations at the spaceport where they now have offices, local crew,

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specialized equipment, back-shop operations, hangar space, as well as access to consumables and utilities. So Scenario 2 would come into play for an EFD based operator. The Scenario 1 mode of operation does not cease at this point, but continues as an operational mode for other visiting operators that enter the field as the market proves itself out.

6.3.3 EFD BASED DEVELOPER

Eventually, superimposed on the two operating scenarios, EFD might be able to see the beginnings of a spacecraft development company based out of EFD developing its own capabilities. As mentioned earlier, such an enterprise is not going to see in the timeframe to 2023 much ability for the firm to get a return on its investment until operations begin in the following decade. To establish when to project an Ellington based development company would start, the very earliest could be a couple of years after the beginning of the first-to-market operators, when they have proven out the market. At this point, it is likely the EFD based development company would not be attempting to reproduce the first-to-market spacecraft technology, but would leap-frog to a newer generation of technology development such as a Point-to-Point. Figure 6-F shows the projection of the respective workforce headcount for a new vehicle development effort at EFD based on vehicle complexity for 5 year and 7 year development programs.

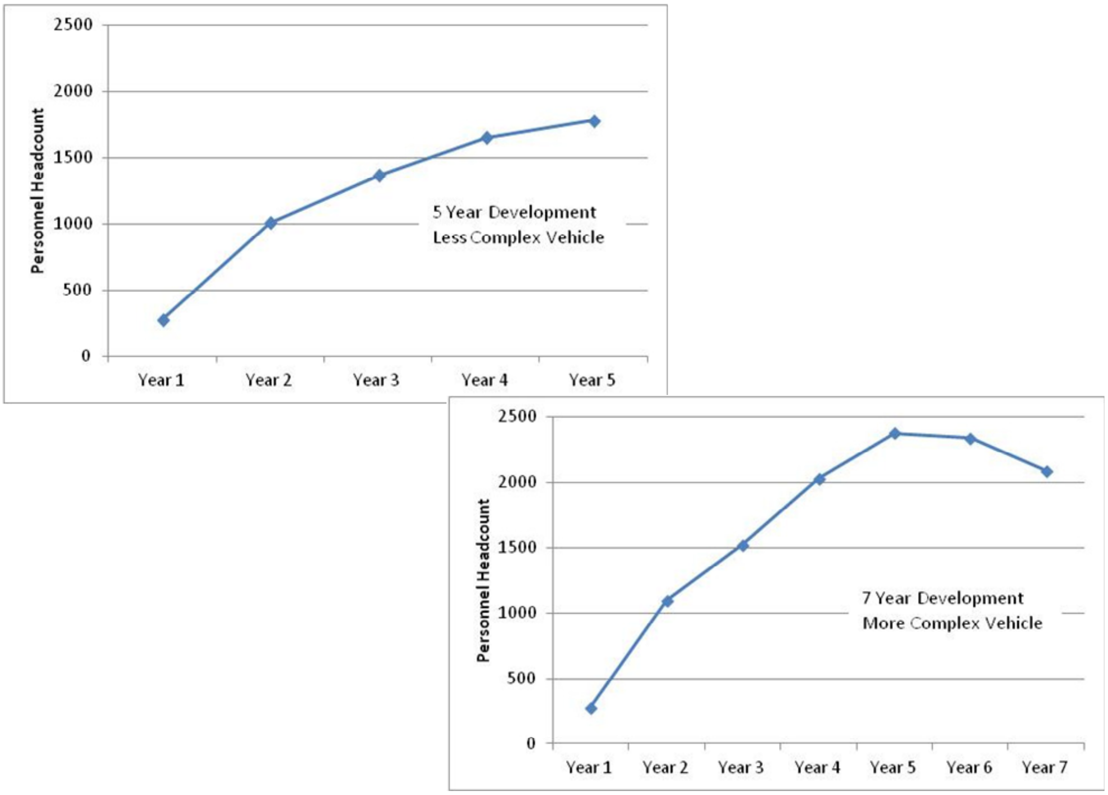

Figure 6-F: Estimated Workforce Headcount for an EFD Based Developer

SOURCE: AEROSPACE ???

[Preliminary Draft for Discussion Purposes Only]

6.4 Research Park

A Research Park is also proposed for Ellington Spaceport, which will further define the spaceport for its overall activities and operations. The Research Park is uniquely positioned to take advantage of it's proximity to NASA Johnson Space Center and the surrounding academic and aerospace community to create a dynamic and successful environment of collaboration for cutting edge research and development. The complete vision for the Research Park is described in Section 7.1 Spaceport Research Park.

6.4.1 TECHNOLOGY SPILLOVERS

The business case regarding research aspects of the spaceport for spaceflight can be far-reaching and difficult to measure. Continued space exploration and aerospace flight will often present new challenges and opportunities for new, innovating technologies, processes, materials, etc. Typically, research parks transfer technology from the knowledge source to the external regional community. Technological advancements can trickle down from the aerospace industry to private and consumer markets to boost labor utilization, productivity, and wages. The spaceport is envisioned to be an engine that drives creation of a high-tech aerospace industry cluster. Any potential technology transfers from the aerospace and space exploration industry to the commercial consumer markets would have to be qualitatively discussed. At this point it is not technically feasible to determine in advance how material, aerospace, and satellite technology will spillover into the consumer market. Quantification of these far-reaching benefits with the opportunities for technology transfers, entrepreneurship, and cooperation would be extremely challenging prior to the full understanding or implementation of that research and is beyond the scope of this study. Ultimately however, the success of the spaceport technology cluster could be measured in terms of: a) local industry concentration compared to the nation, b) exports from the region by the industry, and c) the high-tech industry cluster provides higher wages than the local average wage[6].

Development of the Research Park for the spaceport can and should proceed prior to identification of first-to-market operators utilizing the spaceport for flight operations.

6.5 Activity Timelines

Based on the above discussion of factors influencing possible operating scenarios for the spaceport, projections of spaceport activity timelines were developed using High and Low estimates of when spaceport development and flight operations could commence; these are shown in Figure 6-G.

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[6] San Diego Association of Governments, "Understanding Cluster Analysis"

Assumptions applicable to both High and Low estimates include:

- An earliest probable start date for Research Park
- First Visiting Flight out of EFD based on EFD capture assessment
- Preparation for initial Visiting Flight in prior 2 years
- Visiting Flights duration lasts until frequency becomes less then once per month (Scenario 1)
- Preparation for initial Base of Operations for Visiting Flights (Scenario 2) occurs over 2 years before Visiting Flight Base of Operations begins
- EFD Based Developer begins 2 years after start of EFD Visiting Flights
  - EFD Based Developer takes 5 to 7 years to achieve Initial Operations

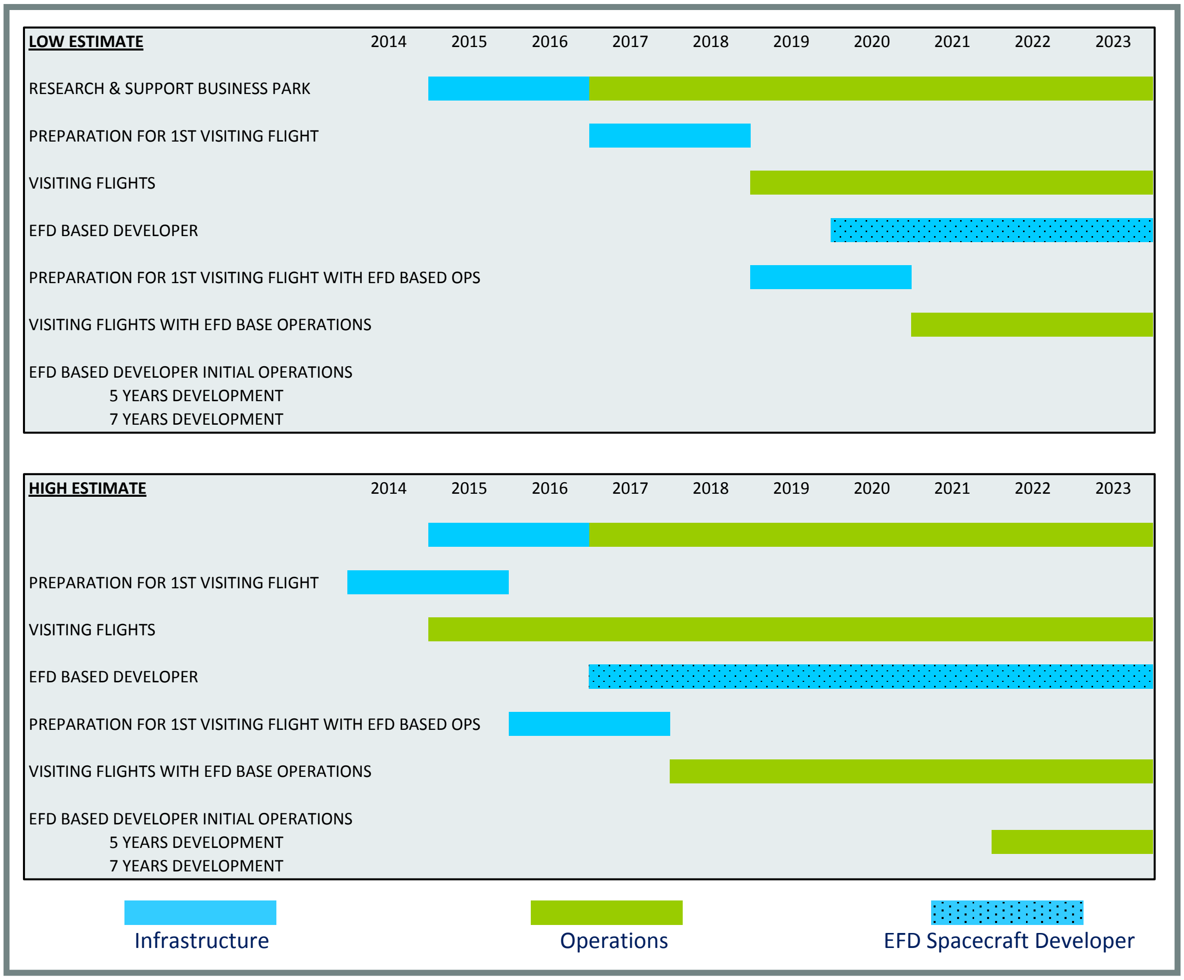

Figure 6-G: Low and High Estimates of Spaceport Activity Timelines

SOURCE: XSC, 2013

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6.6 Value Determinations

6.6.1 MARKET SEGMENT VALUE

Market segments value for EFD were determined using the estimated price per flight projections indentified in the Section 5 Demand Forecast Assessment. As mentioned, prices for individual launches, or seats on vehicles, are expected to decline over time because of vehicle improvements as well as competition. EFD market segments value is then determined as the total annual Price per Seat for Tourism and Research on Reusable Systems plus Price per Smallsat launch. High and low estimates of market share are shown in Figure 6-H. Annual and cumulative values from all EFD launches are seen in Figure 6-I.

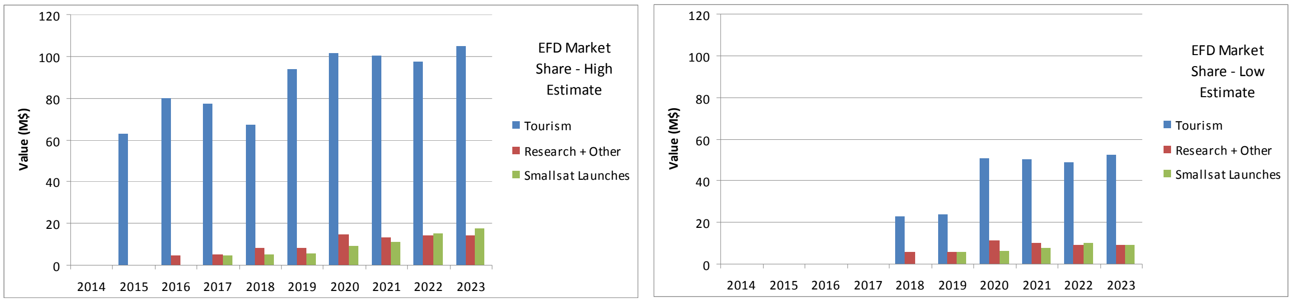

Figure 6-H: High and Low Estimates for EFD Market Share

SOURCE: XSC, 2013

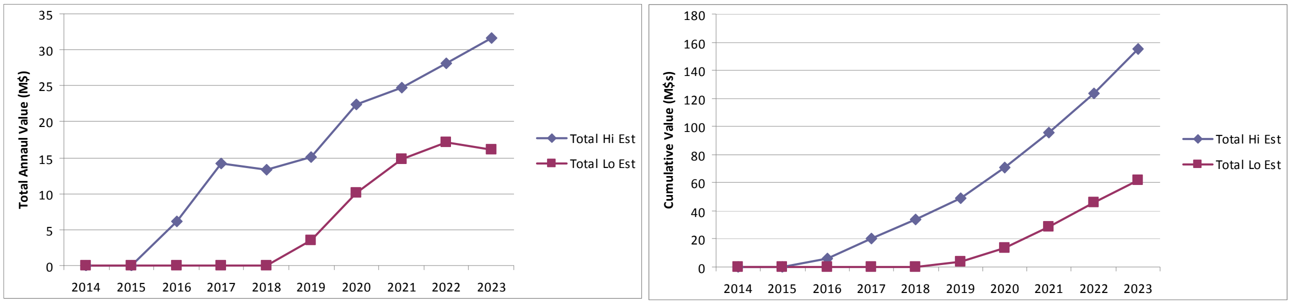

Figure 6-I: Annual Value and Cumulative Value from All EFD Launches

SOURCE: XSC, 2013

6.6.2 SOURCES OF REVENUE

While aircraft and ship operations provide some analogue for Launch and Landing fees it is estimated to take many years to arrive at an appropriate scheme for infrequent space system flight events. Fees could be based on weight, access to various portions of the runway, runway maintenance impact, consumables, number of passengers, equipment leasing, etc. Broad fee type categories could be launch & landing fees; shelter and utilities fees; and fees for offices, support equipment, hangar space and consumables.

7. EFD Spaceport Model

7.1 Spaceport Research Park

The spaceport is envisioned to be an engine that drives creation of a high-tech aerospace industry cluster. The Research Park for aerospace technology research and development, and manufacturing facilities further defines Ellington Spaceport as part of its overall spaceport activities and operations. Ellington's proximity to the NASA Johnson Space Center (JSC), as well as the area's academic and aerospace business communities are assets to leverage for creating within Ellington, a dynamic and successful environment of collaboration for cutting edge aerospace research and development (R&D).

When defining a future vision of space travel and exploration for Ellington, of note is that 'the wheel' has already been invented in Houston. Houston and the surrounding communities have long been known as 'Space City'. When Houston was dedicated as the Center for Manned Space Flight in 1961, the community embraced this emerging industry in only the way that Texans can with that maverick spirit. The reality of Ellington Spaceport hinges on community collaboration.

Collaborative partnerships with academia, industry and non-profits to stimulate innovation and education in science and research disciplines are critical to aerospace innovation. Houston is a city that is anchored by three main industries: space, medicine, and energy. EFD strategic partnering in these key areas will create opportunities for unimagined intersections of innovation. The EFD Research Park can be positioned to be a dynamic, integrated research community that provides R&D leadership into the 21st century.

7.1.1 EFD INNOVATION & INVENTION ENVIRONMENT

Instituting a culture of collaboration and innovation within the Research Park will literally be breaking new ground at EFD. The 440 acre development site is greenfield land. For HAS, it will also be new management territory in understanding how to instill and nurture a collaborative and open culture for the spaceport.

Branding the spaceport as a cluster for aerospace technology innovation to attract talented researchers and entrepreneurs will require pioneering models of operation that a new youth generation of scientist and engineers can relate to. Their philosophy is one of openness, sharing, collaboration and communities, i.e., open source software/open source hardware.

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For example, a third industrial revolution is currently underway worldwide. Manufacturing is going digital. Desktop manufacturing is changing the way products are designed, prototyped and made. Over the last 10 years, manufacturing tools like 3D printers, laser cutters and milling machines have been going from factories and Fortune 500 R&D labs, to desktops and do-it-yourself (DIY) community spaces offering public, shared access to high-end manufacturing equipment. These DIY spaces are interchangeably referred to as hackerspaces, makerspaces, TechShops, and FabLabs. You no longer need to be part of a large company or have the backing of a huge brand to take an idea and make it a reality.

Growth of a culture of collaboration and innovation from the ground up at EFD will begin with defining the type of facilities and infrastructure provided to community users and tenants. Our proposed formula for implementation involves a series of shop spaces, R&D and manufacturing facility types of varying levels of fidelity and resources available. We label these Level I through Level IV facilities, and operate them within an EFD / JSC integrated commercial space economic development plan. We have identified specific facility types to model and/or target for locating at the spaceport for R&D and manufacturing operations. Table 7-A identifies the Level I – Level IV facility types. Further definition of each facility type is also described below.

Table 7-A: Types of Facilities within EFD Aerospace Innovation & Invention Environment

FACILITY TYPE	ENVIRONMENT	FUNCTION	DESCRIPTION
Level I	Trial & Error	Grassroots Makerspace at EFD	• Grassroots DIY Community Space • Basic Equipment/Tools/Safety Training • Limited Space, Equipment, Technology • Membership Fees; Community or EFD Sponsored
Level II	Rapid Prototyping	EFD TechShop & JSC Makershop	• Larger Space, Better Equipment/Safety Training • Equipment Owned/Maintained/Floor Plan (well laid out) • Membership & Equip Use Fees (EFD only) • Dedicated Staff Counselors; Training • Owner Operated at EFD; NASA operated at JSC
Level III	Research & Development	General Dynamics EDGE Aerospace Innovation Center A joint EFD-JSC Initiative for Government/Industry/Academia	• Industry/Academia/Government Collaboration • Think Tank; Idea to Implementation (Rapid) • Access to Test/Research Labs • GD Sponsored; Membership Fees
Level IV	Innovative Manufacturing Processes	Aerospace Manufacturing Innovation Institute An Innovative Manufacturing Institute (IMI) within the National Network for Manufacturing Initiative (NNMI)	• $1B Presidential Initiative to Resurrect Mfg. Regions • Legislation to establish 15 Institutes for Manufacturing Innovation & R&D; Competitive Selection Process • Domestic Products to Market (Rapid) • Training Pipeline • City/State Sponsored

SOURCE: XSC, 2013

[Preliminary Draft for Discussion Purposes Only]

7.1.1.1 Level I – Grassroots Makerspace

Trial & Error Environment

PHOTO SOURCE: 10BITWOKS MAKERSPACE, SAN ANTONIO, TX

Makerspaces are grass roots organizations focused on fomenting idea to implementation efforts. Makerspaces are international in origin, but local in design and development[7]. The purpose of providing this information is to make HAS aware of organizations which could be immediately established at EFD to initiate spaceport Research Park development efforts with community collaboration projects for instilling a culture of innovation. Beginning small, and as demand dictates, these builder shops can evolve and grow with the Research Park development. Further, HAS would be able to assess membership fees for services by sponsoring this offering, or simply as a property lease from a larger makerspace sponsor, such as a Boeing, Lockheed Martin or Northrop Grumman.

Mojave Makers

Mojave Makers, located at the Mojave Air & Spaceport in Mojave, California, is an example of this type of facility enterprise. XSC conducted a survey of the facility. Like all hacker/makerspaces, Mojave Makers was formed to provide space for tinkerers, builders, and inventors; with equipment that you would not necessarily be able to house in your residential garage. Accordingly, their lifeblood depends on membership dues and equipment use fees, augmented by angel investors and grants. Mojave Makers opened doors to their 3,000 square foot facility in January 2012, receiving the first year rent free from the Mojave Air & Spaceport Authority.

Mojave is located in an isolated and economically depressed area. The economic environment has impacted the local school districts, who in turn have sought support from Mojave Makers for tutoring, teaching assistance and access to their equipment. Mojave Makers have received a number of grants to support these community assistance efforts.

Mojave Makers started out as an observation by the two originators/founders of Mojave Makers, Mike Clive, and Ethan Chew that there were no makerspaces within 50 miles of Mojave. Ethan having come from Makers Local 256 of Huntsville, AL and Clive coming from CrashSpace in LA, decided to change that. Primarily because there was nothing to do in Mojave and they wanted a “cool place to work on projects”. Their Charter is to provide an awesome space in Mojave for anyone to hang out, have fun, work on projects and have something

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[7] Makezine.com: “Is it a Hackerspace, Makerspace, TechShop, or FabLab”, Gui Cavalcanti, posted 2013/05/22; http://makezine.com/2013/05/22/the-difference-between-hackerspaces-makerspaces-techshops-and-fablabs (accessed 6/21/2013)

to do in Mojave. It mainly started as a member-supported organization. They initially relied on members and memberships contributing by paying membership dues, holding events and more. They received their administrative support and sponsorship for the facility respectively from the Space Studies Institute and the Mojave Air & Spaceport. Both strongly believed in Mojave Maker's mission to give the Mojave Air & Spaceport employees something to do after work and give people a reason to live and work in Mojave. The Space Studies Institute provided insurance and non-profit status. Proximity to their jobs, the attractive lease, other potential members and airport workers were key in establishing Mojave Makers. Since the organization was sponsored by the airport, they were provided one of the facilities on the complex.

Due to their operational environment in and on an airport, they are limited to the types of projects they may undertake or sponsor, such as bright light displays outside, or projects which make or emit smoke. If they do have a smoke related project they must notify the fire department and seek approval; which requires a number of certifications and coordination with other agencies to mitigate the risk of a fire.

Mojave Makers would like to accept any project, but are constrained by equipment, space and safety. As an example, they were forced to turn down a homebuilt aircraft project and instead point the person to the nearby T-hangars due to lack of space, and had to decline a rocket project that required compressed gas bottles due to lack of the required insurance.

In interviewing Mr. Chew, the following telling comment expresses some of the challenges in establishing a makerspace: "…as a makerspace, core funding sources come from memberships and donations for having cool projects and holding cool events. Profit margins for makerspaces tend to be very thin (1% or less, at times negative), so one must not expect profit and really work the publicity angles to attract members. You can apply for grants for doing educational work or special projects, but that is secondary to being a mackerspace. Therefore, one must focus on getting members and building a community that attracts and supports, serves and helps members work on their projects".

7.1.1.2 Level II – EFD TechShop & JSC Makershop

Rapid Prototyping Environment

PHOTO SOURCE - TECHSHOP: SEATTLE STARTUP WEEKEND, MAKER EDITION

TechShop is actually a trademarked name of a chain of for-profit spaces started in 2006 in Menlo Park, California. They were founded by Jim Newton, scientist of 'Mythbusters' fame. TechShops refer to themselves as open-access public workshops. They offer public access to high-end manufacturing equipment in exchange for membership fees. TechShops are established in communal facilities providing members an opportunity to build, fabricate and make things in a collaborative environment. There are no Non-Disclosure Agreements among members. TechShops have always focused on providing public access to a variety of skill areas with supporting equipment infrastructure; all of their facilities include woodworking, machining, welding, sewing, and CNC fabrication capabilities.

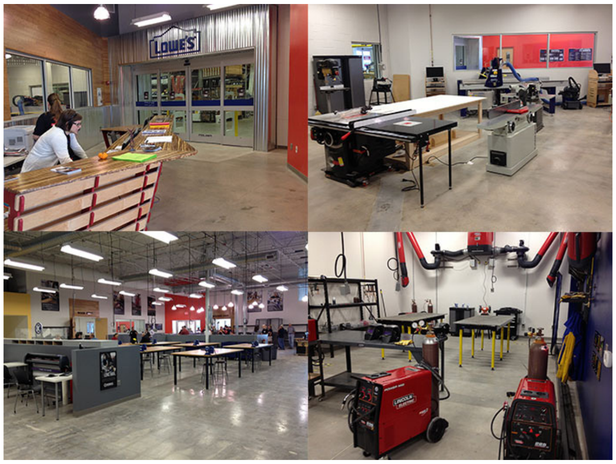

PHOTO SOURCE: TECHSHOP AUSTIN/ROUNDROCK

XSC conducted a survey of a TechShop franchise in Austin (Roundrock), Texas. The facility is located minutes away from potential sponsors Dell, Intel, Google, Samsung and GE. This was a major consideration for the location selected. As it is, the Round Rock TechShop shares facility space with a local Lowes store; they are separated by automated double glass sliding doors. Members of the TechShop receive discounts on materials for their projects from the Lowes store. If the members need angle iron or aluminum billets, Lowe's will order and deliver, members have access to the readily available materials at Lowe's, through the partnership.

The machinery, equipment and tooling are the latest technology. TechShop instructors provide initial training and safety orientation on use of the equipment. At this time, they do not provide any type of individual certifications. The TechShop provides a comprehensive fabrication environment, which can be used as a production shop floor. An overview of their facility capability is shown in Table 7-B.

Table 7-B: Typical TechShop Facility Overview

Woodworking Shop	Machine Shop (up to 4 axis)
Laser Cutting	Textiles
CNC (CAD/CAM)	Electronics
Vacuum Forming	Welding
Tube Bending	Sheet Metal
Rapid Prototyping (3D Printer)	Metal Shop
Arts & Crafts (Screen Printing)	Autodesk
Sandblasting/Grinding	Finishing/Painting
Plastics/Composites (injection molding)	Collaborative Area of Workbenches/Tools
Member Storage Lockers for Projects	Vehicle Area (inside/outside)

SOURCE: TECHSHOP, AUSTIN/ROUNDROCK

Additional equipment includes a waterjet cutter with a 5' X 10' bed and a hole puncher in their sheet metal shop which will punch holes in up to ½ inch metal. They do charge an additional $3/minute for use of the waterjet cutter. Their mig/tig welding shop has 3 workstations with individual pull down vent-a-hoods. They have 3 laser cutters next to the 3D printer. The collaborative area is a series of 10 workbenches with vices and a wall of tools and equipment (shadow-boarded).

TechShop owns and maintains all the equipment, tooling and machinery in the facility. In touring the facility, it presents a very clean, 'Visual Factory' environment, with congenial staff very passionate about what they are

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doing at TechShop. TechShop has monthly class schedules and schedules for renting the equipment. It is a very organized and well-kept facility.

Sources of funding for Tech Shops are investors and angels, in addition to corporate sponsors. There are also grant vehicles available, but TechShop did not disclose details of those resources. The various memberships and fees for use provide funding for daily operations.

EFD TechShop

Tech Shop's business model is to seek new locations in cities/areas that have both the general population in numbers and the pre-existing presence of maker and inventor communities to support a TechShop in the short-term and long-term. To fund and open a store, they look to form relationships with companies, groups, investor groups, organizations, and/or educational institutions in the surrounding community that are interested in partnering with them on various levels, e.g., providing straight funding, guaranteeing bulk membership pledges for their employees/members/students, guaranteeing events/training contracts for their employees/members/students, and/or providing real estate options for the building location. It costs about $2.5M - $3M to open a new TechShop.

Currently, TechShop is focused on opening locations in Phoenix, and Washington, D.C., which are cities where they have already formed a strong relationship with local companies/organizations/educational institutions. This is the path TechShop envisions for their future locations. For consideration of an aerospace focused TechShop at EFD, the initial part of the process is approaching TechShop with HAS and partners to enter into a partnership for bringing a franchise to the Houston area given the above criteria. In our survey discussions, they expressed keen interest in hearing about a proposal for a spaceport located TechShop at EFD.

JSC Makershop

The NASA JSC Makershop was established to provide NASA JSC Engineering Services Division and their supporting contractors an area in which to develop their structural concepts. It is a place for JSC civil servant and contractor engineers to materialize their early ideas for structural concepts in a prototype and collaborative environment without going through a formal review and approval process as they develop their next mission.

NASA JSC divisions provide seed funding, roughly $10,000 to $20,000 for engineers to 'prove' their structural concept in the Makershop. Once the concept/idea is approved by the requiring division; the next stage of development and implementation is either transferred to the Technology Division, or contracted out to a NASA JSC contractor to complete toward flight hardware status.

The NASA JSC Makershop opened its doors in November 2011, and is housed in a 6,000 sq. ft. WWII era motor pool garage/tin building #348, near the Space Center Blvd gate. The building is basically 2 rooms split 25/75. The smaller room serves as an office area, meeting/development/collaborative area with white boards/flipcharts, and this is where the laser cutter and 3D printer are housed. The larger room is where the machine and wood working shop operates. The NASA JSC Makershop is a small basic machine and wood working shop, made up mostly of surplus drill presses and lathes. They do have a laser cutter and small 3D printer. Most of the metal work is accomplished in other larger JSC Engineering Services Division buildings, with the finishing work of the structural concept being done in the Makershop.

Currently, the Makershop is only available to NASA JSC civil servants and supporting contractor engineers. However, we were informed that they are evaluating several concepts to allow the Makershop to be more open to a broader community. One of the concepts is to move the JSC fence line so that the Makershop would be more available to the general public.

An EFD / JSC Integrated Commercial Space Economic Development Plan described below in Section 7.3, provides further discussion regarding integrated usage of an EFD TechShop and the JSC Makershop.

7.1.1.3 Level III – GD EDGE R&D Center

Research & Development Environment

The EDGE® Innovation Network is a General Dynamics C4 Systems (GD C4 Systems) collaboration model where industry, academia, and non-profit organizations, along with government entities, collaborate in an open community environment to rapidly deliver new technologies and innovative capabilities. GD C4 Systems is the sponsor and owner of the EDGE® concept. It was initially designed to address new technologies in human factors and safety for war fighters and first responders and the platforms they utilize in the performance of their respective missions, but has since evolved to other industry focus areas, e.g., IT or space related technologies. The EDGE® Innovation Network is an international network with over 360 current member organizations. The Network is comprised of members, EDGE® Innovation Center facilities, and sharing of information via a Knowledge Management System (KMS), and periodic events. Its mission is to "create and maintain an open environment where members and customers can characterize, nurture, develop and deliver current and emerging technologies and capabilities to equip a more mobile, better connected and better informed end-user". NASA's Goddard Space Flight Center (GSFC) in Greenbelt, Maryland is the Network's newest partner organization.

EDGE® Space Innovation Center

The EDGE® Space Innovation Center is located just minutes away from NASA GSFC. The Center brings together industry, academia, non-profit and government organizations in the space community to collaborate and rapidly deliver new technologies and innovative capabilities. The Center supports space technology innovations across all space-oriented government entities including NASA, Air Force, Navy, National Reconnaissance Office (NRO), National Geospatial-Intelligence Agency (NGA), and National Oceanic and Atmospheric Administration (NOAA). Innovations may span from single algorithms and tools for integrating space-bound hardware to complex ground data systems and optical communication systems and their components.

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Table 7-C: EDGE® Network Locations

Scottsdale, AZ	South Wales, United Kingdom
Aberdeen Proving Grounds, MD	Ottawa, Canada
Seabrook, MD *	Orlando, FL
Ft. Bliss, TX	College Station, TX
Annapolis Junction, MD	Sterling Heights, MI
Leavenworth, KS	Taunton, MA
Quantico, VA	

SOURCE: EDGE® INNOVATION NETWORK

The EDGE® Space Innovation Center officially opened with a ribbon cutting ceremony on March 22, 2013. It is housed within the GD C4 System's Seabrook 11,700 sq. ft. facility. The EDGE®Space Innovation Center is the 13th and newest Network Center. Locations of the other 12 Network Centers are shown in Table 7-C. The GD C4 System office includes 36 employees of varying functional disciplines. The focus of this new center is for Space Explorers and the platforms that carry them to their operating environment. Members of the Space Innovation Center include GD C4 Systems, NASA GSFC, GDIT, CISCO, IBM, L3, Dell, SAIC, Microsoft, Motorola, Oceus Networks and Juniper Networks, and others. Membership has four different levels; Executive, Technology, Academic and Non-Profit, and Contributing and Business Service. Membership fees are based on size and status ranging from $0 to $50,000. Membership benefits are also based on membership level.

The GD EDGE® Innovation Network is a global collaborative environment between industry, government, non-profit organizations and academia. The Innovation Centers provide space and laboratories in which to stimulate collaboration and innovation. Since this is an international network, there are certain restrictions which apply to the flow of information between contributing members, participation, and input from domestic and international government agencies. Membership is guided by Federal Acquisition Regulations (FARs), International Traffic in Arms Regulations (ITARs), Arms Export Control Act (AECA) and a variety of US Federal Regulations. Benefits for non-US-based members may be limited in order to comply with U.S. export control regulations.

EFD EDGE® Aerospace Innovation Center

The GD EDGE® Innovation Network model is an extension, evolution, and advanced level of the Makerspaces and TechShops collaboration model. The EDGE® model is more of a 'think tank' for advanced R&D operations with access to test and research laboratories as a result of belonging to the EDGE® Network.

There is the potential for this environment to be of immediate support to Ellington Spaceport as a research and development testing ground for attracting an aerospace technology cluster at EFD.

HAS could establish as the center-piece of its R&D facilities, an EDGE® Aerospace Innovation Center within the EFD Spaceport infrastructure, which would lead to a synergistic and collaborative partnership with not only NASA JSC, but also with area Universities, aerospace companies, and non-profit organizations dedicated to the aerospace industry within the Houston area.

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7.1.1.4 Level IV – National Network for Manufacturing Initiative (NNMI)

Aerospace Manufacturing Environment

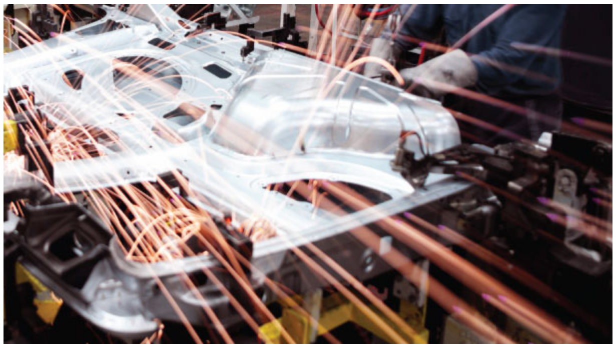

PHOTO SOURCE: PUBLIC DOMAIN

Closing the gap between R&D activities and the deployment of technological innovations all the way from invention to product development and process prototyping to manufacturing at scale, and then commercializing is the logical next level of activity for EFD to provide for in its facility development plan (the Level IV manufacturing innovation facility). Closing this gap is also a crucial competitive challenge to maintain manufacturing innovation in the global marketplace. Successfully mastering all the stages from lab to marketplace requires contributions from a large network of organizations; from suppliers of equipment, parts, and services to schools, colleges, and training programs to utilities and other infrastructure systems.

This challenge has been recognized at the national level as a threat to future prosperity. In the President's fiscal year 2014 budget, the Administration proposes creating a network of up to 15 regional Institutes for Manufacturing Innovation (IMIs). This network of manufacturing institutes is to be funded by a proposed one-time, $1 billion investment through the National Network for Manufacturing Initiative (NNMI). The President's proposed NNMI and the regional collaborations created are intended to deal with barriers to rapid and efficient development and commercialization of new advanced product and manufacturing-process innovations[8].

The NNMI program will be managed by the interagency Advanced Manufacturing National Program Office (AMNPO). Participating agencies include the Department of Defense, Department of Energy, Department of Commerce's National Institute of Standard and Technology (NIST), NASA, the National Science Foundation, Department of Education, and other agencies. To establish a regional IMI, a strong coalition between industry partners, state and local agencies, foundations, regional stakeholders, and others is required for co-investment with federal efforts[9].

The goal to establish a network of 15 regional manufacturing institutes will enable companies to collaborate and access the capabilities of research universities and other science and technology organizations to support scaling up innovative manufacturing and assembly processes. At the same time, the IMI's will help to meet the challenge of building the pool of high-skilled talent that advanced manufacturing requires.

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[8] Executive Office of the President, National Science and Technology Council, Advanced Manufacturing National Program Office; "National Network for Manufacturing Innovation: A Preliminary Design", January, 2013.

[9] Advanced Manufacturing Portal, http://www.manufacturing.gov/nnmi_overview.html, (Accessed April 10, 2013).

The common focus with each Institute is on integrating capabilities through collaborations at facilities designed and equipped to address cross-cutting manufacturing challenges, thereby finding solutions that have the potential to retain, expand, or innovate new industrial production in the United States.

The individual focus however, within each institute under the NNMI can have widely varying scopes, with each having a specific technology focus to leverage and expand the industrial, research, and institutional strengths of the region they serve. Each Institute will have a unique and well-defined focus area, such as an advanced material, a manufacturing process, an enabling technology, or an industry sector.

For example, the proof-of-concept pilot institute in Youngstown, OH, was competitively selected for establishing the National Additive Manufacturing Innovation Institute (NAMII). On 8/16/2012, an initial award of $30M in federal funding was matched by an additional $40M from the winning consortium. The consortium includes manufacturing firms, universities, community colleges, and non-profit organizations from the Ohio-Pennsylvania-West Virginia 'Tech Belt', including 40 companies, 9 research universities, 5 community colleges, and 11 non-profit organizations. The NNMI program currently has defined 3 additional institutes which they seek proposals for:

- Lightweight and Modern Metals Manufacturing Innovation (LM3I) Institute
- Digital Manufacturing and Design Innovation (DMDI) Institute
- Clean Energy Manufacturing Innovation (CEMI) Institute

The institutes will be designed for collaboration and maximization of shared infrastructural resources. The focus of each institute will be unique, determined through a competitive application process, but all IMI's will concentrate on adopting, refining, and applying promising emerging technologies. The proposing teams will be driven by the needs of the industries they serve and the opportunities created by new technologies within those industries.

Ellington Spaceport Aerospace Manufacturing Innovation Institute

The NNMI program can offer HAS a pathway toward its vision of the spaceport becoming a focal point for aerospace innovation. With establishment of an aerospace focused IMI at the spaceport, it can be a regional catalyst for attracting aerospace manufacturing and accelerating growth of an aerospace manufacturing cluster in Houston.

HAS should work in conjunction with industry partners, state and local agencies, foundations, universities, and others to assemble a team for proposing to the NNMI the establishment of an "Aerospace Manufacturing Innovation Institute" (AMII) to be located at the spaceport Research Park.

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7.2 Sustainability of an Open Source Collaboration Model

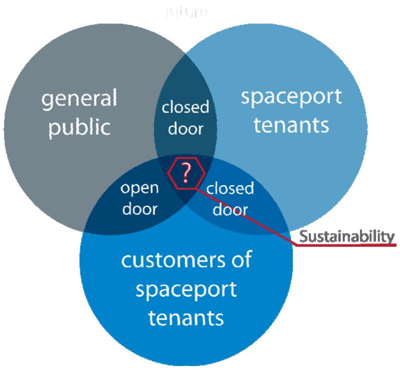


Figure 7-A: Managing Transparency

SOURCE: XSC, 2013

The Level 1 through Level IV research facility concept as laid out above implies an ever progressing level of collaboration complexity available to the spaceport users and tenants who avail themselves of these proposed spaceport facility resources. It also presents challenges to sustainability of an open-source collaborative environment discussed at the onset of this section of the report, beginning with the question of how to grow a culture of collaboration and innovation from the ground up at EFD?

With open-source collaboration, transparency is a key ingredient to innovation. This however, becomes particularly daunting within an aerospace culture traditionally bound by constraints of proprietary processes, ITAR, safety, mission assurance, etc. The arguments against viability of open source collaboration within the commercial aerospace industry go something along the lines of …the technology developers maintain tight control over who touches their hardware because of, 1) lack of industry standards which in turn allow independent mission assurance regimes; and 2) a high degree of vertical integration with developer/operators, where everything is done in-house.

Currently, the commercial spaceflight industry is in debate over the issues of how to ensure stringent safety measures are adhered to and to what degree mission assurance principals are employed, to the point of "if ever there is an accident due to shortcuts, the industry is going to be in real dire straits from which it may not recover". Some believe that "lip service" is being given to these issues since each company employs its own quality regime as they proceed to deploy their respective technologies. If this is actually the guiding principal how this industry gets rolled out, then it would stand to reason these companies are going to be really careful about who touches their machines. They know they are not going to do aerospace equivalent mission assurance, but in how they interpret the state of health of their systems, they are not going to let just any qualified mechanic touch their machine; they are going to take very good care that they remain in full control of their system and who has access to how it functions.

In the example of an EFD based spacecraft developer eventually operating from Ellington we have pointed out that in the current environment of the commercial spaceflight industry, spacecraft developer/operator's are extremely vertically integrated. The Spaceship Company, previously discussed in the User Needs Assessment, is the only company out there manufacturing hardware for anybody else. Everybody else is doing it themselves with their own people. Even in the case of the Spaceship Company which is building WhiteKnight2 and building Spaceship2, and will also build the carrier for Stratolaunch. There still exists the vertical integration issue with the Space Ship Company as well, because Virgin Galactic owns the Space Ship Company (much like in the way United owns Boeing), and they are not inclined to let just anybody touch their spaceship.

[Preliminary Draft for Discussion Purposes Only]

7.2.1 EFD COLLABORATION MODEL

So if the goal is to create a commercial spaceport for the 21st century which taps into the potential of community-oriented innovation, there will need to be a way to manage the two cultures of traditional closed aerospace processes and the new generational paradigm of openness, sharing, and collaboration. We can do so by making *"an active and adaptive spaceport culture"*.

To fully understand what this means, this study began investigating a framework for how an open-source collaboration model could be managed at Ellington. Although not necessarily within the study scope, we develop a preliminary model. Describe below are the basic premises of the model. We recommend HAS continue development of a management plan based on the basic premises of the EFD collaboration model.

Product Invention Management

At first a product is something which consists of raw materials and the ingenuity of the sole inventor, or collection of inventors, who will eventually work to bring the spark of imagination to life. As the aerospace product evolves, the raw materials used to create it are only as valuable as the quality of collaboration, inventiveness, and discipline used to convert the raw materials into the final product. As it evolves, the collaboration, inventiveness, and discipline used to create the product become embodied within it, reflected in its final form and the way the product functions under the extreme conditions of space flight.

Regardless of whether the product fails as soon it leaves the manufacturing line, or it performs admirably time and time again, the ingredients of that product's creation will be reflected in the product's performance. In the hostile environment of space the ingenuity of the product is put to the test. Inventiveness and collaboration are not enough. We need discipline to ensure the high level of product quality capable of withstanding the demands of a rapidly growing commercial space flight industry.

The graphic in Figure 7-B expresses the relationship between the evolutions of an aerospace product and the way collaboration, inventiveness, and discipline combine to move that product forward toward a healthy completion when utilizing the Level 1 – Level IV spaceport collaboration facilities.

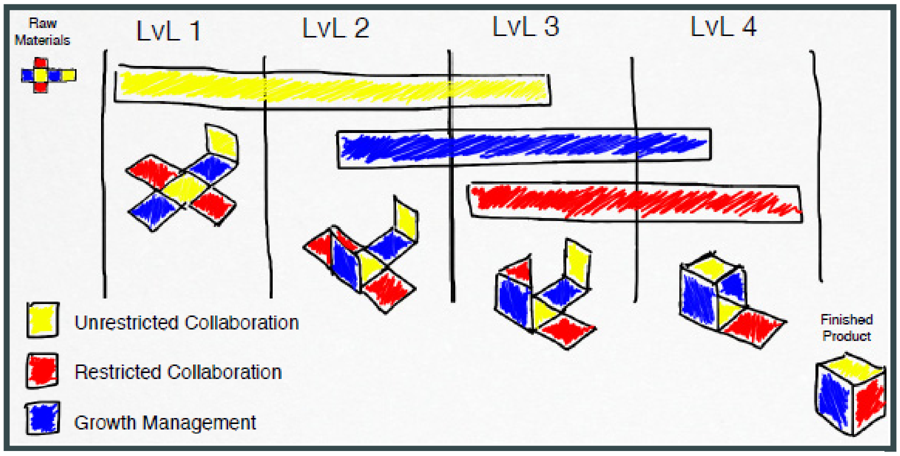


Figure 7-B: Level 1 – Level IV Facility Collaboration Model

SOURCE: XSC, 2013

Restricted collaboration has an inherent level of quality assurance built into it. But it requires the free-license of unrestricted collaboration to drive innovation. Growth management then becomes the middle ground between unrestricted and restricted collaboration. It ensures the healthy growth of the product, but beyond that, it provides the level of transparency needed to shape the overall culture of innovation as this culture pushes aerospace products out overtime.

Facility Flow of Product Development

The path of entrance for users of EFD research facilities whether they be to test out ideas to tinker with, or R&D discoveries to productize, or manufacturing of products to commercialize is not necessarily a linear process, (although it can be), when utilizing the Level 1 – Level IV spaceport collaboration facilities.

A member user or entrepreneur should be able to inject their project needs at any facility level depending on the fidelity/maturity of the project, or level of collaboration required. Depicted in Figure 7-C**,** is a flowchart of how products/concepts could migrate and be managed through the EFD facility levels.

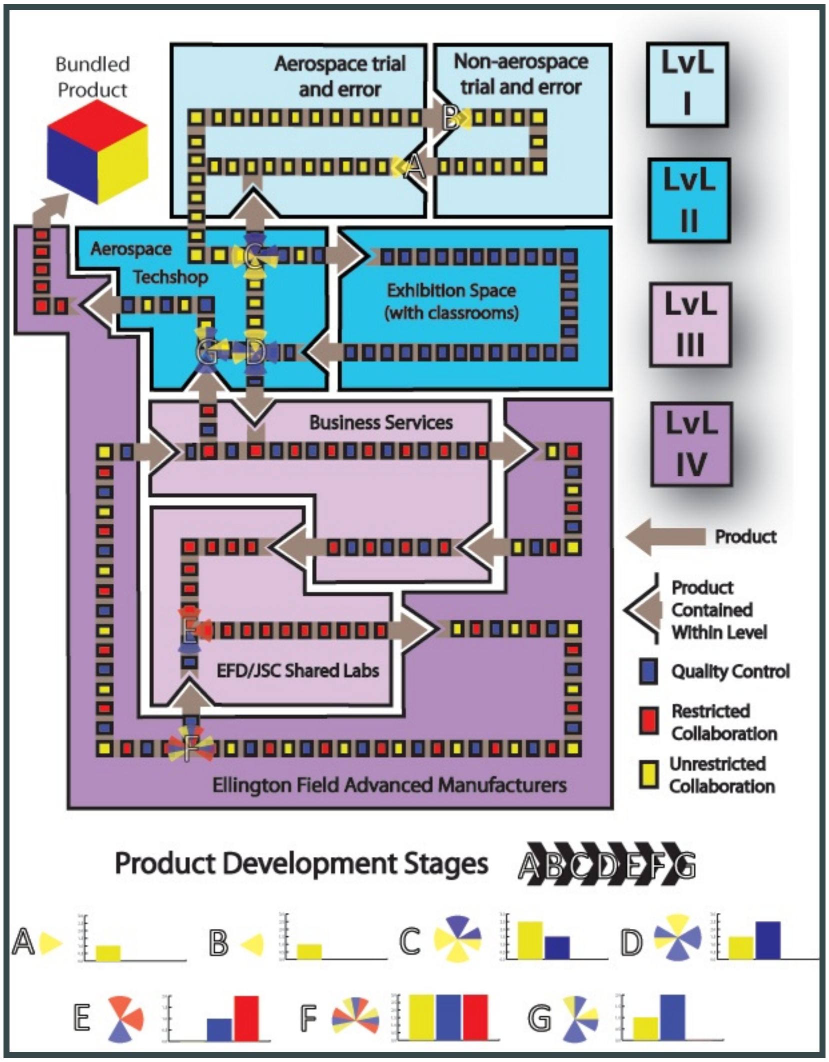
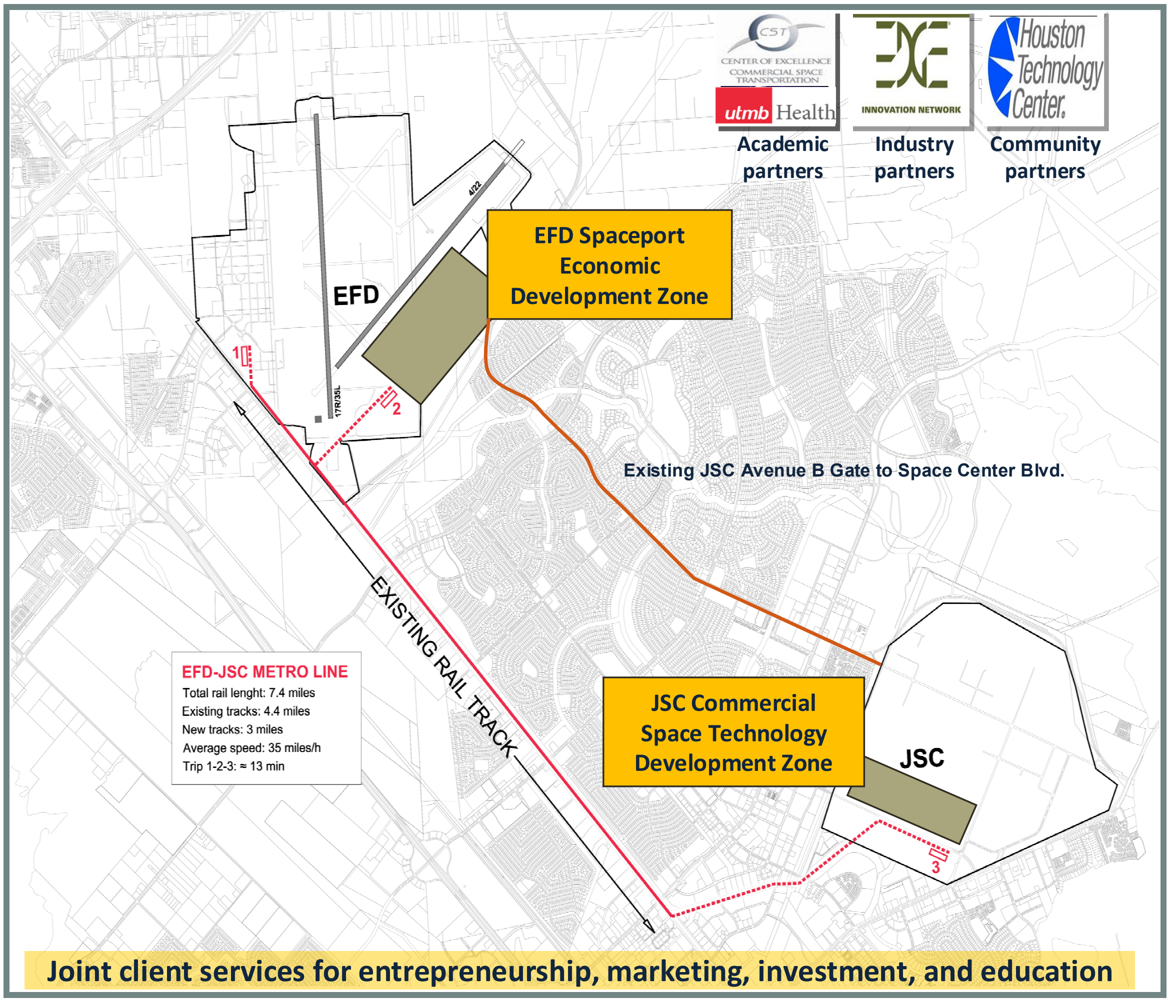


Figure 7-C: EFD Spaceport Research Park Product Development Flow

SOURCE: XSC, 2013

7.3 EFD / JSC Integrated Commercial Space Economic Development Plan

Adjacent to the parcel of land where the spaceport will be located is the NASA Johnson Space Center (JSC) Sonny Carter Training Facility (where astronaut training takes place for neutral buoyancy operations to simulate weightlessness). The main JSC campus is approximately 3.5 miles away and physically connected to EFD by roadway with Space Center Blvd. from JSC Avenue B gate to the spaceport's proposed entrance point shown in Figure 7-D. This regional powerhouse of science and technology convergence provides EFD customers, users and operators a local available resource unmatched in few communities across the globe.



Joint client services for entrepreneurship, marketing, investment, and education

Figure 7-D: Collaborative and Physical Connections between EFD and JSC

SOURCE: XSC, 2013

Both HAS and JSC have an interest in fostering commercial spaceflight through creation of dynamic and successful environments for cutting edge research. Opportunities for development and strengthening EFD/JSC collaboration have been pointed out in the Level I – Level IV spaceport Research Park facilities discussion. In parallel to development of the spaceport Research Park, JSC has an ongoing effort for fostering development of commercializing its space technologies. It has partnered with the Houston Technology Center (HTC) to open a new Acceleration Center at JSC[10].

The purpose of this joint effort between HTC and JSC is to foster collaboration and development with academia, aerospace and non-aerospace industries, other federal agencies, and the public by incubating and accelerating the growth of emerging technologies. The plan is to work with small to mid-sized technology companies to help them commercialize new technologies, drawing on expertise in the NASA/JSC community. The focus is to help entrepreneurs who have ideas for new space technologies "spin in" their ideas to JSC and help "spin out" and license JSC technologies for use in other industries.

> ***The synergy between the goals of HAS and JSC can be maximized by integrating their respective plans for commercial space economic development.***

The basic plans for these two initiatives are compared in Table 7-D. An integrated commercial space economic development plan could also institute joint client services for providing training and/or access to entrepreneurship and start-up needs such as marketing, investment, and education. These services would further integrate collaboration between the two institutions.

Table 7-D: Integrating EFD /JSC Goals for Commercial Space Economic Development

JSC SPACE TECHNOLOGIES INCUBATOR/ACCELERATOR FOR COMMERCIAL SPACE START-UPS	EFD RESEARCH PARK FOR COMMERCIAL AEROSPACE TECHNOLOGIES R&D AND MANUFACTURING FACILITIES
• Spins out JSC developed technology for licensing and commercializing through HTC accelerator	• Taps into the potential of community-oriented innovation and provides access to research facilities
• Provides Level II Makershop facility open to civil servants and contractors to prototype concepts prior to formal acceptance by Engineering Directorate	• Provides Level I Makerspace & Level II Aerospace TechShop facilities open to general population innovators, inventors, & entrepreneurs
• Spins in transfer of technologies developed outside of NASA and through the joint development of new technologies by NASA in conjunction with its partners in private industry and the universities	• Provides Level III R&D Aerospace Innovation Center for NASA/Industry/Academia partnership for commercial spaceflight technology areas
• As start-up companies mature and ready for manufacturing phase, transitioned off-site to operate (at EFD)	• Operates aerospace manufacturing innovation institute, and provides manufacturing facilities and lease space
• Provides access to expertise and intellectual capital within the NASA/JSC community	• Provides access to suborbital and orbital space through spaceport operations

SOURCE: XSC, 2013

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[10] Houston Business Jounal: "NASA's Johnson Space Center Looks to Prove Long-term Relevance in Houston", posted Apr 12, 2013, http://www.bizjournals.com/houston/print-edition/2013/04/12/nasas-johnson-space-center-looks-to.html?page=all (accessed 5/31/2013)

Equally important is to connect the resources of these two initiatives and their opportunities to students to add relevance to existing Science, Technology, Engineering, and Mathematics (STEM) programs by helping students become more aware of STEM applications. Interdisciplinary thinking with programs that address the intersection of STEM education and entrepreneur education should be encouraged.

7.4 Point-to-Point Technology Research

POINT-TO-POINT TRANSPORTATION

Future transportation of cargo or humans between different locations

Point-to-point (P2P) transportation is the "holy grail" of suborbital spaceflight. Compared to conventional air transportation, suborbital P2P transportation offers the potential for significant reductions in travel time on long-distance flights. A flight from Houston to Abu Dubai for example, could be done in less than 2 hours[11]. Long distance P2P however, is unlikely to be realized for at least another decade. Vehicle development timelines are projected to range from 10 to 12 years for a jet/rocket based system and 15-20 years for a combined cycle system. Our analysis of the current status of P2P technology development can be found in 10.Appendix D.

Technology challenges are principally in areas of operability, long life, reliable operations and systems technology integration. Spaceport operations, ground systems and infrastructure development for spaceport city pairs are additional challenges. Development of the destination spaceport is assumed concurrent with the originating spaceport. An EFD conversion to accommodate international P2P flights also requires use or conversion of another spaceport. HAS should determine and explore candidate destination spaceport(s) for similar considerations and jointly sponsor the appropriate studies for technical and economic feasibility.

The operational and technology challenges for long distance P2P flight present an opportunity for EFD to establish itself as a location whose focus is on enabling point-to-point technology research.

7.4.1 LEVERAGE JSC AND UTMB FOR SUBORBITAL P2P TRANSPORTATION RESEARCH

In section 7.1, we discussed the attributes of establishing a Level III R&D Aerospace Innovation Center for NASA/Industry/Academia collaboration in commercial spaceflight technology. EFD could be very specific in the focus area of research this facility pursues by encouraging research that "pushes out" P2P technology readiness levels. By leveraging JSC technical capabilities and other Houston area academic and industry assets

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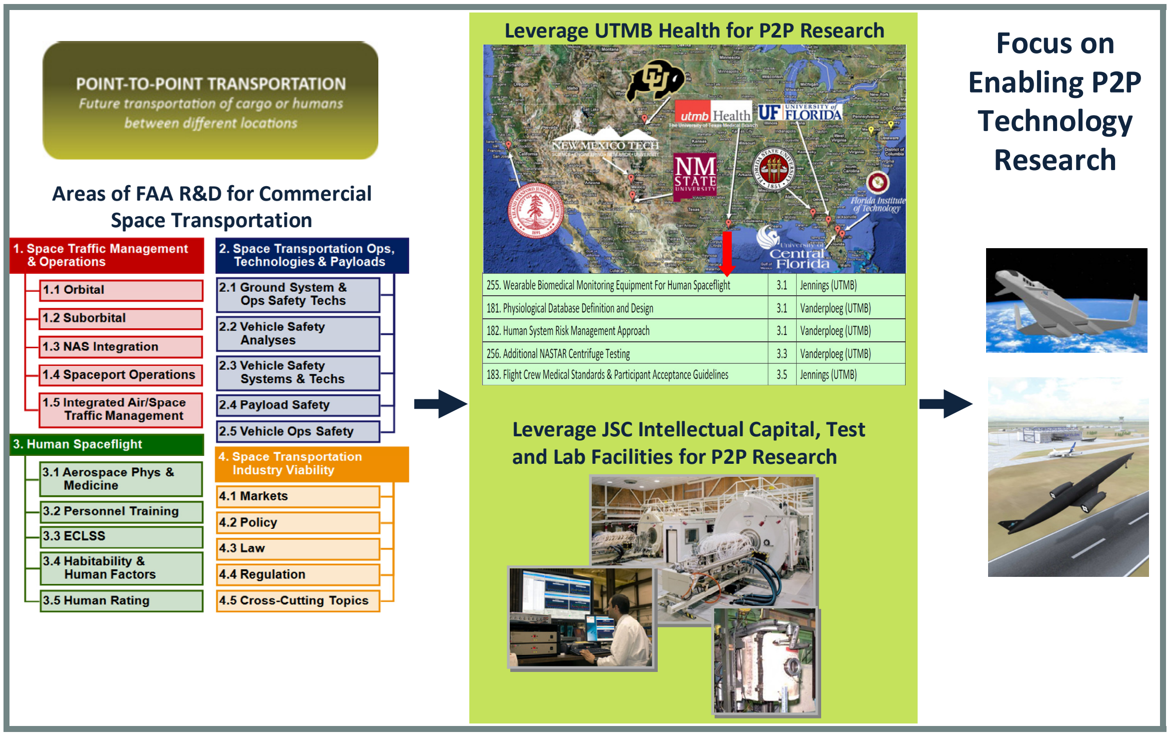
[11] Short distance P2P CONUS flights from Houston do not seem feasible. Our initial analysis indicates P2P within the continental U.S. (CONUS) from Houston imply a small door-to-door time differential compared to competing same day transportation services. Price premium and limited initial routes will make a business case for a CONUS-based capability from Houston extremely challenging to close. Coast-to-coast CONUS (e.g. NY and LA) are most desirable spaceport locations from a CONUS flight capture perspective. Houston as a hub for international P2P city pairs however is a viable market option to pursue.

such as the University of Texas Medical Branch at Galveston (UTMB) membership in the FAA's Center of Excellence program, the spaceport could be well positioned to become a cluster for P2P technology research.



255. Wearable Biomedical Monitoring Equipment For Human Spaceflight	3.1	Jennings (UTMB)
181. Physiological Database Definition and Design	3.1	Vanderploeg (UTMB)
182. Human System Risk Management Approach	3.1	Vanderploeg (UTMB)
256. Additional NASTAR Centrifuge Testing	3.3	Vanderploeg (UTMB)
183. Flight Crew Medical Standards & Participant Acceptance Guidelines	3.5	Jennings (UTMB)

Figure 7-E: Positioning EFD for Point-to-Point Technology Research

SOURCE: XSC, 2013 (IMAGES FROM FAA, NASA, ROCKETCRAFTERS, SKYLON)

FAA Center of Excellence for Commercial Space Transportation

The FAA Center of Excellence (COE) program was established in 1990. Nine COEs have been established by the FAA including the Center of Excellence for Commercial Space Transportation (COE CST). COEs are intended to be a 10-year partnership of academia, industry, and government to create a world-class consortium to address current and future challenges for commercial space transportation. The three main goals of every COE include research, training, and outreach[12]. A unique attribute of the COE program is the one-to-one matching requirement for every federal dollar granted to a COE university. The matching requirement can be satisfied through direct or in-kind contributions from any non-federal funding source, including industry, universities, or state and local government organizations.

The FAA Office of Commercial Space Transportation (AST) sponsors the COE CST. The research of the COE CST conducted within FAA AST is broken into four major research areas and sub-areas shown in Figure 7-F.

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[12] Year 1 Annual Report, Federal Aviation Administration Center of Excellence for Commercial Space Transportation, December 2011.

These areas of research are well within the expertise and experience base of the Houston aerospace community, and its relevant test and lab facilities infrastructure. UTMB and JSC are but two examples of community assets available to EFD for focusing its technology research on tackling the challenges of suborbital P2P spaceflight.

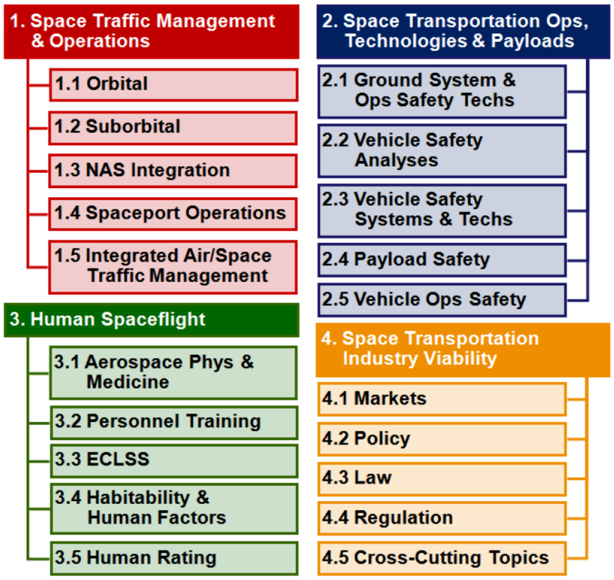

Figure 7-F: FAA AST Areas of Research

SOURCE: FAA AST, 2011

UTMB: UTMB is a member university in the COE CST along with eight other member universities. Combined, the nine universities bring over 50 other government, industry and academic organizations as research partners. UTMB has a long history of medical support and human spaceflight physiological research with NASA. This is complemented by more recent involvement in the commercial orbital and suborbital spaceflight industry supporting space flight participant visits to the ISS and preparation of passengers and crew for suborbital space flights.

NASA JSC: JSC provides EFD with next door access to one of the nation's preeminent engineering, test, and laboratory complexes. With the dismantling of the Shuttle program, JSC has excess technical capabilities and capacities to provide. Table 7-E maps the critical P2P technology need to relevant directorates or test labs available at JSC to support P2P research and technology development at EFD.

Table 7-E: Point-to-Point Technology Need Matched to JSC Capability

TECHNOLOGY AREA	JSC CAPABILITY: LAB/TEST ENVIRONMENT/ DIRECTORATE
Propulsion	JSC Engineering Directorate - Energy Systems Test Area
Thermal Protection & Management	JSC Engineering Directorate - Radiant Heat Testing
Vehicle Design & Structure	JSC Engineering Directorate - Structures Test Laboratory
Communications	JSC Engineering Directorate -Communication Systems Simulation Laboratory (CSSL)
Guidance, Navigation & Control (GN&C)	JSC Engineering Directorate - Advanced GN&C Development Laboratory
Reliability	JSC Engineering Directorate - Relex Reliability Prediction Tool
In-Flight Safety/Crew and Passenger Safety	JSC Flight Crew Operations Directorate
Space Radiation	NASA Space Radiation Analysis Group at JSC
Space Debris	NASA Orbital Debris Program Office at JSC.
Pilot & Crew Requirements	JSC Flight Crew Operations Directorate / JSC Mission Operations Directorate
ECLSS	JSC Engineering Directorate / JSC Mission Operations Directorate

SOURCE: XSC, 2013

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7.5 Spaceport Model Schematic

Our proposed model for Ellington Spaceport is an integrated aerospace research and development environment for collaboration and innovation at all levels of community involvement. The Level I – Level IV facilities concept provides users access to the testing and development of ideas and hypothesis at all phases of project development; from entry level trial and error testing, to rapid prototyping and development with access to flight opportunities for testing or operation in space, and eventual product manufacturing. Aligning the transition of Ellington Spaceport with NASA JSC as a key partner creates unique opportunities to promote scientific discovery and technological development. Figure 7-G depicts a schematic overview of this model of internal and external collaboration nurtured by services for promoting entrepreneurial endeavors.

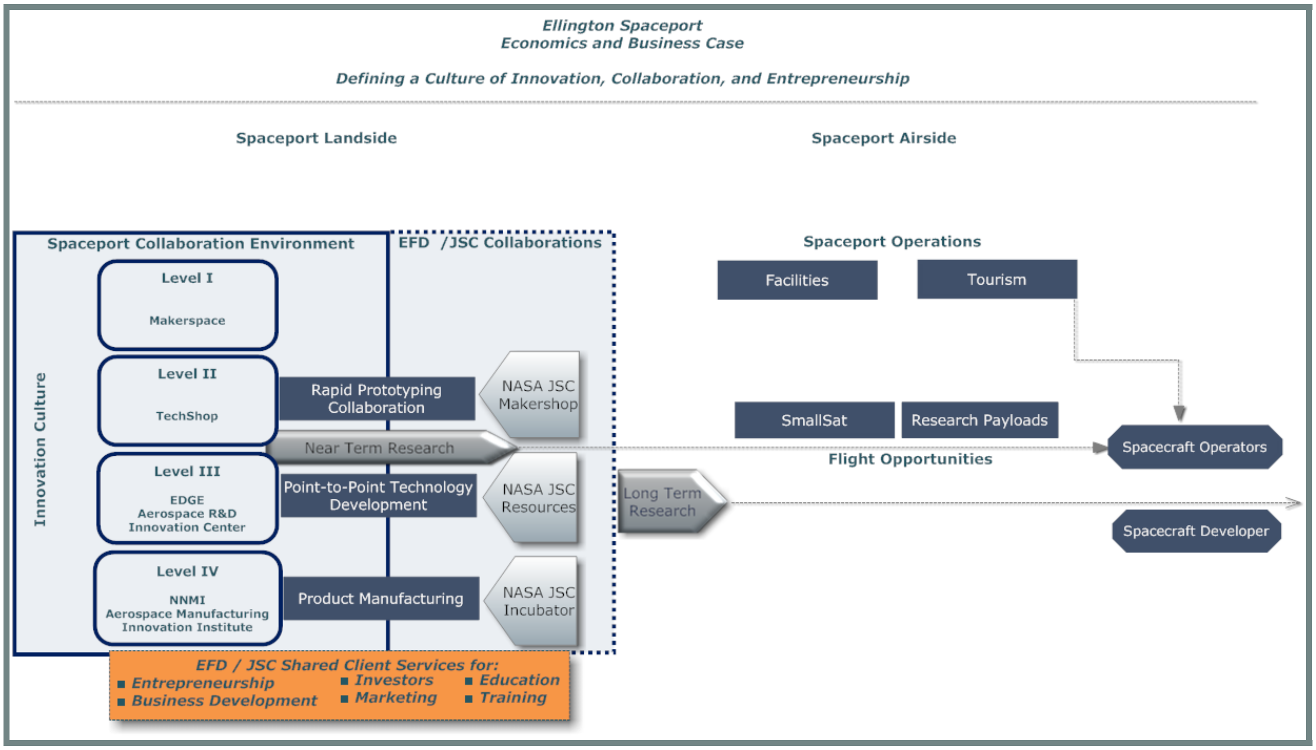

Figure 7-G: Spaceport Model Schematic

SOURCE: XSC, 2013

The schematic places a focus on P2P research and technology development for EFD, and we propose that EFD cultivate a reputation for P2P technology development, but not necessarily exclusive to other aerospace research in general.

Key aerospace engineering activities to name a few could include: component and composite development and fabrication; and space vehicle assembly. Commercial activities could include: zero-gravity scientific and medical experiments; microsatellites; astronaut training and development; and space tourism.

7.6 Case Studies

Apart from the spaceport facilities airside operations, the spaceport development area is essentially a mix-use development project. During the course of this study, common physical characteristics of planned developments were identified and compared against potential additional features under discussion for development of the EFD site as shown in Table 7-F. These added features further define the spaceport in terms of the spaceport operations, the R&D and manufacturing park, and additional mixed use characteristics. Three case studies of technology hubs were also assessed to discover any lessons learned, or aspects of what makes them successful or not successful, as applied to Ellington Spaceport for technology park developments.

Table 7-F: Common Features of Planned Developments

COMMON PHYSICAL CHARACTERISTICS OF PLANNED DEVELOPMENTS			PORT SAN ANTONIO (INDUSTRIAL PARK)	BROOKS CITY -BASE (HYBRID MODEL)	ONE NORTH (HIGH-TECH PARK)	ELLINGTON SPACEPORT (HYBRID MODEL)
Activities		Workforce Training	√		√	√
		Trade School / College / University	√	√	√	√
		Built Environment Encourages Collaboration			√	√
		Operational Support Encourages Collaboration	√		√	√
		Light Industrial	√	√	√	√
		Heavy Industrial	√	√		√
		Community Makerspace / Workshops				√
		Research & Development Centers			√	√
		High-Tech Enterprises	√		√	√
		Boutique Retail Store Fronts		√	√	√
		Restaurants / Mobile Food Vendors			√	√
		Entertainment / Leisure / Public Activities		√	√	√
		Residential	√	√	√	
		Hotel / Conference Center			√	√
Transportation	Rail	Light rail – access to off-site network			√	√
		Heavy Rail – on-site, or access to off-site network	√			√
	Mode	Automotive	√	√	√	√
		Aeronautic	√			√
	Green Network	Designated Bicycle Lanes			√	√
		Interconnected Sidewalk System			√	√
		Traditional Parks	√		√	√

SOURCE: XSC, 2013

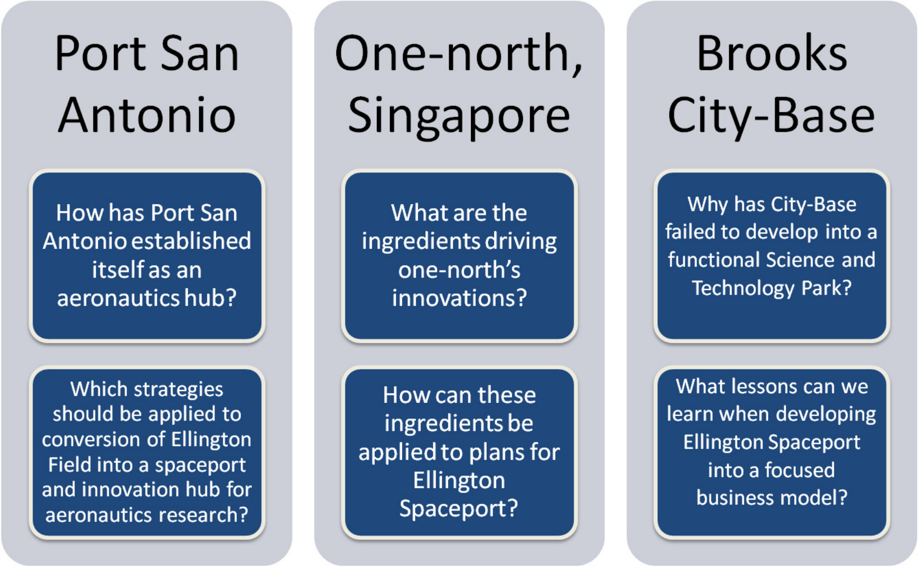

Figure 7-H: Relevant Case Study Questions

SOURCE: XSC, 2013

We examined two BRAC (Defense Base Closure and Realignment Commission) cases located in San Antonio, TX, and a technology park located in Singapore. The BRAC bases we analyzed are Kelly AFB (now Port San Antonio) and Brooks AFB (now Brooks City-Base). Each BRAC project exhibits aspects comparable to the proposed spaceport project site. The One-north development is a 494 acre technology business park in Singapore developed to house R&D and high technology activities in the biomedical sciences, information communication technology, and media industries with the basis of creating a "global talent hub" and a knowledge-based economy. In performing the case study analysis relevant questions translatable to EFD were identified. Figure 7-H describes the relevant questions of the case study approach.

7.6.1 PORT SAN ANTONIO

Because of the inherent value of Kelly's infrastructure, facilities, personnel, and a more directed leadership, results of the analysis revealed Kelly AFB to have undergone a much smoother transition to its new commercial use than Brooks City-Base. When transferred to civilian control, Kelly maintained itself as a highly industrialized aeronautic facility with multimodal transportation capabilities. Immediately, this proved to be the foundation for maintaining a sustainable business model for the port, and improving connectivity among its different functions overtime.

Since Kelly AFB was sold to the City of San Antonio in the late nineties, the development authority of Port San Antonio, as designated under the parameters of BRAC, has built off existing facilities while simultaneously adding other functions to meet shifts in regional dynamics. For instance, to meet increasing demand for services tied to natural gas projects in the Marcellus Shale, a tenant of the port required expansion of the railways on-site by four hundred percent. With a multimodal transportation network of rail, road, and air in place, and the logistics to tie it all together in a designated Free-Trade Zone, the benefits of increased rail capacity is obvious. Commercial enterprises are provided with a multimodal transportation model, and become capable of adapting to changes in the economic landscape with greater proficiency. The challenge for a tenant of the port becomes balancing the simple mathematics of rail, air, or road.

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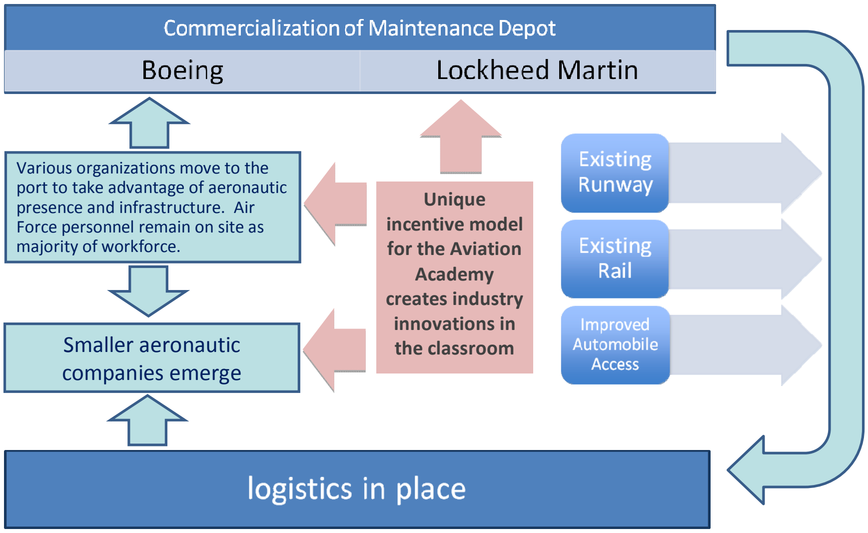

Figure 7-I: Port San Antonio Development Strategy

SOURCE: XSC, 2013

Air support has come naturally to the Port as existing aeronautic facilities were upgraded to meet demand of commercial customers. The aerospace industry presence comprises 31 percent, or roughly 4,000 of the jobs at the port. Companies such as Boeing and Lockheed Martin have remained long-term tenants. Together, those companies provide over half the aerospace jobs at the Port. Boeing alone employs 2,000 local workers, with an estimated expansion of over 400 by 2014. To add to the economic benefit for the city, recent expansion of leasable land with runway access could add an additional 4,000 jobs to the area.[13] Just as the rail expansion has benefited commercial activity at the port, so will expansion of the runway.

The presence of aerospace companies trickles down. In relying on developments of the private aerospace businesses, the Air Force retains a presence on site, which translates to over 6,000 jobs, or 50 percent of the workforce at Port San Antonio. Four percent of jobs go to government support and 3 percent to logistics. An additional 12 percent of jobs arise from the various types of companies servicing the larger port community. It is important to note that the average wage of a worker in Port San Antonio is over twice that of the average wage of someone working in the greater San Antonio Metropolitan area.

A 2007 economic impact analysis conducted by the University of Texas at San Antonio revealed Port San Antonio to have an overall economic impact of 2.5 billion dollars, bringing approximately 17,000 jobs to the city. A year later, with added Boeing facilities and a shift in Air Force personnel on-site, the port's impact increased to 3.3 billion dollars and 22,763 jobs.[14]

Figure 7-I above diagrams contemporary proof of the importance of local economic health outlined in the Port's Master Plan. This is evident in the port authority's involvement with local educational institutions. In the spirit of the master plan's community-building aspects and focus on developing the aeronautics industry, the port has worked with St. Phillips Community College to provide educational outreach for youth interested in working with the aerospace industry.

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[13] Port San Antonio, *Who We Are and What We Do*: March 20, 2013 http://www.portsanantonio.us/StoreImages/collateral/who%20we%20are.pdf, (accessed May 16, 2013)

[14] Welch, Creighton A., *SA reaping billions from Port San Antonio*, SA Express News: 05/2/08

Through St. Phillips, the Alamo Academies program of Alamo Colleges has maintained a steady presence on the port through its Aerospace Academy. The program of the academy allows high school students to take coursework in aeronautics in addition to receiving direct on-the-job training through a number of companies operating on-site. A recent sale to the college of 30 acres of land and a 40,000 square foot facility attests to the healthy relationship between the community and the port.[15]

CASE STUDY RELEVANT QUESTION: *How has Port San Antonio established itself as an aeronautics hub?*

- Built off existing aeronautic resources to attract the key anchor tenants: Boeing and Lockheed Martin.
- Maintained much of existing federal workforce and the experience and knowledge they brought to the table.
- Enhanced transportation resources and logistics for all companies.
- Through the Aviation Academy, educational opportunities for the local population are linked with on-the-job training at port companies.
- Initiated a free-trade zone to encourage international trade.

CASE STUDY RELEVANT QUESTION: *Which strategies should be applied to conversion of Ellington Airport into a spaceport and innovation hub for aerospace research?*

- Ensure spaceport research facility Levels I, II, and III collaboration occurs at Ellington, to nurture organic growth of culture of collaboration and innovation.
- Enhance communications and physical connectivity between groups involved in different phases.
- Brainstorm incentives for manufacturers, most notably a tax break for providing on-the-job training and educational outreach to the general public interested in the spaceport, but also people involved with the different phases of the spaceport.
- Provide logistical and operational support for all parties involved in the spaceport and EFD/JSC initiatives.

7.6.2 ONE-NORTH, SINGAPORE

The One-north development is strategically positioned in the heart of Singapore, and is designed to host a cluster of world-class research facilities and business park space. The focus is on supporting growth of Biomedical Sciences, Information Technology, Media, Physical Sciences and Engineering. One-north's overall plan combines educational institutes, residences and recreational amenities with research facilities and business park space, in a work-live-play-learn environment, where multi-national talent, ideas and business opportunities are nurtured by leading scientists, researchers and "…technopreneurs from around the world".

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[15] Port San Antonio, *Building Futures: 2012 Year in Review*,

http://www.portsanantonio.us/StoreImages/collateral/annual%20report2012.pdf, (Accessed May 16, 2013)

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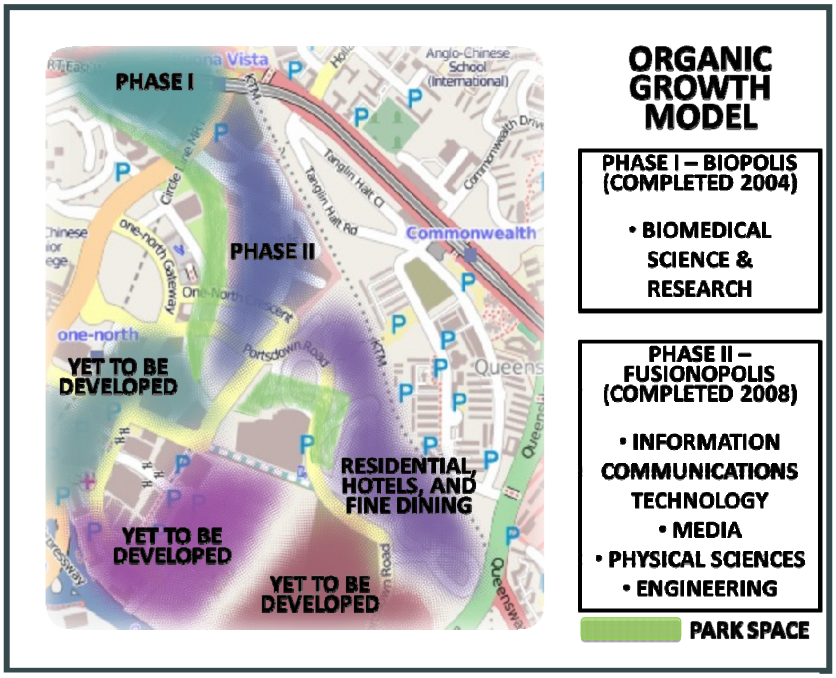

Figure 7-J: One-north Planned Development Areas

SOURCE: ONE-NORTH, SINGAPORE

One north is being developed progressively in several phases, over a period of 20 years. Officially launched in 2001, it is widely considered a successful planned development.

The Phase I Biopolis development is a biomedical R&D hub at one-north. It houses public research institutes and private research organizations. Biopolis was developed in three sub-phases beginning in 2001-2004. Now complete with infrastructure and services catering to biomedical R&D activities, basic clinical research, and medical technology research.

The Phase II Fusionoplis development at One-north is an R&D hub for information technology, media, physical sciences and engineering industries. Fusionopolis is the first work-live-play-learn development in One-north. Opened in October 2008, it houses public agencies such as A*STAR as well as private companies to foster collaborations across industries, research institutes and businesses. Additional sub-phase development provides for dry and wet laboratories, clean rooms and vibration sensitive test-bedding facilities, and a business park and laboratory space to house agencies and companies for collaborative endeavors.

A*STAR is public-private organization that merges R&D capabilities with academia and commercial industries. It uses it presence at One-north to maximize capabilities for providing advanced workforce training, incubation funds, research funds, and a wide array of business consultation services to One-north members.

CASE STUDY RELEVANT QUESTION: *What are the ingredients driving One-north's innovations?*

- An organic growth model allows One-north to adapt to market changes and the shift in internal dynamics of the organizations there.
- The linear park system, connection to the nearby metro rail, and close proximity to the University of Singapore allows for ease of access to on and off-site resources. The close proximity of facilities, and the corridors between them, uses connectivity to spur collaboration.
- A*star is a public-private collaboration that works between the government and all the different organizations of One-north. It does many things, including upgrades to R&D facilities, workforce training classes, connecting businesses with university resources, and access to funding for startups and existing clients of One-north.

CASE STUDY RELEVANT QUESTION: *How can these ingredients be applied to plans for Ellington Spaceport?*

- Having the Level I – Level IV innovation facilities operate under an organic growth model allows for the role of each to adjust to the changing character of the spaceport as it forms its identity over time.
- Treat innovative ideas/projects at the Level I and Level II facilities as one group, and Level III and IV facilities as another. When separated as such, there exists a greater potential for substantive collaboration at the outset. Once ideas at the Level I Makerspace are reworked at the Level II TechShop, they can be given another dose of originality at the Makerspace before being finalized and pushed onto a Level III R&D effort where their functionality is put to the test in a real-world scenario before going into production, or being reworked in Levels I, II, or III.
- Slowly expand work areas to force collaboration through increased density, and also generate ideas for how to appropriately develop unused areas.
- An integrated approach to logistical and operational support of activities at the spaceport will need to be comprehensive enough to solve multiple problems while also fostering innovation. A management organization that functions much like the A*star to coordinate business services and nurture ideas and business opportunities should be adopted.

7.6.3 BROOKS CITY-BASE

City-Base has led to positive developments for San Antonio's Southside, but it is not taking shape as a planned development should. For that, its future is uncertain. For a large planned development of its size, a clear and executable vision is necessary to ensure long-term sustainability.

Brooks AFB, with its runway removed years before being slated by BRAC for closure, and with no rail access to attract tenants, was not able to realize the highest and best use obtained when it was a center for aeronautic activities. Without the transportation infrastructure in place to provide efficient use of its 1,200 plus acres, and a large amount of its acreage remaining undeveloped, the opening sentence of its 2011 Annual Report, "Brooks City-Base has truly recognized its economic renaissance during the 2011 fiscal year," appears to be a dubious claim.[16]

The Brooks Development Authority has made progress, enhancing the natural beauty of City-Base by creating riparian habitats, attracting several anchor tenants, including two educational institutions, reconstituting its residential neighborhood, building a sizable apartment complex, attracting dozens of retail giants along its Northwest border, and completing drainage and road enhancements, but the overall "master-planned" component of the City-Base idea has not come to life as the Port San Antonio one has. The Port functions as

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[16] Brooks Development Authority, *An Economic Renaissance: Redeveloping San Antonio's Southside*

http://www.brookscity-base.com/about-brooks-city-base/annual-reports/, (Accessed May 16, 2013) a unified whole. It would be easy to call City-Base a success, but existing enterprises and infrastructure lack the functional relationship which makes for a structured business model based on the strategic practices a master planned community of that size must live by. The relationships among the elements of City-Base exist arbitrarily in relation to the concept as a whole. Based on the nature of what they do, the graphic in Figure 7-K, expresses the dissimilar nature of the tenants of City-Base and how that fact reveals an incomplete business model.

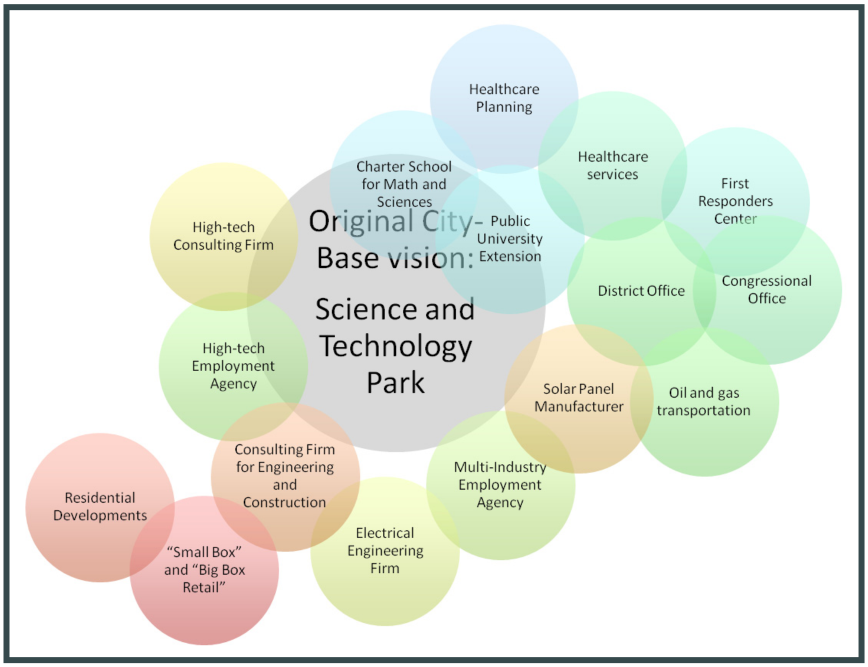

Figure 7-K: City-Base Disparate Development Growth

SOURCE: XSC, 2013

City-Base does give back to the area, for in 2011, according to the Annual Report, it provided an economic output of 1 billion dollars. But inspection of the whole park suggests the majority of this output was generated from the "big box" retail area on the fringe of the site: something exclusive of the core development model. In passing beyond the retail area, and driving through the entire City-Base, facilities appear fragmented, especially the northwestern portion containing the campus of the former School of Aerospace Medicine. The campus is abandoned for all but a small contingency of first responder personnel. The nearby gate is sealed and the original barbed-wire fencing is still installed along the northwest boundary of the property. Examining success of the transition from Kelly to Port San Antonio highlights the importance of retaining functional relationships among the different parts of a large, master-planned development. The inability of City-Base to form into a cohesive whole over time stems from the relationship between its large size and accessibility to transportation modes.

CASE STUDY RELEVANT QUESTION: *Why has City Base failed to develop into a functional Science and Technology Park?*

- Growth model incompatible with resources: By failing to subdivide the 1,200 plus acres of City-Base into pockets of phased growth, (in order to encourage an organic growth model of innovation and collaboration through physical proximity), early City-Base leadership chose a development model better-suited to the type of facilities and infrastructure available to the development authority at Kelly AFB.
- Failure to differentiate between military and commercial organizational structure: A mission parameter was enough to facilitate collaboration among the fragmented facilities of Brooks Air Force

Base, but due to the protective nature of private enterprise, innovation at a foundational level is best initiated through proximity and shared resources, such as incubator spaces and unique funding mechanisms.

CASE STUDY RELEVANT QUESTION: *What lessons can we learn when developing Ellington Spaceport into a focused business model?*

- Understand how the different pieces of the spaceport might change overtime as a result of decisions made at an early juncture.
- As the spaceport is being planned, understand obstacles that might jeopardize healthy relations between NASA JSC and the spaceport due to differences between the operational structure of each, and the way varying access to resources might impact the effectiveness of collaboration.
- Develop strategies for resolving the possible problems.
- Form a solid understanding of how the various components of the spaceport interact, and what a hopeful outcome of an interaction might be. Understanding the inner workings of NASA JSC in this regard would also help the mission of the spaceport.

7.6.4 INTEGRATION OF CASE STUDIES INTO SPACEPORT PLAN

Figure 7-L illustrates results of lessons learned from the case studies for integration into the spaceport development plan.

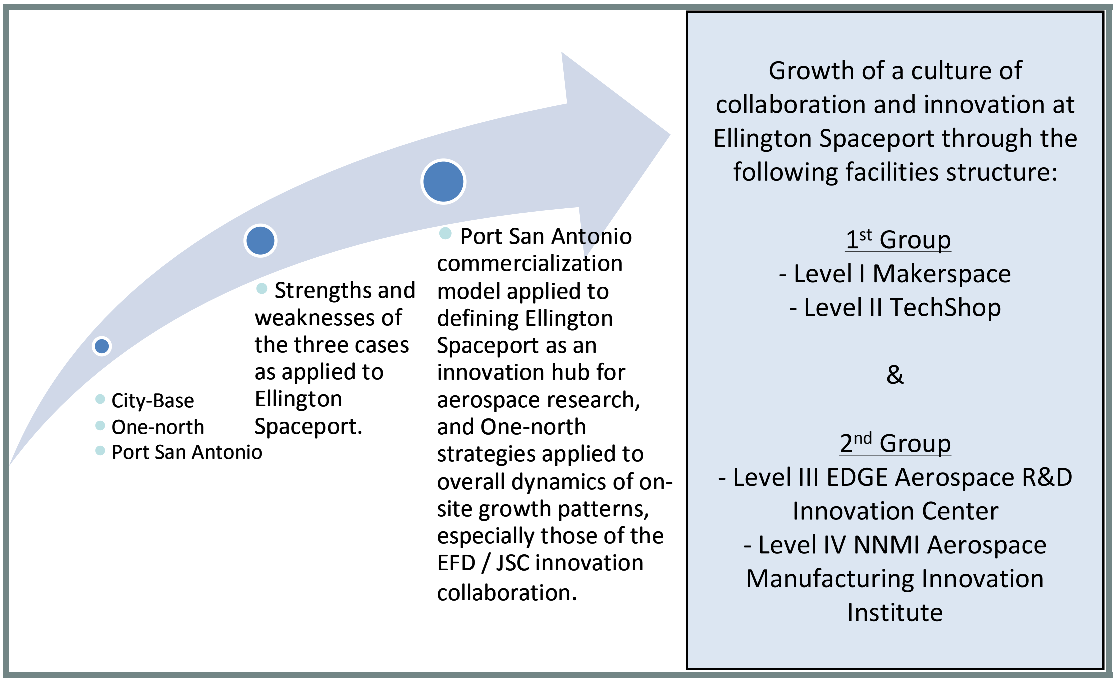

Figure 7-L: Application of Case Studies to Spaceport Plan

SOURCE: XSC, 2013

8. Infrastructure Projections for Economic Development

8.1 Spaceport Development Area

Based on our facility projection models, the Ellington Spaceport development plan build out includes 2.6 million square feet of building area comprised of hangars, terminal, office, R&D space, shop space, manufacturing facilities, classrooms, labs, museums, and conference and education centers.

The majority of new construction for the spaceport will be on 440 available acres of greenfield land at the southeast section of Ellington Airport, outlined in blue in Figure 8-A. (NASA's Sonny Carter Training Facility housing the Neutral Buoyancy Laboratory can be seen in the far background of the top photograph.) The spaceport development area will require new roads and infrastructure, including runway extension options, and taxiway and apron improvements. For this study, both EFD runways 17R/35L and 4/22 were considered for runway extension options for purposes of informing all master planning contingency considerations. Runway extension details are shown in 10.Appendix E. In all likelihood, runway 17R/35L will be the primary takeoff and landing runway for the spaceport. Depicted in red outline in Figure 8-A, is the Inhabited Building Distance (IBD) requirement (explosive protection zone) for both runways shown with extension options to 10,000 feet and 12,000 feet respectively. Planning for placement of facilities with regard to the IBD requirement for runway 4/22, (adjacent to the spaceport development area), reduces the available acreage for development to 310 acres.

Figure 8-A: Ellington Spaceport Development Area

SOURCE: TOP PHOTO AND BOTTOM OVERLAY, XSC, 2013

However, the most robust scenario for spaceport facility projections assumes a Stratolauncher class system would operate from Ellington. As the

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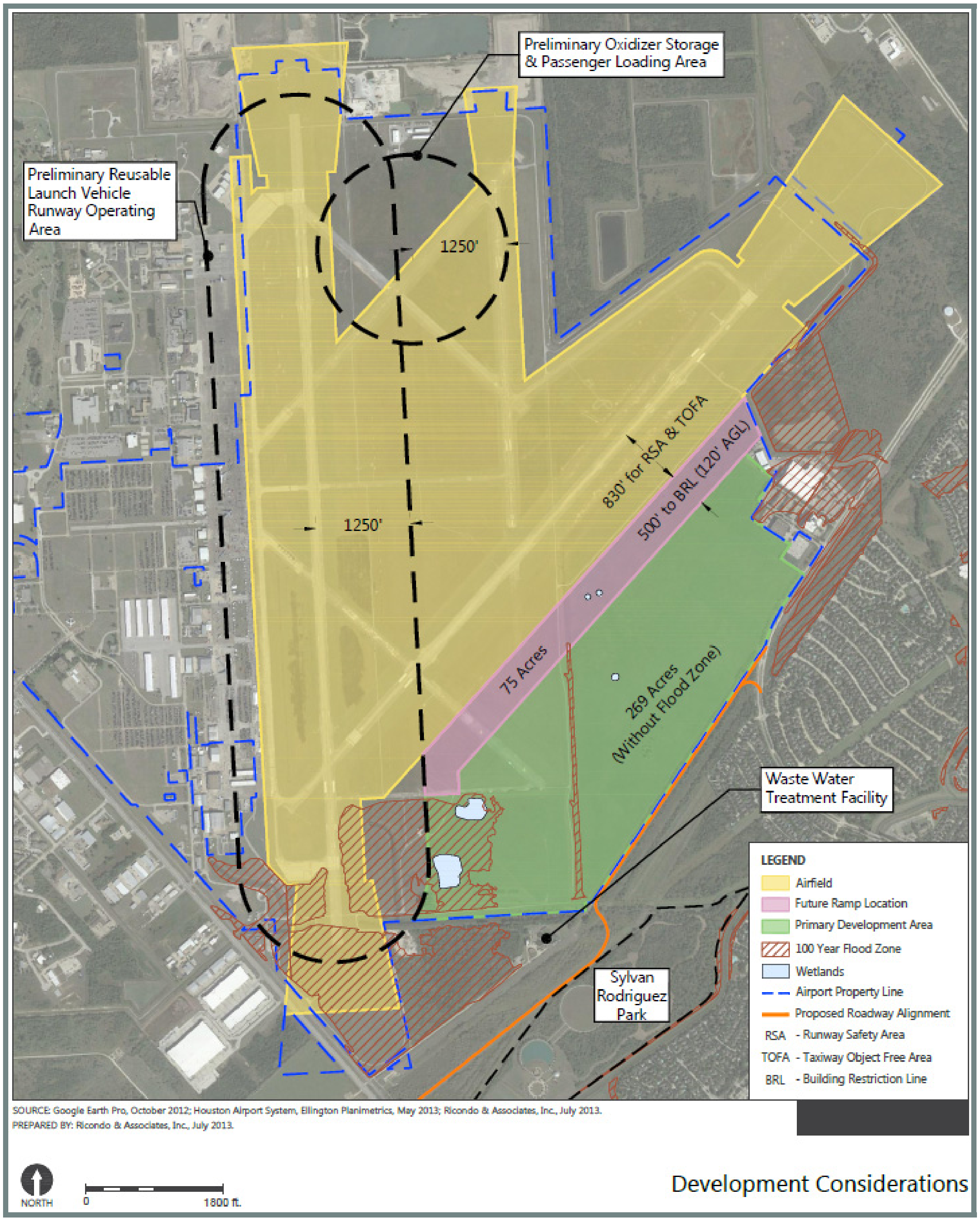
largest class of aircraft wingspan to plan for, the Stratolauncher's 385 foot wingspan requires a 550 foot runaway/taxiway centerline separation distance shown in Figure 8-B. This further reduces the developable area in the southeast corner of EFD to approximately 269 acres (without 100-year flood zone).



SOURCE: Google Earth Pro, October 2012; Houston Airport System, Ellington Planimetrics, May 2013; Ricondo & Associates, Inc., July 2013.
PREPARED BY: Ricondo & Associates, Inc., July 2013.

Figure 8-B: EFD Developable Area for Spaceport Facilities

SOURCE: RICONDO & ASSOCIATES, INC, JULY 2013

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8.2 Infrastructure Projection Building Blocks

There is not enough data available to project flight rate related capacity requirements because there are no operational systems upon which to make valid models. At this time, making facility changes or provisions based upon capacity driven analysis would be pure conjecture. We therefore relied on a market driven analysis to model the spaceport infrastructure and facilities projections.

Figure 8-C integrates the set of building blocks used to model the facility projections. Market segments serviceable by EFD are represented by the bar graphs based on the number of launches along the Y-axis projected from the demand forecast. Associated market values are shown along the X-axis for the ten-year period. Along the secondary Y-axis is the average number of days between launch events for each market segment. The activity timelines below the graph are driven by the amount of market activity which determines when the vehicle class type servicing the markets come on-line. Facility projection needs are then derived.

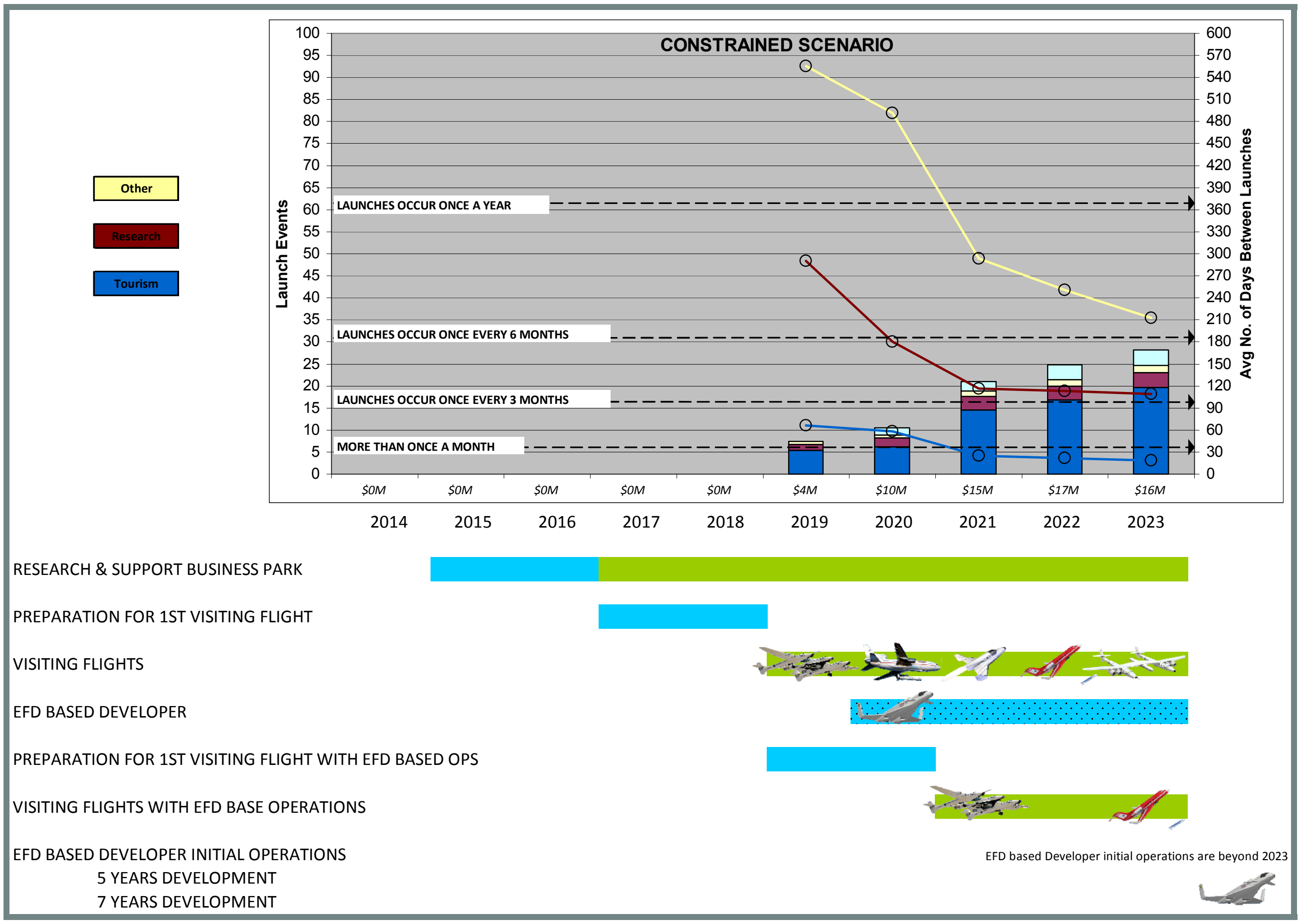

Figure 8-C: Market Driven Spaceport Development - Constrained Scenario

SOURCE: XSC, 2013

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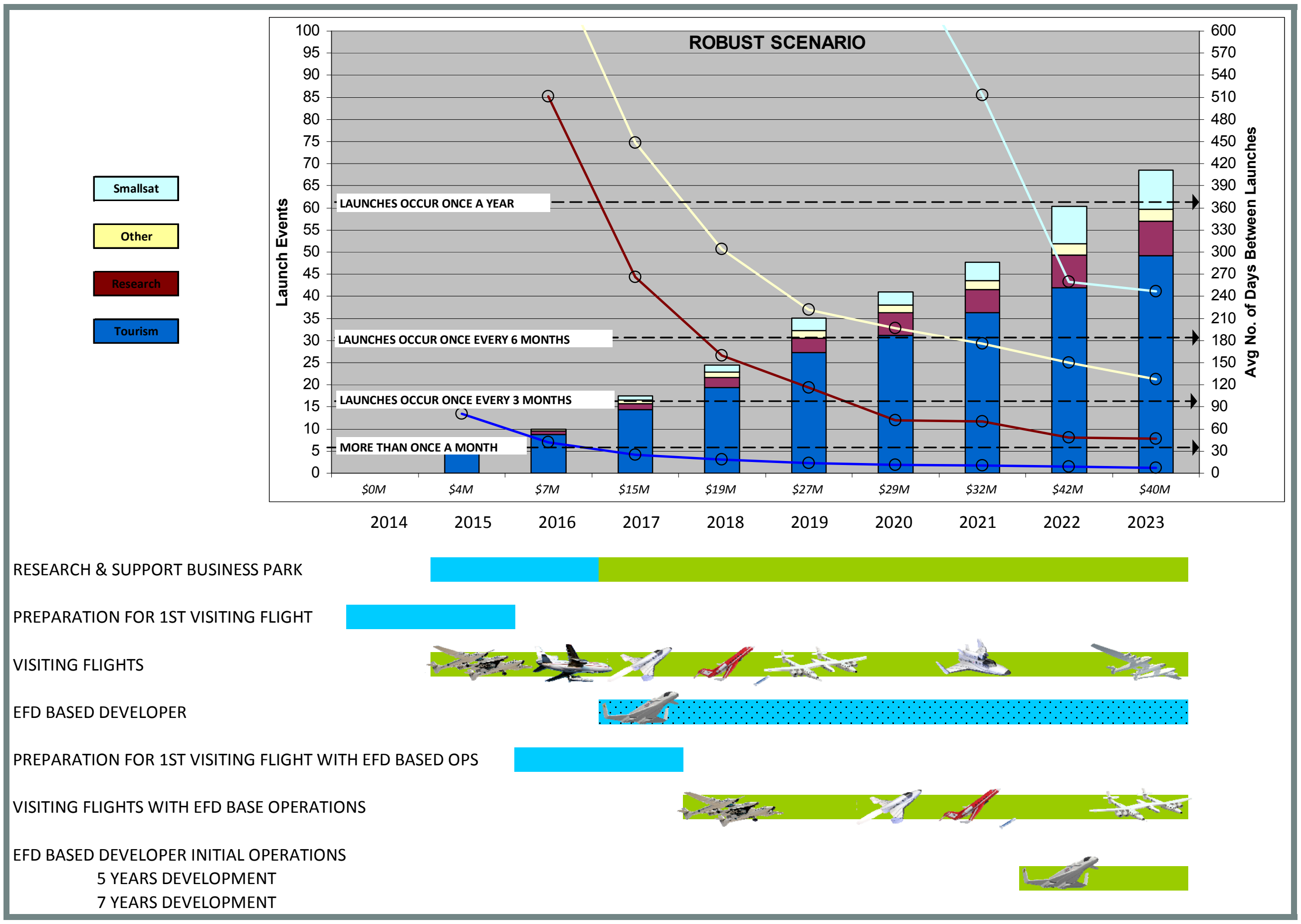

Figure 8-D: Market Driven Spaceport Development - Robust Scenario

SOURCE: XSC, 2013

The market analysis for a robust spaceport development scenario is illustrated in Figure 8-D above. Along the secondary Y-axis the downward slope of the lines indicates greater frequency of launch events by each market segment, and shows when the frequency of launches crosses certain time thresholds, i.e., launches occurring once a year, or once every 6 months, or once every 3 months, or more than once a month (the average number of days between launch events). For example, the tourism market does not demand the need for a visiting flight operator to establish a permanent EFD base of operations until 2021 in the constrained scenario, or 2018 in the robust scenario respectively, when tourism launch frequencies begin approaching more than once a month. The downward trend of the slope line also offers a forecast for when to begin planning preparations for construction of facilities needed by the potential operator of an EFD based operation.

In both constrained and robust scenarios, development of the Research Park proceeds along the same time frame since it is not dependent on the availability of when space vehicle operators begin conducting operations from the spaceport. Also note that in the robust scenario, an EFD based developer could conceivably see beginning of commercial operations as early as 2022, but in the constrained scenario commercial operations would not begin until sometime well after the forecast period.

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8.3 Spaceport Facilities Dynamic Modeling

An Excel-based spaceport facilities data base (10.Appendix E), was developed for bookkeeping square footage allocations, associated cost estimates, and dynamic modeling for constrained, baseline, and robust scenario analysis. Table 8-A identifies the different facility/infrastructure types considered. Facilities are grouped into categories of Flight Operations; R&D; Manufacturing; Retail; and Transportation. Facility functions, size allocations, and cost estimates were evaluated based on data gathered from a combination of the User Needs Assessment, facilities identified in the RS&H Ellington Spaceport Technical Feasibility Study, and primary site surveys conducted by XSC.

Table 8-A: Spaceport Facilities Development List

FLIGHT OPERATIONS			R&D	TRANSP.	RETAIL	MFG.
Passenger Preparation Area *	Spaceflight Training Center wtih Equipment *	RLV Processing Facility – D *	Level I Makerspace	Metro Station	Aerospace Museum *	Level IV NNMI Manufacturing
Terminal Visitor Center *	Payload Processing/Clean Room *	RLV Processing Facility - E	Level II Techshop/Makershop	Parking Garage	Museum Static Display Grounds	Production Facility 1 (runway access)
Admin Offices	Oxidizer Storage *	Engine Test Pad *	Level III EDGE Aerospace R&D Center	Outdoor Parking	Technology Park Visitor Center	Production Facility 2 (truck access)
Passenger Terminal *	Fuel Storage Area *	Runway Extension *	Office Areas	Road Network & Utilities	Hotel & Conference Center	
Medical Facility	RLV Processing Facility - A	Spaceport Tarmac & Pavement	Conference Areas	SE Access Road	Shops/Food Court	
Oxidizer & Passenger Loading Area w/ Taxiway *	Combined RLV & Payload Processing Facility - B	Spaceport Physical Plant	Classrooms	Rail Spurs	Parks / buffer zones	
Mission Control *	RLV Processing Facility - C	Multi/purpose Buildings				

* = equivalent spaceport facility as identified in RS&H Technical Feasibility Study

SOURCE: XSC, 2013

Bubble diagram algorithms were developed to model the square footage inventory for relative size determinations of facility types. These are tied to the spaceport activity timelines developed earlier to reveal spaceport growth patterns. The bubble diagrams follow the facility grouping categories of Flight Operations; R&D; Manufacturing; Retail; and Transportation. Shown in Figure 8-E below are the bubble shapes representing square footage sizes for each facility. They are distributed along the 10 year development timeline period according to the need date of the facility type as dictated by the market analysis described above.

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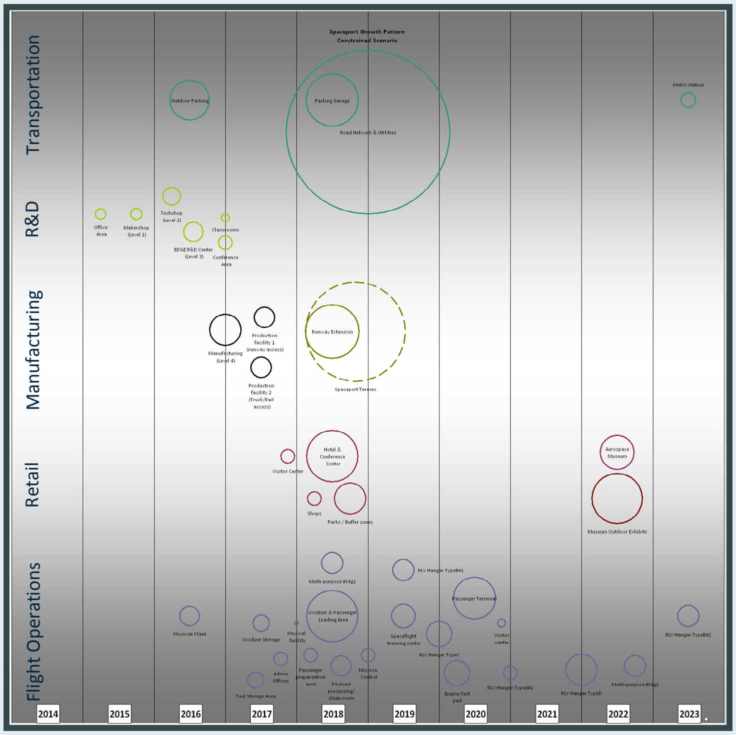
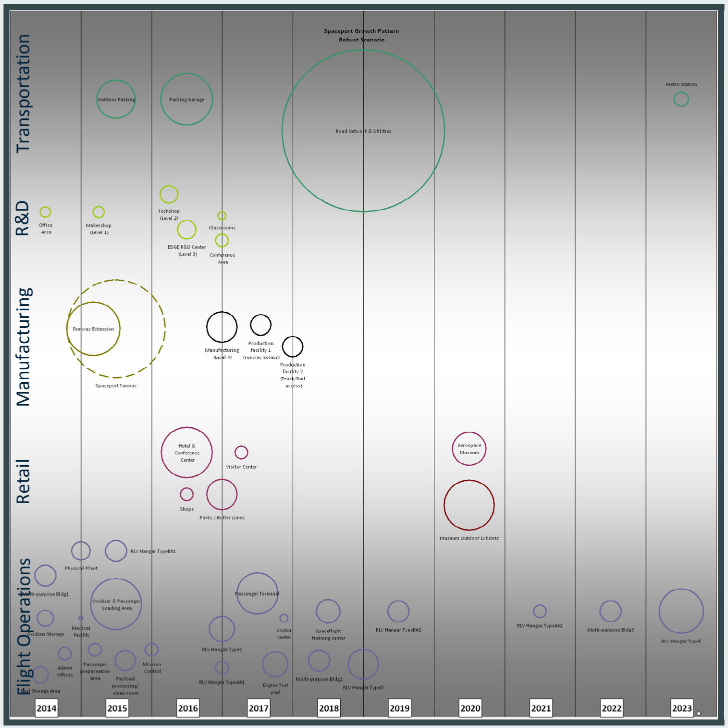


2014 -2023 CONSTRAINED

NAME	Year	AREA
Passenger Preparation Area	2018	10,000
Terminal Visitor Center	2020	3,730
Admin Offices	2017	10,000
Passenger Terminal	2020	90,000
Medical Facility	2018	1,080
Oxidizer & Passenger Loading Area	2018	135,000
Mission Control	2018	10,000
Spaceflight Training Center	2019	30,000
Payload Processing/ Clean Room	2018	23,000
Oxidizer Storage	2017	15,000
Fuel Storage Area	2017	15,000
RLV Hangar TypeA#1	2021	10,000
RLV Hangar TypeA#2		
RLV Hangar TypeB#1	2019	25,000
RLV Hangar TypeB#2	2023	25,000
RLV Hangar TypeC	2020	35,000
RLV Hangar TypeD	2021	50,000
RLV Hangar TypeE		
Engine Test Pad	2020	35,000
Runway Extension	2018	149,850
Spaceport Tarmac	2018	500,000
Physical Plant	2016	20,000
Multi-purpose Bldg1	2018	25,000
Multi-purpose Bldg2	2022	25,000
Multi-purpose Bldg3		
Level 1 Makershop	2015	7,000
Level 2 Techshop	2016	17,000
Level 3 EDGE R&D Center	2016	20,000
Office Area	2015	6,000
Conference Area	2017	10,000
Classrooms	2017	4,000
Level 4 Manufacturing Facility	2016	50,000
Production Facility 1 (runway access)	2017	23,000
Production Facility 2 (truck/rail access)	2017	23,000
Aerospace Museum	2022	60,000
Museum Outdoor Exhibits	2022	130,000
Technology Park Visitor Center	2017	10,000
Hotel & Conference Center	2018	135,000
Shops	2018	10,000
Parks / Buffer zones	2018	50,000
Metro Station	2023	12,000
Parking Garage	2018	140,000
Outdoor Parking	2016	80,000
Road Network & Utilities	2017	1,350,341
SE Access Road		924,000
Rail Spurs		0



2014 -2023 ROBUST

NAME	Year	AREA
Passenger Preparation Area	2015	10,000
Terminal Visitor Center	2017	3,730
Admin Offices	2014	10,000
Passenger Terminal	2017	90,000
Medical Facility	2015	1,080
Oxidizer & Passenger Loading Area	2015	135,000
Mission Control	2015	10,000
Spaceflight Training Center	2018	30,000
Payload Processing/ Clean Room	2015	23,000
Oxidizer Storage	2014	15,000
Fuel Storage Area	2014	15,000
RLV Hangar TypeA#1	2017	10,000
RLV Hangar TypeA#2	2021	10,000
RLV Hangar TypeB#1	2015	25,000
RLV Hangar TypeB#2	2019	25,000
RLV Hangar TypeC	2017	35,000
RLV Hangar TypeD	2018	50,000
RLV Hangar TypeE	2023	104,000
Engine Test Pad	2017	35,000
Runway Extension	2015	149,850
Spaceport Tarmac	2015	500,000
Physical Plant	2014	20,000
Multi-purpose Bldg1	2014	25,000
Multi-purpose Bldg2	2018	25,000
Multi-purpose Bldg3	2022	25,000
Level 1 Makershop	2015	7,000
Level 2 Techshop	2016	17,000
Level 3 EDGE R&D Center	2016	20,000
Office Area	2014	6,000
Conference Area	2017	10,000
Classrooms	2017	4,000
Level 4 Manufacturing Facility	2016	50,000
Production Facility 1 (runway access)	2017	23,000
Production Facility 2 (truck/rail access)	2017	23,000
Aerospace Museum	2020	60,000
Museum Outdoor Exhibits	2020	130,000
Technology Park Visitor Center	2017	10,000
Hotel & Conference Center	2016	135,000
Shops	2016	10,000
Parks / Buffer zones	2016	50,000
Metro Station	2023	12,000
Parking Garage	2016	140,000
Outdoor Parking	2015	80,000
Road Network & Utilities	2014	1,350,341
SE Access Road		924,000
Rail Spurs		0

Figure 8-E: Spaceport Growth Patterns for Constrained and Robust Scenarios

SOURCE: XSC, 2013

[Preliminary Draft for Discussion Purposes Only]

Application to Master Plan

To help inform the spaceport master planning effort, the bubble diagrams were used as a tool for a first order approximation of interrelationships of facilities, shown in Figure 8-F. Bubble shapes were arranged for determining interrelationship within a facility's primary group to establish the degree common functionality exists for optimizing housing within a single building structure or compound. External relationships of facilities to the different group categories were then assessed to determine what degree of cohesiveness could be accomplished for planning and layout of zoning areas in the master plan. Established zoning areas were then applied to a master plan layout, Figure 8-G.

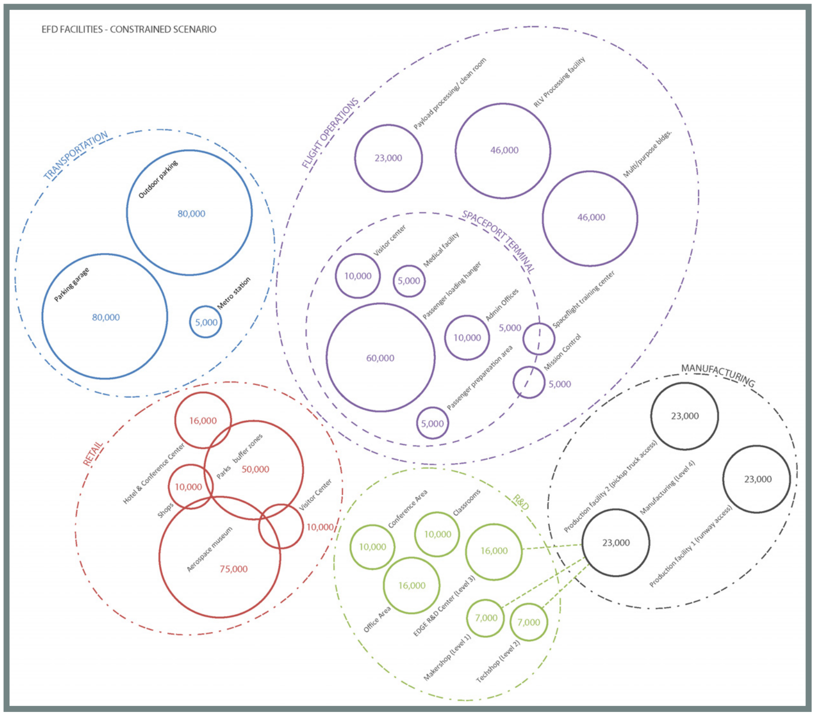


Figure 8-F: Spaceport Facility Interrelationships

SOURCE: XSC, 2013

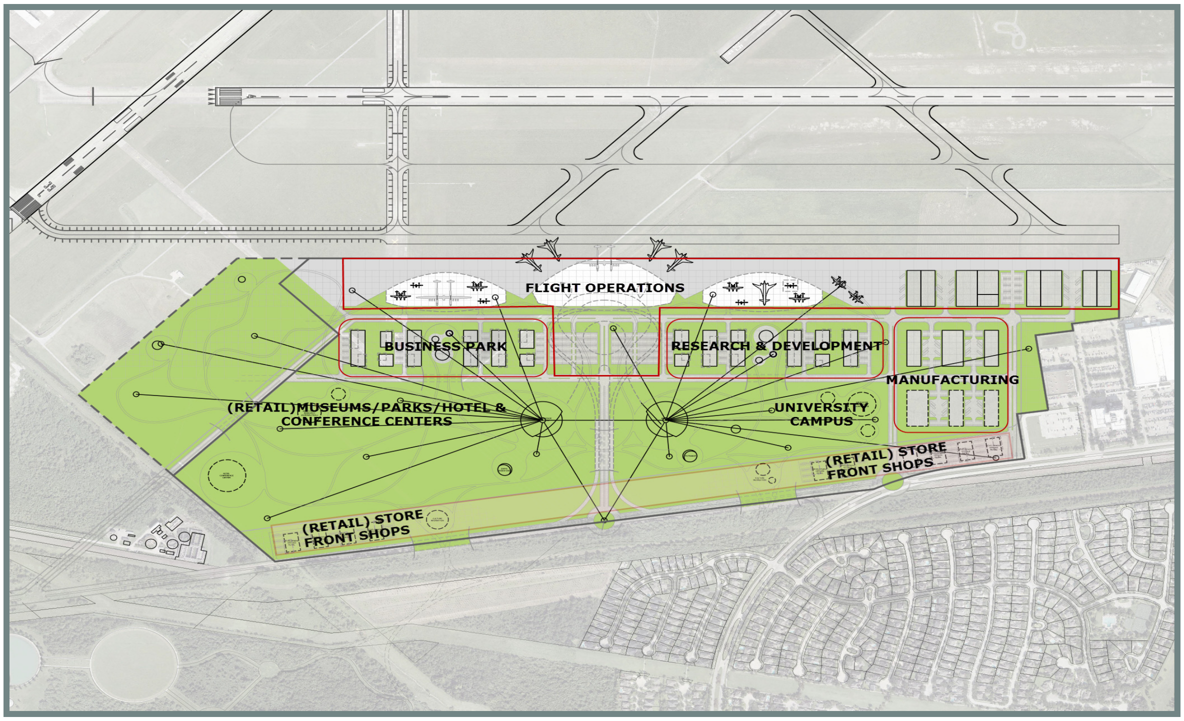


Figure 8-G: Spaceport Master Plan Layout

SOURCE: XSC, 2013

[Preliminary Draft for Discussion Purposes Only]

8.4 Spaceport Design Concept

Value of Branding with an Iconic Facility

A spaceport is a highly emblematic project, which should be iconic in its character. Thus, the vision must also be translatable into a brand and marketing message that can be communicated to a larger audience, beyond those most directly associated with the project.

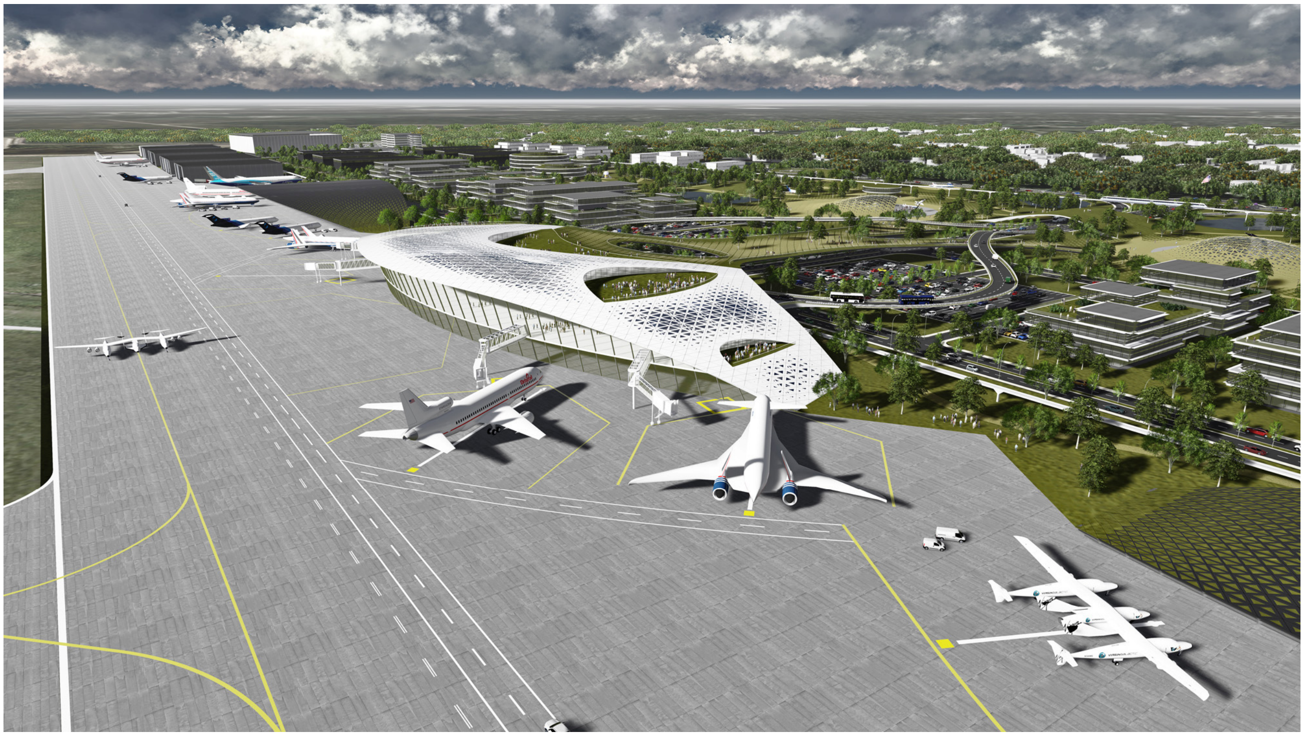
A marketing outreach campaign can be used to gain community support, attract operators, tenants and investors, and to generate a sense of excitement for the future and for the vision in general. If not properly managed however, the excitement or buzz at the beginning of the announced desire to establish a spaceport can wane and the initial enthusiasm and focus can be lost. Visualizing what the spaceport could look like is one tool for maintaining public interest, and the value of branding with an iconic facility as a means to engage and sustain public excitement and support for the spaceport can set Ellington apart from other competing spaceports.

For visualization, marketing, and business development purposes, a spaceport design concept was created by XSC based on the results of our market driven research process. A series of concept illustrations were created to provide HAS with a marketing tool for promoting the spaceport vision, branded as *"Houston Spaceport"*:

SOURCE: XSC, 2013 HOSTON SPACEPORT ENTRANCE

[Preliminary Draft for Discussion Purposes Only]

SOURCE: XSC, 2013 HOUSTON SPACEPORT DESCRIPTION



SOURCE: XSC, 2013 HOUSTON SPACEPORT TERMINAL (AIRSIDE)

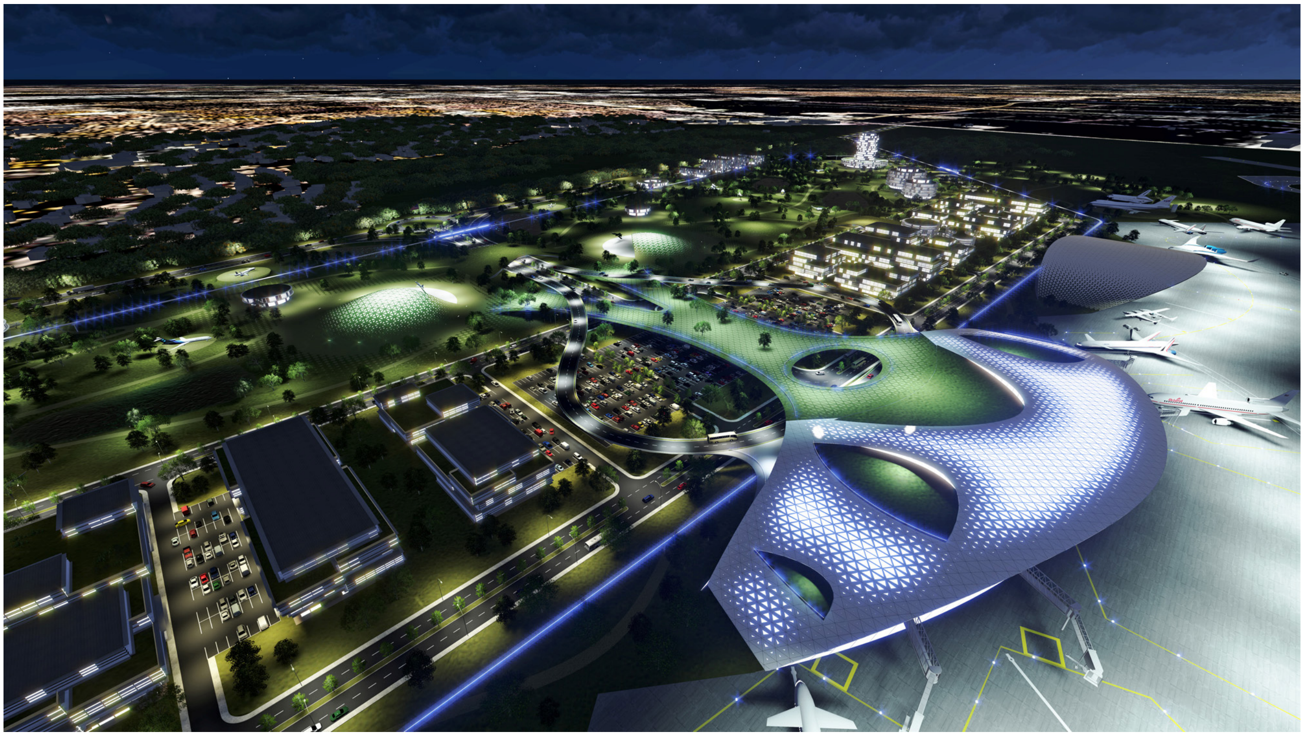
[Preliminary Draft for Discussion Purposes Only]

SOURCE: XSC, 2013 HOUSTON SPACEPORT VIEWED FROM NASA SONNY CARTER TRAINING FACILITY

SOURCE: XSC, 2013 HOUSTON SPACEPORT AEROSAPCE MUSEUM

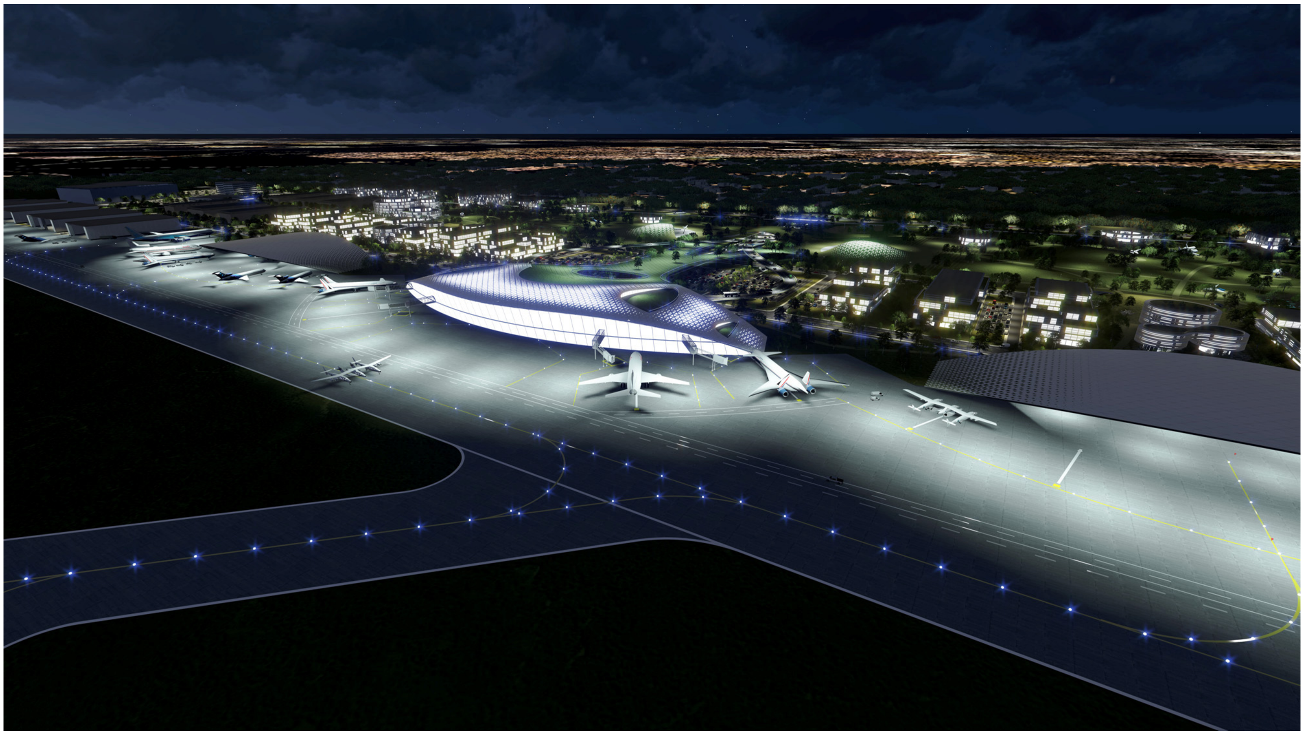
[Preliminary Draft for Discussion Purposes Only]

SOURCE: XSC, 2013 HOUSTON SPACEPORT TERMINAL (LANDSIDE)



SOURCE: XSC, 2013 HOUSTON SPACEPORT TERMINAL LOOKING SOUTH

[Preliminary Draft for Discussion Purposes Only]



SOURCE: XSC 2013 HOUSTON SPACEPORT TAXIWAY

SOURCE: XSC, 2013 HOUSTON SPACEPORT AERIAL NIGHT VIEW

8.5 Cost Estimate

Cost estimates in the facilities database (10.Appendix E), are based on estimated square footage requirements of the listed facility or infrastructure type. Table 8-B below racks up land usage and the total identified square feet estimates in various categories. Total costs are representative of the constrained and robust scenarios above, depicted in Figure 8-C and Figure 8-D respectively.

With both scenarios, the same "end-state" is achieved for the spaceport build-out growth projection. This accounts for the relatively minor cost difference between the constrained and robust scenario. The main difference being in the timeframe in which the respective facilities are projected to come online.

We performed a validation check by comparing the ROM cost estimate for spaceport facilities identified in the RS&H Technical Feasibility Study[17] against our cost estimate, (the facilities subset is identified in Table 8-A). The RS&H high option range of $120,400,000 was comparable to our robust scenario estimate of $116,700,000 for this same facilities subset.

Some master plan elements were not included in the cost estimate. For example, the land area for a potential university or community college campus located at the spaceport was provided for, but building square footage allocations were not assigned. Other plan features not included in the cost are the rail line extensions and spaceport rail system, the new road access boulevard from Highway 3 connecting to Space Center Blvd., and land acquisitions that may be needed for runway extensions.

Table 8-B: Spaceport Land Usage and Cost Estimate

CATEGORY	CONSTRAINED SCENARIO	ROBUST SCENARIO
Total Construction Area: SE Buildings + Flightline (ft2)	3,426,001	3,565,001
Total Flightline Construction Area (ft2)	819,850	819,850
Total Building Area: (ft2) SE area	2,606,151	2,745,151
Total Land Area Used (ft2) SE area only	2,296,619	2,435,619
Total Land Area Left (ft2) SE area only	11,206,981	11,067,981
Building Factor (%)	17.01%	18.04%
Total Cost	**$286,024,270**	**$308,264,270**

SOURCE: XCS, 2013

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[17] Houston Airport System: "Ellington Airport, Spaceport Feasibility Study", February 10, 2012, RS&H Project 212-2264-000; page 5-6.

[Preliminary Draft for Discussion Purposes Only]

9. Economic Impact Assessment

Objective: Assess local economy impact of EFD spaceport launch-related activities.

9.1 Introduction

Conversion of Ellington Airport to a spaceport is a significant undertaking, representing a direct injection into the local Houston-Sugarland-Baytown, Texas Metropolitan Statistical Area (MSA)[18] economy of hundreds of millions of dollars. The total economic impact of Ellington Spaceport may be viewed as the return on any investment made by the City of Houston or State of Texas in bringing the spaceport to fruition, including any tax benefits or other incentives offered to developers, tenants, or users.

Economic benefit occurs in several waves and may show up in various metrics. The first wave—or *direct impact*—is incremental local spending (or incremental "final demand") to build and operate the spaceport. This might include locally sourced building materials, leasing of construction equipment, or in-region purchased labor, such as architect and engineering (A&E) services. Every incremental dollar injected into the economy then circulates to wholesalers sell building materials to the distributors from whom the spaceport buys them, for example, or to sellers of construction equipment who might purchase them to lease. These represent the second wave of circulation or *indirect* impact. A final type of impact is known as *induced*, comprising incremental consumption from employees who owe their jobs (or increased earnings) to the spaceport. This could include, for example, incremental expenditures on restaurant meals, dry cleaning, or childcare. Types of metrics where economic impact may be observed include output (e.g., gross area product), employment (e.g., number of jobs), or earnings (e.g., dollars generated).

This section presents the approach taken to estimating the economic impact of the Ellington Spaceport project on the local economy, the relevant inputs and assumptions used in formulating this estimate, and the conclusions reached about the economic impact of the Ellington Spaceport. The scope of the economic impact assessment is establishment of the flight operations capability at Ellington, with some investment in local transportation (i.e., outdoor parking, road network and utilities) to support those operations. Unless otherwise indicated, the local area for which the economic impact is assessed in the Houston-Sugarland-Baytown, Texas MSA (Houston MSA).

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[18] The Houston-Sugarland-Baytown, TX MSA includes Austin, TX; Brazoria, TX; Chambers, TX; Fort Bend, TX, Galveston, TX; Liberty, TX; Montgomery, TX; San Jacinto, TX; and Waller, TX

In practice, the Spaceport Research Park is also expected to have a substantial economic impact on the Houston MSA. Because of its early planning stage, however, detailed estimates for tenancy (and associated employment) for the research park are not available. For consistency sake, therefore, the research park was excluded from the economic impact assessment. As the project progresses and the plans of both the project sponsors and the tenant community are better defined, additional economic impact may be calculated within this model.

9.2 Methodology

The relationship between direct economic investment and ultimate economic impact is known as a multiplier, with different multipliers representing different economic impacts (e.g., there are separate multipliers for output, employment, and earnings). There are several sources for multipliers; for this analysis, the multipliers used come from the U.S. Bureau of Economic Analysis (BEA) and are based on the BEA's Regional Impact Modeling II (RIMS) economic models[19]. Because the RIMS multipliers are generally accepted for their credibility and level of detail, they are fairly standard for economic impact assessments.

RIMS multipliers are specific to industries, as defined by a system of codes called the North American Industrial Classification System (NAICS codes). To apply the multipliers correctly, the underlying final demand (i.e., expenditures) must be assigned to one or more NAICS codes to correctly identify the affected industries. The precision of the economic impact increases with the granularity of the expenditure data. The Ellington Spaceport economic impact is based on two major types of expenditures: construction (i.e., spending to build/convert the spaceport) and operations (i.e., spending to run flight operations once the spaceport has been built.) Expenditure data is still estimated at a high level at this stage of the project, so expenditures have been grouped into two NAICS codes: Construction and Air Transportation. Table 9-A presents the output multipliers for these two codes, as well as selected more detailed NAICS codes that may be used as spending plans become more developed. While there are some differences between the high level NAICS codes and the more granular ones, the differences are relatively small, suggesting that the magnitude of any estimation error due to aggregation is small.

The two sources of economic impact for Ellington Spaceport are construction and launch operations. The construction impact derives from capital to be spent on a one-time basis over the next ten years to convert the current Ellington Airport to a spaceport. The operations impact is based on local expenditures needed to support the launch business over a five (pessimistic scenario) to nine (optimistic scenario) years. The basis for expenditures to which the multipliers are applied is:

- Construction costs defined in the EFD Spaceport Facilities Database, 10.Appendix E
- Operations costs based on the revenue estimates derived from the launch forecast in Section 6
- Assumptions as to locally sourced content for both construction and operations

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[19] For details on the RIMS II models and their multipliers, please see http://www.bea.gov/regional/rims/rimsii/.

[Preliminary Draft for Discussion Purposes Only]

Table 9-A: Selected NIACS Codes

NAICS CODE	DESCRIPTION	OUTPUT MULTIPLIER
230000	Construction	2.2413
481000	Air Transportation	2.2822
324121	Asphalt paving mixture and block manufacturing	1.8765
324122	Asphalt shingle and coating materials manufacturing	1.7214
324191	Petroleum lubricating oil and grease manufacturing	2.0115
325510	Paint and coating manufacturing	1.9566
327320	Ready-mix concrete manufacturing	1.7245

SOURCE: XSC, 2013

Construction costs and revenue inputs were estimated in constant 2013 dollar terms, but were deflated to 2010 dollars to align with the time frame during which the multipliers were generated. Final results are therefore stated in constant 2010 dollars. Because of the high level of estimates at this point in the development of the project, the objective of the economic impact evaluation is to establish a range within which that overall impact will fall. Although baseline numbers are useful in deriving a most likely view, optimistic and pessimistic scenarios were used to establish the range. Where necessary, "best case" assumptions were coupled with the optimistic scenario and "worst case" assumptions with the pessimistic scenario to create an inclusive range.

Construction represents the lion's share of total expenditures and, accordingly, economic impact. Construction expenditures were considered for 21 types of facilities associated with Flight Operations and also for Outdoor Parking and Road Networks & Utilities. Baseline cost estimates are presented in Table 9-B, with aggregate optimistic and pessimistic scenario estimates, and their timelines, shown in Figure 9-A. The cost estimates were generated by multiplying an overall cost-per-square-foot estimate by the number of square feet required for each facility, with no additional insight offered into such breakdowns as materials vs. labor or locally sourced vs. regional imports. For purposes of this analysis, an additional assumption was added that 75% of construction costs were expended locally. While little data is publicly available to support this assumption, it was internally validated by comparing the resultant multipliers with overall multipliers for airport construction projects in both the State of Texas and the U.S. overall.

[Preliminary Draft for Discussion Purposes Only]

Table 9-B: Construction Costs by Line Item (Baseline)

FACILITY TYPE	TOTAL COST	YEAR FINISHED
Passenger Prep Area	$3,000,000	2016
Terminal Visitor Center	$596,800	2018
Admin Offices	$1,600,000	2015
Passenger Terminal	$14,400,000	2019
Medical Facility	$172,800	2016
Oxidizer & Passenger Loading Area with Taxiway	$8,100,000	2016
Mission Control	$3,000,000	3016
Spaceflight Training Center with Equipment	$39,000,000	3018
Payload Processing / Clean Room	$7,981,000	2018
Oxidizer Storage	$2,025,000	2015
Fuel Storage Area	$405,000	2015
RLV Processing Facilities – A through E	$23,200,000	2020
Engine Test Pad	$3,010,000	2018
Runway Extension	$13,510,000	2016
Spaceport Tarmac / Pavement	$22,695,000	2016
Spaceport Physical Plant	$2,284,400	2015
Multipurpose Buildings	$8,000,000	2020
Outdoor Parking	$3,631,200	2016
Road Network & Utilities	$58,456,304	2016
Total	**$173,676,311**	**2020**

SOURCE: XSC, 2013

Expenditures associated with flight center operations were based on total revenue, as forecast in the launch forecast. These expenditures would include some combination of costs for facilities, infrastructure, operations and maintenance (O&M), propellants and other consumables, hands-on labor, and payload integration. To ascertain the value of incremental, locally sourced demand, the following assumptions were applied to the launch revenue forecast:

- 4% of projected revenue was assumed to be spent locally for "visiting" flights: those with no operational based at Ellington or in Houston
- 12% of projected revenue was assumed to be spent locally for operators who had established a base at Ellington

These percentages are based on the collective body of proprietary and public work performed by the team's experts. For the most pessimistic scenario, all flights were assumed to remain visiting flights, while the most optimistic scenario included the assumption that a local base of operations would be established in 2018 (likely representing a single customer). Table 9-C shows assumed levels of locally sourced expenditures during the forecast period and their assumed percent of total revenues.

Table 9-C: Operational Expenditure Assumptions

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Locally sourced operational expenditures (Optimistic)	0	$202.000	$400,000	$700,000	$2,928,600	$4,212,000	$4,923,000	$5,702,000	$7,234,500	$8,229,000
Percent of Total Revenue (Optimistic)	4%	4%	4%	4%	12%	12%	12%	12%	12%	12%
Locally sourced operational expenditures (Pessimistic)						$298,000	$418,500	$835,333	$993,000	$1,128,000
Percent of Total Revenue (Pessimistic)	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%

SOURCE: XSC, 2013

Figure 9-A shows the impact of optimistic and pessimistic scenarios on the timing of expenditures:

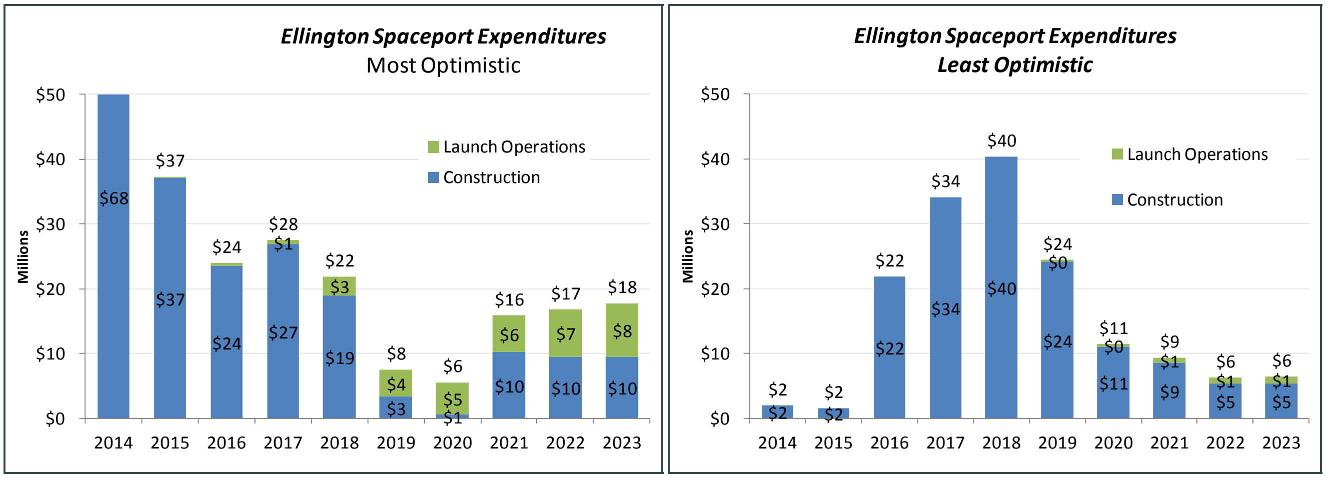

Figure 9-A: Expenditure Summaries for Optimistic and Pessimistic Scenarios

SOURCE: XSC, 2013

9.3 Results

Overall, we expect the total impact on output (i.e., Gross Area Product) of the flight operations portion of the spaceport project to fall between $285 and $455 million by 2023, with an impact on earnings in the $60–100 million range. Moreover, the project is expected to bring between 130 and 200 jobs per year to the region. Table 9-D shows a breakdown of high and low impacts associated with construction, operations, and total.

Table 9-D Summary of Economic Impact Results (Million Constant 2010 $)

		OUTPUT IMPACT	EARNINGS IMPACT	EMPLOYMENT IMPACT	YEARS OF OPERATIONS
Optimistic Scenario	Construction	$371	$80	168	9
	Flight Operations	$84	$17	34	
	Total	$455	$97	202	
Pessimistic Scenario	Construction	$275	$59	124	5
	Flight Operations	$9	$2	6	
	Total	$284	$61	131	

SOURCE: XSC, 2013

To validate, these economic impact numbers were compared to published numbers for airport projects in the State of Texas and in the U.S. overall[20]. The multipliers for the Ellington Spaceport were compared to the implicit aggregate multipliers for airports projects, with the following results:

- Ellington Spaceport's blended output multiplier is 2.14, a bit below a multiplier of 2.56 for both Texas and the U.S.
- Ellington Spaceport's blended earnings multiplier is 0.55, comparing favorably with Texas' 0.3 multiplier and the U.S. 0.31 multiplier
- Ellington Spaceport's employment multiplier is 2.09, nearly identical to Texas' employment multiplier of 2.08, and a bit below the U.S. 2.15 employment multiplier.

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[20] CDM Smith, "The Economic Impact of Commercial Airports in 2010", prepared for Airports Council International – North America, January, 2012.

9.4 Conclusions

Conversion of Ellington Airport to Ellington Spaceport will entail numerous costs, benefits, and risks. It is up to the Houston Airport Systems (HAS), as well as the City of Houston to determine whether the investment they contemplate in encouraging this conversion brings a return to the Houston economy. The best way to frame the results of this economic impact assessment is to consider it as an estimate of the "benefit" in a "benefit/cost" assessment. That is, these impact numbers could be used to help economic development authorities to understand how much of an incentive (e.g., tax benefits, low costs for land use, facilitated permitting, etc), if any at all, they can afford to offer to a spaceport developer who may support achievement of priority economic objectives.

The economic impact model as it stands is based on very high-level, top-down cost estimates, rather than bottom-up estimates that would offer greater insight into the categories of expenditures to be made. As this project progresses toward implementation, more detailed attention will be paid to generating cost/spend estimates. The current model may be easily retrofitted or adapted to a more detailed set of assumptions, allowing HAS to consider an economic impact estimate within a more narrow range. HAS may also use the model to evaluate alternative scenarios for key decisions it needs to make. For example, if there is a more economic way to build part of the infrastructure, HAS may weigh the fiscal benefits of a less expensive project with the multiplier impact of employing more people in the endeavor of converting the spaceport.

9.4.1 KEY OMISSION

One key omission from the economic impact assessment is the economic impact of the research park, due to the uncertainties around market uptake for its services. Current estimates suggest that the research park will be one quarter to one third the cost of building out flight operations capabilities. Furthermore, it is possible that the potential for economic stimulation coming out of the research park could exceed that of the flight operations (particularly if there is a greater concentration of locally-sourced expenditures). If economic impact were proportional to relative capex, inclusion of the research park in the economic impact analysis could increase the estimated output impact by another $75–160 million.

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10. Study Conclusions and Recommendations

Go forward with spaceport planning ➔ preparedness meets opportunity

- Case in point: planning at Spaceport America began in late 1980s-early 1990s, and took until 2005 for a commercial industry to emerge to meet a market demand; (likewise, suborbital point-to-point transportation is still 20 years away but planning should begin now)

- Spaceports located in populated, international business centers will emerge globally over the next 30 years. Houston is in a very strong position to be one of the first of these to emerge.

- Recommend that planning activities for runway extension continue to move forward.

    - Runway expansion may be a mandatory requirement by potential tenants in future. While we are not recommending that the runway be built today, it is best that Ellington be prepared for this potential requirement. (including having finance alternatives in place)

It is anticipated that the earliest flights out of EFD would occur as a result of being more attractive a site then other spaceports. It is therefore likely that EFD would have to pay for the privilege of hosting early flights as opposed to receiving fees in order to establish the Houston area market. It could be that this condition lasts for the first 2 or 3 visits by first-to-market operators.

- If first-to-market operators commence operational flights in 2015, the start of a new development system based at EFD would not start before 2017 or 2018. An additional 5 to 7 years of development and test would mean an initial operational capability in 2022 to 2025 – well downstream of a time frame of financial significance to current decisions.

Begin low-cost, but visible spaceport marketing campaign

- Seek early successes to build the brand

- Does not need to be a huge, expensive campaign; but developing brochures and attending key conferences are recommended.

[Preliminary Draft for Discussion Purposes Only]

  - Key conferences include the New Suborbital Researchers Conference; ISPCS (International Symposium for Personal and Commercial Space)

- Include point-to-point emphasis in marketing brochures

The synergy between the goals of HAS and JSC can be maximized by integrating their respective plans for commercial space economic development.

- Integrate EFD / JSC commercial space economic development plans
  - Collaborate with JSC to establish international point-to-point suborbital transport technology development center
  - Initiate JSC / HAS Director to Director dialogue/meetings early in the planning process
  - Establish Spaceport Advisory Board early in the planning process

The operational and technology challenges for long distance P2P flight present an opportunity for EFD to establish itself as a location whose focus is on enabling point-to-point technology research.

- Begin identifying potential international point-to-point partner spaceports
  - Identify sister airport for joint P2P study of infrastructure development needs, e.g. Inchon Airport, S. Korea; Abu Dabi, United Emirates
- Focus R&D on P2P technology development
  - Place strong emphasis on aerospace biomedical research; (leverage UTMB Health and their membership with FAA Center of Excellence)
  - Leverage access to JSC facilities, labs, and intellectual talent

Development of the Research Park for the spaceport can and should proceed prior to identification of first-to-market operators utilizing the spaceport for flight operations.

- Branding the spaceport as a cluster for aerospace technology innovation to attract talented researchers and entrepreneurs will require pioneering models of operation that a new youth generation of scientist and engineers can relate to. Their philosophy is one of openness, sharing, collaboration and communities, i.e., open source software/open source hardware.

- Begin nurturing culture of collaboration/innovation early (use existing vacant facility to setup a Makerspace

  - Consider sponsoring the Level I Makerspace facility, or seek out local community sponsor

- Begin discussion with TechShop Network for locating a TechShop at EFD; seek out investor for establishing the Level II TechShop business model

- Develop implementation plan for defining mechanisms of instituting culture of collaboration and innovation

  - Provide funding to develop spaceport management implementation plan, to continue investigating a framework for how an open-source collaboration model could be managed at Ellington based on the basic premises of the EFD collaboration model discussed in paragraph **Error! Reference source not found.**.

HAS could establish as the center-piece of its R&D facilities, an EDGE® Aerospace Innovation Center within the EFD Spaceport infrastructure, which would lead to a synergistic and collaborative partnership with not only NASA JSC, but also with area Universities, aerospace companies, and non-profit organizations dedicated to the aerospace industry within the Houston area.

- Consider joining the GD EDGE network or use it as the model for the Level III R&D center

HAS should work in conjunction with industry partners, state and local agencies, foundations, universities, and others to assemble a team for proposing to the NNMI the establishment of an "Aerospace Manufacturing Innovation Institute" (AMII) to be located at the spaceport Research Park.

- Consider the National Network for Manufacturing Initiative (NNMI) as a pathway for establishing an aerospace manufacturing cluster

- Requires competing for one of the 15 Innovative Manufacturing Institutes to be established nationally

- Requires an extensive local/regional/state lobbying effort, and assembling of a broad coalition of collaborating stakeholders

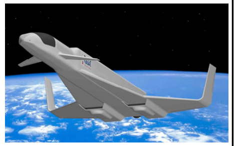
[Preliminary Draft for Discussion Purposes Only]

Appendix A Acronyms

[Preliminary Draft for Discussion Purposes Only]

Appendix B Launch Vehicle Survey

[Preliminary Draft for Discussion Purposes Only]

	Stratolaunch Systems	The Spaceship Company (Scaled Composites)	Virgin Galactic	Orbital Sciences	XCOR		Genration Orbit	Rocket Crafters
								
Vehicle	**Stratolaunch**	**Launcher One**	**Space Ship 2**	**Pegasus XL**	**Lynx Mark II**	**Lynx Mark III**	**GO Launcher 2**	**Sidereus**
Developer	Stratolaunch systems	Virgin Galactic	Virgin Galactic	Orbital Science Corporation	XCor	XCor	Generation Orbit	Rocket Crafters
City/State	Mojave	Mojave	Mojave	Mojave	Mojave	Mojave	Atlanta	Utah
RWY length (ft)	12,500	12,000	12,000	10,000	7,900	7,900	8,000	?
Propulsion	LOX/RP1	Two-stage liquid fuel	Hybrid, Nitrous Oxide (N2O)	SRB	LOX-Kerosene	LOX-Kerosene	LOX-paraffin	Hybrid, LOX
# of stages	2	2	1	3	1	1	2	2
Payload type	Satellites	Small satellites	Tourism	Small satellites	Tourism / Payload	Small satellites	Small satellites	P2P / Tourism
Payload (lb)	13500	500	X	980	310	1433	100	?
Payload (kg)	6100	255	X	443	140	650	30	?
Crew	X	X	6	X	2	X	X	8
Orbital Insertion category	LEO	LEO	Suborbital	LEO	Suborbital	LEO	LEO	Suborbital
Insertion height (km)	380	380	110	380	100	380	740	100
cost / launch (million $)	15	10	0.8	30	0.095	0.095	?	?
Technology Readiness Level (TRL)	4	6	7	9	5	5	2	3
Tests start	2015	2015	2013	1989	2014	2014	?	?
Operations start	2018	2016	2014	1990	2015	2015	?	?
Hangar / Launch v. processing facility (sq.ft.)	103,257	14,400	47,000	34,000	10,375	10,375	10,000	27,000
Payload processing facility (sq.ft.)	●	10000	X	27,000	X	●	10,000	?
Liquid oxygen / RP-1 fueling systems (sq.ft.)	●	●	●	X	X	X	●	?
Telemetry system (sq.ft.)	●	●	?	●	X	X	X	?
Range safety/flight termination system (sq.ft.)	●	●	●	●	X	X	X	?
Passenger / Visitors Terminal (sq.ft.)	X	X	32600	X	●	X	X	?
Support and administrative (sq.ft.)	X	X	25,597	X	●	●	X	?
Training, lounge, dressing rooms (sq.ft.)	X	X	29,419	X	●	X	X	?
Website	LINK	LINK	LINK	LINK	LINK	LINK	LINK	LINK
Notes		high launch cost?	min. required, hangar - 160x90ft	Payload installed at assembly building, Vandenberg, CA		Should we add Mark II, space tourism vehicle?	LEO altitudes up to 740km (400NM)?	Three different vehicles in development: Sidereus, Sidereus 2A, Cosmos Clipper

● Required but area size not determined
X not applicable
? Data missing
Verify

[Preliminary Draft for Discussion Purposes Only]

Developer	**Stratolaunch**	**Stratolaunch**	**Virgin Galactic**	**Virgin Galactic**	**Virgin Galactic**	**Orbital Sciences**	**Orbital Sciences**	**XCOR Aerospace**	**XCOR Aerospace**	**XCOR Aerospace**	**Generation Orbit**	**Generation Orbit**	**Generation Orbit**	**Rocket Crafters**	**Rocket Crafters**
Vehicle	Carrier	Pegasus 2	White Knight Two	SpaceShipTwo	LauncherOne	Stargazer	Pegasus XL	Lynx Mark I	Lynx Mark II	Lynx Mark III	GO Carrier	GO Launcher 1	GO Launcher 2	Firehawk	Sidereus
Function	Carrier	Booster	Carrier	Spacecraft	Booster	Carrier	Booster	Launch/Spacecraft	Launch/Spacecraft	Launch/Spacecraft	Carrier	Booster	Booster	Launch/Spacecraft	Launch/Spacecraft
Contractor	TCS	Orbital Sciences	Scaled Composites	Scaled Composites	Virgin Galactic	Lockheed	Orbital Sciences	XCOR Aerospace	XCOR Aerospace	XCOR Aerospace	Gulfstream	Generation Orbit	Generation Orbit	Rocket Crafters	Rocket Crafters
Target Market	Air Launch	Orbital Payload	Air Launch	Suborbital Tourists - Research	Orbital Payload	Air Launch	Orbital Payload	Test Vehicle	Suborbital Tourists - Research	Suborbital Tourists - Research		Sub-orbital research and hypersonics	Orbital Payload	Sub-orbital Pilot Training	Suborbital Tourists/Research/Point-to-Point
Base	Mojave	KSC	Spaceport America	Spaceport America	Spaceport America	Mojave	VAFB	Mojave/Midland	Midland	Space Florida				Front Range	Titusville
Introduction Year	2016	2017	2008	2013	2016	1994	1990	2013	2015	2016			201X	2015	2016
Vehicle Characteristics															
# of Stages	1	3	1	1	2	1	3	1	1	1		1	2	1	1
Mass (lb.)	1.3M		17000	21428		430K	51,000				69,700				
Wingspan (ft.)	385	tbd	141	27		155	22	24	24	24	77			24	
Length (ft.)	285	120	78	60		177	58	30	30	30	83			30	
Height (ft.)	50		25	80		55	10				24				
Ops Radius/Range (nmi)	1000		2000			4500					3650				1600
Diameter (ft.)		12.2		7.5			50 inch								
Flight Crew	3		2	2		3		1	1	1	2			2	2
Passengers			10	6				1	1	1					TBD
Payload Length (ft.)					3.3		7			11		5	3.5		
Payload Diameter (ft.)		5M Fairing			2.5		3.9			2.5		1.5	2.7		
Payload to Sub-orbital				1300				265 lb.	265 lb.	265 lb.+ 650 lb.		220			
Payload to LEO (lb.)		13,500			100 - 500		980						66		
Propellants	jet	solid/solid/cryo	jet	N2O/HTPB	LOX/hydrocarbon	jet	solid	lox/kerosene	lox/kerosene	lox/kerosene	jet	lox/paraffin	lox/paraffin	jet/N2O/secret	jet/N2O/secret
Launch Frequency				4/day			months	3-4 per day	3-4 per day	3-4 per day		1/mo		multiple/day	multiple/day
Flight profile		30k ft. release													
Spaceport Support/Facilities															
Runway Length	12,500		12,000			7949 @ 540k lb.		7900	7900	7900	8000			3500	8500
Runway Width	200														
Vehicle Manufacturing/Hangar	103K sq. ft.		47,000 sq. ft.			Outside		10,375 sq. ft.			15,000 sq. ft.	15,000 sq. ft.	15,000 sq. ft.		400,000 sq. ft.
Carrier/Launch Veh Mating		103K sq. ft.		47,000 sq. ft.	47,000 sq. ft.		outside tented								
Launch Vehicle Assembly/Processing		140x40 ft.			10,000 sq. ft.		27,000 sq. ft.								
Payload Processing		30,000 sq. ft.					27,000 sq. ft.								
Pilot/Passenger Facilities			29,400 sq. ft.					austere	austere	austere					
Command and control support															
Vehicle and Payload Command															
Monitoring and Control Systems															
Tracking and Communications		x			x		x					x	x		
Weather Tracking Systems	x	x	x	x	x		x					x	x		
Range Safety		x			x		x					x	x		

[Preliminary Draft for Discussion Purposes Only]

Appendix C Spaceport Comparative Statistics & SWOT Analysis

[Preliminary Draft for Discussion Purposes Only]

C.1 Spaceport Statistics

This section contains brief descriptions of the spaceports analyzed over the course of the competitive review. In addition to presenting the pertinent statistic for the highlighted facilities, each facility entry contains a SWOT (Strengths, Weaknesses, Opportunities, Threats) matrix.

C.1.1 CECIL FIELD

Location: Jacksonville, Florida

Operator: Jacksonville Aviation Authority

Space Industry Clients: None announced

Start of Operations: Received FAA spaceport license in January, 2010, though no commercial space flights have taken place.

FAA License: Licensed by the FAA through January 2015

Cecil Field is located on the site of Naval Station Cecil Field, which was closed by the military in 1999. Since that time the airport has served mainly as a maintenance center for military aircraft with some civilian activity, including the flight training program for Florida State College Jacksonville.

The facility is run by the Jacksonville Aviation Authority and is located within Jacksonville city limits. While there are no commercial space activities currently operating at Cecil Field, it is the first and so far only airport in Florida to have an FCC license for horizontal takeoff and landing spacecraft.

Advantages at Cecil Field include its location its proximity to major transportation hubs as well as support from the Florida state government. It has acquired a FAA license for commercial space operations. It is poised to host a commercial space client but no such client has been announced or rumored.

However, any commercial space client would have to overcome some of the disadvantages of Cecil Field. Jacksonville, and Florida in general, is home some of the busiest air traffic in the country, which could hamper flexibility of test operations out of Cecil Field. Also, only one of the runways at Cecil Field is long enough to host craft like SpaceShipTwo and Lynx, and lengthening the other runways could be hampered by limited free real estate surrounding the facility. Also, the concrete/asphalt composition of Cecil Field’s runways could pose a safety hazard to vehicles like the Lynx which utilize liquid oxygen as an oxidizer.

Cecil Field SWOT Analysis

	Helpful	Harmful
Internal Origin	Strengths • Motivated operating authority interested in developing spaceport • Located within major metropolitan area with easy access for domestic and international space passengers • Location on East Coast makes it more attractive for potential trans-Atlantic flights	Weaknesses • Must coordinate spaceport activities with airport activities • Asphalt runways pose risk to some rocket-powered takeoffs.
External Origin	Opportunities • Proximity to open water will aid future orbital flights if pursued • FAA licensed as a spaceport • State spaceport authority exists to assist lobbying/funding efforts • State indemnification law protects users from litigation • Recipient of Federal grant funds for development of spaceport activities	Threats • No anchor client established nor publically forthcoming • Limited space around the airport constrains ability to extend runways

C.1.2 ELLINGTON SPACEPORT

Location: Houston, Texas

Operator: Houston Airport System

Space Industry Clients: None announced

Start of Operations: Currently no commercial space activity taking place

FAA License: No FAA license currently but pursuing a license with the hope of acquiring one by late 2014

Ellington Airport is one of three major airports located in the Houston metropolitan area, and is currently the least active. Ellington serves as the home base for several US Coast Guard and Texas National Guard units, as well as NASA training and research aircraft. The bulk of activity at Ellington Spaceport is devoted to private general aviation.

Ellington is run by the Houston Airport System and is located within the Houston metropolitan area. While the facility has hosted a strong NASA presence since the 1960's, there has been no commercial space activity at the site to date.

Ellington's advantages as a future hub of commercial spaceflight are due to its unique location, having proximity to one of the largest transportation hubs in the U.S. as well as one of the largest concentrations of space industry expertise in the country. It has strong support from the Houston Airport System to develop its potential as a spaceflight center, as well as a pool of highly skilled space industry professionals in the area. Texas also has enacted indemnification legislation to protect spaceflight operators from litigation in the event of flight mishaps.

Ellington's disadvantages as a spaceport are mostly due to the early stage of its development as well as the difficulties of sharing airspace with two other large airports within a 35-mile radius. Currently, Texas has no dedicated state spaceport authority to push its agenda at the state government level, it is not expected to acquire a FAA commercial space license until late 2014 at the earliest, and it has no commercial spaceflight client attached to the facility. Also, its runways are all less than 10,000 feet long, the accepted minimum length for operating spacecraft such as the SpaceShipTwo and Lynx, and it is unclear if runway lengthening would be feasible given the restricted amount of real estate surrounding the facility.

Ellington Spaceport SWOT Analysis

	Helpful	**Harmful**
Internal Origin	Strengths • Motivated operating authority interested in developing spaceport • Located within major metropolitan area with easy access for domestic and international space passengers • Concrete runways enable use of rocket-powered takeoffs	Weaknesses • Must coordinate spaceport activities with airport activities • Need to coordinate with Hobby and IAH airports for airspace
External Origin	Opportunities • Proximity to open water will aid future orbital flights if pursued • State indemnification law protects users from litigation	Threats • No anchor client established nor publically forthcoming • Limited space around the airport constrains ability to extend runways • Not yet FAA-Licensed • No official State Spaceport Authority • No Federal funding awarded to date

C.1.3 FRONT RANGE AIRPORT

Location: Watkins, Colorado (Denver metropolitan area)

Operator: Front Range Airport Authority

Space Industry Clients: Letter of Intent signed with Rocket Crafters, Inc.

Start of Operations: No current commercial space activity

FAA License: None currently, but plans to seek one at an unspecified future date

Front Range Airport is a small facility located three miles south of Denver International Airport. It is the smallest facility in this survey in terms of land area covered and development of infrastructur,. Activity at the facility is almost entirely dedicated to private general aviation flights.

Front Range is operated by the Front Range Airport Authority and is located in the Denver metropolitan area, 15 miles east of downtown Denver. There is no history of space activity of any kind at Front Range and there are currently no space industry facilities on site.

Front Range's advantages as a future commercial spaceflight center are due primarily to its location and its potential space industry clients. Front Range is located in a relatively unpopulated area that happens to be in close proximity to the major transport hub of Denver. This has the dual advantage of giving it plenty of room to potentially grow while keeping it accessible to outside visitors. It has also managed to sign a letter of intent with Rocket Crafters, Inc., an early-stage suborbital vehicle developer.

Front Range's disadvantages as a future commercial spaceflight center revolve around the limited infrastructure of the site as well as the lack of regulatory support. Front Range is a small facility with little infrastructure in place to handle commercial passenger operations. Its two runways are well short of the accepted 10,000-foot minimum length (although the airport does have expansion plans) and their asphalt composition is a potential fire hazard for vehicles such as the Lynx. It does not yet have an FAA commercial spaceport license. Moreover, Colorado does not have a dedicated statewide commercial spaceflight authority to draw support from the state legislature, although there is an informal coalition of groups supporting the proposed spaceport.

Front Range Airport SWOT Analysis

	Helpful	**Harmful**
Internal Origin	Strengths • Located just outside major metropolitan area with easy access to major international airport for domestic and international space passengers	Weaknesses • Must coordinate spaceport activities with airport activities • Asphalt runways pose risk to rocket-powered takeoffs. • Land-locked location restricts possibility for orbital or point-to-point flights
External Origin	Opportunities • Anchor client established • State indemnification law protects users from litigation • Open space around the airport suggests easy ability to extend runways • Federal grant awarded to help fund feasibility study	Threats • Not yet FAA licensed • No official state spaceport authority

C.1.4 KALAELOA SPACEPORT

Location: Kapolei, Hawai'i (Honolulu metropolitan area)

Operator: Hawaiian Office of Aerospace Development

Space Industry Clients: None currently

Start of Operations: No current commercial space activity

FAA License: None currently but has received $200,000 in state funding to begin licensing process

Kalaeloa Spaceport is the proposed name for a commercial spaceflight facility located on the grounds of the former Naval Station Barbers Point. The facility was previously a dedicated military base but military operations were shut down in 1999 and the facility was handed over to State of Hawai'i. The site currently hosts private general aviation activities.

Kalaeloa is operated by the Hawai'i Office of Aerospace Development and is located on the western outskirts of Honolulu, approximately 25 miles away from the city center and 20 miles from Honolulu International Airport. It does not currently host any commercial space activity.

Kalaeloa's advantages as a potential commercial spaceflight facility are its location and the support provided by the state government. Its proximity to Honolulu makes it easily accessible to potential Asian customers as well as others who take advantage of the well-known and deeply entrenched tourism industry in Hawai'i. The state government has also provided funding towards the facility's development and has also enacted indemnification legislation to encourage commercial spaceflight operators to settle there.

Kalaeloa's disadvantages as a future commercial spaceflight facility are centered on the limitations of its infrastructure as well as a lack of clients. Kalaeloa's facilities are hemmed in on all sides, either by development or the Pacific Ocean, limiting its ability to lengthen its runways, which a fall short of 10,000 feet in length; the runways are also of asphalt composition, creating a potential safety hazard for vehicle using liquid oxygen.

Kalaeloa Spaceport SWOT Analysis

	Helpful	**Harmful**
Internal Origin	Strengths • Located within major metropolitan area with easy access for domestic and international space passengers • Location in mid-Pacific makes it more attractive for potential trans-Pacifc flights	Weaknesses • Must coordinate spaceport activities with airport activities • Asphalt runways pose risk to rocket-powered takeoffs
External Origin	Opportunities • Proximity to open water will aid future orbital flights if pursued • State indemnification law protects users from litigation • Recipient of Federal grant funds for development of spaceport activities • Recipient of state funding	Threats • No anchor client established nor publically forthcoming • Limited space around the airport constrains ability to extend runways • Not FAA licensed as a spaceport

C.1.5 MIDLAND AIRPORT

Location: Midland, Texas (Midland/Odessa metropolitan area)

Operator: City of Midland

Space Industry Clients: XCOR Aerospace

[Preliminary Draft for Discussion Purposes Only]

Start of Operations: Renovations of XCOR facilities underway with start of research activities planned for late 2013

FAA License: None currently but pursuing a license with the hope of acquiring one by late 2013

Midland Airport is a moderately-sized commercial airport serving the Midland/Odessa metropolitan area. It was originally founded as a military installation but has served mainly as a commercial passenger airport since the 1960s. Currently the facility hosts a mix of commercial, military, and private general aviation activity.

Midland Airport is operated by the City of Midland and is located roughly halfway between Midland and Odessa, about 7–8 miles from each city. In addition to hosting commercial passenger flights, Midland Airport will serve as the research and testing facility for the XCOR Lynx spacecraft starting in late 2013.

Midland's advantages towards establishing itself as a commercial spaceflight center lie with a local government amenable to its development as well as having attracted an established commercial space client. The Midland Development Corporation, the city-affiliated economic development organization, has been a strong supporter of commercial spaceflight at Midland Airport, and the State of Texas has enacted indemnification legislation to protect spaceflight operators from litigation.

Midland's disadvantages are due to its location. While it is a short flight away from major transportation hubs, it is not one in and of itself. The Midland/Odessa metropolitan area has a population of about 300,000 but lies approximately 350 miles from the nearest major metropolitan area, Dallas/Fort Worth.

Midland Airport SWOT Analysis

	Helpful	Harmful
Internal Origin	Strengths • Motivated operating authority interested in developing spaceport	Weaknesses • Located far from major metropolitan area with easy access for domestic and international space passengers • Must coordinate spaceport activities with airport activities • Asphalt runways pose risk to rocket-powered takeoffs

	Opportunities	Threats
External Origin	• Anchor client established • Proximity to open water will aid future orbital flights if pursued • State indemnification law protects users from litigation • Recipient of Federal grant funds for development of spaceport activities	• Limited space around the airport constrains ability to extend runways • Land-locked location restricts possibility for orbital or point-to-point flights • Not FAA licensed as a spaceport

C.1.6 MOJAVE AIR & SPACE PORT

Location: Mojave, California, 100 miles north of Los Angeles

Operator: East Kern Airport District

Space Industry Clients: Stratolaunch Systems, Scaled Composites, Masten Space Systems, Orbital Science Corp., Virgin Galactic, XCOR Aerospace, Interorbital Systems, miscellaneous small companies

Start of Operations: Has been a center for aviation research since 1960s but commercial space activities began with construction and testing of SpaceShipOne in early 2000s

FAA License: FAA license first granted in June 2004 with current license good through June 2014

Mojave Air & Space Port is a moderately-sized facility that differs from the other facilities in this survey due to its unique focus. Like several of the other facilities in the survey, Mojave originated as a military airfield before being passed to civilian authorities, but unlike them Mojave does not function as a commercial or private general aviation airport. Rather activities at Mojave are focused on aircraft maintenance and storage as well as flight testing and development of experimental air and space vehicles.

Mojave is operated by the East Kern Airport District and is located in the Mojave Desert north of Edwards Air Force Base and approximately 100 miles from Los Angeles. It has been a center of private aircraft development since the 1970s, due to its proximity to the aircraft industry centers of Lancaster and Palmdale as well as the facilities at Edwards AFB. The National Test Pilot School is located is co-located at Mojave and Scaled Composites, a well-known pioneer in experimental aircraft design and construction, has called Mojave home since the early 1970s. Mojave has more commercial space tenants than any other facility in the survey. Scaled Composites, Stratolaunch Systems, Masten Space Systems, Virgin Galactic, XCOR Aerospace, Interorbital Systems, and Orbital Sciences have facilities at Mojave.

Mojave's has the facilities, the open airspace surrounding it, the pool of highly skilled workers, and the already established core group of commercial space companies, to make it one of the most competitive facilities in this survey. Commercial spacecraft have already flown from Mojave, with SpaceShipTwo currently undergoing its flight test program from the facility.

Mojave's main disadvantage lies in its relatively remote location. The nearest major transportation hub is Los Angeles, at least a two-hour journey away. Also, the facility lacks passenger facilities, as it is a research and development site not geared towards processing passengers.

Mojave Air & Spaceport SWOT Analysis

	Helpful	Harmful
Internal Origin	Strengths • Motivated operating authority interested in developing spaceport • Location near West Coast makes it more attractive for potential trans-Atlantic flights	Weaknesses • Asphalt runways pose risk to rocket-powered takeoffs. • Located far from major metropolitan area with easy access for domestic and international space passengers
External Origin	Opportunities • Several anchor clients established or publically forthcoming • FAA licensed as a spaceport • Recipient of Federal grant funds for development of spaceport activities • Relatively open space around the airport facilitates ability to extend runways	Threats • Distance from open water will hamper future orbital flights if pursued

C.1.7 OKLAHOMA SPACEPORT

Location: Burns Flat, Oklahoma, 100 miles west of Oklahoma City

Operator: Oklahoma Space Industry Development Authority

Space Industry Clients: None currently, but formerly host to Armadillo Aerospace and Rocketplane Kistler

Start of Operations: Commercial space activity started in 2006 but has since shut down with no future activity in the immediate future

FAA License: First acquired FAA license in June 2006 and has current license through June 2016

Oklahoma Spaceport is a repurposed strategic bomber base that was closed down as an active military base in 1969. It currently does not see much activity aside from the occasional training exercise by the Air Force and some private general aviation use.

The facility is operated by the Oklahoma Space Industry Development Association and is located in rural Oklahoma, approximately 100 miles west of Oklahoma City. Oklahoma Spaceport has previously hosted Rocketplane Kistler and Armadillo Aerospace. However, Rocketplane Kistler became defunct while Armadillo Aerospace relocated its test program to Spaceport America.

While Oklahoma Spaceport boasts open airspace and plenty of room at the site, along with a runway suitable for strategic bomber operations, it is currently not competitive as a commercial spaceport. It has an FAA license but lost the commercial space tenants it once had with no sign of new tenants to replace them. There is a state spaceport authority, but there is little indication that its efforts will achieve success in the foreseeable future.

Oklahoma Spaceport's isolation from major transportation hubs and lack of recent activity do not bode well for its future as a commercial spaceport. There are other facilities in this survey that offer more convenient locations and have demonstrated a more dynamic attitude towards attracting and keeping tenants.

Oklahoma Spaceport SWOT Analysis

	Helpful	**Harmful**
Internal Origin	Strengths • Motivated operating authority interested in developing spaceport • Isolation and long concrete runway enable rigorous testing schedule for potential users	Weaknesses • Located far major metropolitan area with easy access for domestic and international space passengers • Land-locked location restricts possibility for orbital or point-to-point flights
External Origin	Opportunities • FAA licensed as a spaceport • State spaceport authority exists to assist lobbying/funding efforts • Recipient of Federal grant funds for development of spaceport activities	Threats • Distance from open water will hamper future orbital flights if pursued • No anchor client established nor publically forthcoming

C.1.8 SHUTTLE LANDING FACILITY

Location: Kennedy Space Center, Florida, 50 miles east of Orlando

Operator: NASA

Space Industry Clients: No commercial client currently, but owned and operated by NASA for Space Shuttle operations

Start of Operations: Operated 1984–2011 as the main landing site of the Space Shuttle with no space activity taking place since then

FAA License: No FAA License currently and no announced plans to acquire one in the foreseeable future

The Shuttle Landing Facility (SLF) is unique among the potential spaceports in this survey due to its ownership, its past purpose, and its location at a major government space launch facility.

The SLF is located on the grounds of the Kennedy Space Center (KSC) and is owned by NASA. It opened in 1984 and served as the main landing facility for the Space Shuttle until the shuttle program ended in 2011. In late June 2013, NASA announced it had selected Space Florida to enter into negotiations for the state agency to take over maintenance and operations of the SLF for potential commercial customers.

The facility’s infrastructure, its location not far from the major transportation hub of Orlando, and the fact that KSC offers a source of highly skilled labor would be advantages for a commercial spaceport. Also, Space Florida is actively looking to repurpose and utilize infrastructure left over from the Space Shuttle program. The facility has mentioned as a possible test or operations site for the Stratolaunch orbital launch system.

Unfortunately, the fact that the facility is NASA-owned and located at KSC could mean more red tape and regulation for any potential commercial space tenants, depending on the terms of any agreement reached between NASA and Space Florida on commercial operations of the SLF. Also, the onsite infrastructure is very basic and passenger facilities would have to be built onsite.

Shuttle Landing Facility SWOT Analysis

	Helpful	Harmful
Internal Origin	Strengths • Located close to major metropolitan area with easy access for domestic and international space passengers • Location on East Coast makes it more attractive for potential trans-Atlantic flights	Weaknesses • Must coordinate spaceport activities with airport activities • Issue of ownership murky as to ability of commercial operators to utilize the site
External Origin	Opportunities • Proximity to open water will aid future orbital flights if pursued • State spaceport authority exists to assist lobbying/funding efforts • State indemnification law protects users from litigation • Recipient of Federal grant funds for development of spaceport activities	Threats • No anchor client established nor publically forthcoming

C.1.9 SPACEPORT AMERICA

Location: 45 miles north of Las Cruces, New Mexico, 110 miles north of El Paso, Texas, 185 miles south of Albuquerque, New Mexico

Operator: New Mexico Spaceport Authority

Space Industry Clients: Virgin Galactic, SpaceX, Armadillo Aerospace, UP Aerospace, Lockheed Martin

Start of Operations: Formally opened October, 2011

FAA License: Licensed since 2008, current license extends through December 2013

Spaceport America is unique in this survey because it is the world's only dedicated commercial spaceport, being built from scratch to serve the commercial spaceflight industry.

Operated by the New Mexico Spaceport Authority, it was officially opened in late 2011 and is currently hosting commercial space research and development flights. It will also be the future site of commercial human flights to space through Virgin Galactic. In addition to Virgin Galactic, Spaceport America hosts test flights by Armadillo Aerospace, UP Aerospace, and Lockheed Martin; SpaceX agreed earlier this year to conduct future flights of its Grasshopper reusable launch vehicle technology demonstration testbed at the spaceport.

Spaceport America is the most competitive facility in this survey principally because is already a working commercial spaceport. It boasts the combination of facilities, tenants, funding, publicity, and FAA approval that no other potential spaceport can.

Spaceport America's only major disadvantage is its remote location. Located 110 miles from the nearest major transportation hub, Spaceport America is one of the least conveniently located of the facilities in this survey. Other than that however, it possesses every advantage to maintain its lead as America's leading commercial spaceport for the foreseeable future.

Spaceport America SWOT Analysis

	Helpful	**Harmful**
Internal Origin	Strengths • Motivated Operating Authority interested in developing spaceport • Isolation and long concrete runway enable rigorous testing schedule for potential users	Weaknesses • Located far from major metropolitan area with easy access for domestic and international space passengers • Land-locked location restricts possibility for orbital or point-to-point flights
External Origin	Opportunities • Several anchor clients established or publically forthcoming • FAA licensed as a spaceport • State spaceport authority exists to assist lobbying/funding efforts • State indemnification law protects users from litigation • Recipient of Federal grant funds for development of spaceport activities	Threats •

[Preliminary Draft for Discussion Purposes Only]

Appendix D Point-to-Point Technology Status

[Preliminary Draft for Discussion Purposes Only]

D.1 Leveraging JSC for P2P Research at EFD

Point-to-Point Technology Status Matrix

TECHNOLOGY AREA	DESCRIPTION (RELEVANCE FOR P2P)	TECHNOLOGY ISSUES TO OVERCOME	CURRENT DEVELOPMENT STATUS FOR P2P	TRL	JSC CAPABILITY: LAB/TEST ENVIRONMENT / DIRECTORATE
Propulsion	• Highly operable/quick-turn LOX/Hydrocarbon Engines • Combined Cycle Propulsion (RBCC, TBCC) • Rotating Detonation Engines (RDEs)	• Integrated airbreathing & rocket engines • High performance over wide range of operating conditions • High reliability & operable rocket engine systems	• Far from fully integrated operable systems • Transitions to/from airbreathing being explored at fundamental levels • Currently no development in long life, highly operable fully reusable engines	• Rockets TRL 4-5 • Combined cycle TRL 1-3 • Air-breathing TRL 6-8	JSC Engineering Directorate Energy Systems Test Area
Thermal Protection & Management	• Sharp leading edge TPS, highly operable with built-in health mgmt • Materials range from metallics to advanced ceramic-based composites • Could also consider active cooling systems	• High heat load designs for extended duration/environments • Operability allowing quick-turn with minimal maintenance • Light weight systems • Specific technologies needed are highly dependent on mission details	• Ceramics and metallics currently being explored to accommodate sharp leading edges and robustness • TPS operability not yet primary consideration • Limited active cooling development/testing	• Passive System TRL 4-5 • Active systems TRL 2-3	JSC Engineering Directorate Radiant Heat Testing
Vehicle Design & Structure	• High Temperature Composite Structures (minimize TPS requirements) • High L/D designs	• Demonstrate high reuse, low inspection vehicle design • Material compatibility in relevant environments • Sharp leading edge shapes for high L/D	• Only < Mach 2 operational experience • Greater than Mach 5 material technologies have very limited flight experience • Additional development required on sharp leading edge designs	• Mach 4-6 TRL 4-5	JSC Engineering Directorate Structures Test Laboratory
Communications	• Ground based communication systems existing technology • Space-based would benefit from lightweight transponders and low cost space comm networks	• Lightweight, low cost communications for space based communications • Doppler compatibility	• TDRSS, INMARSAT • Need light weight transponders, low cost recurring operations	• TRL 7-9	JSC Engineering Directorate Communication Systems Simulation Laboratory (CSSL)

[Preliminary Draft for Discussion Purposes Only]

TECHNOLOGY AREA	DESCRIPTION (RELEVANCE FOR P2P)	TECHNOLOGY ISSUES TO OVERCOME	CURRENT DEVELOPMENT STATUS FOR P2P	TRL	JSC CAPABILITY: LAB/TEST ENVIRONMENT / DIRECTORATE
Guidance, Navigation & Control	• Robust GN&C architecture with multiple fault tolerance (redundancy) • Rapid mission planning • Compatibility with traditional aircraft traffic	• Coordination between space and air traffic systems • Explore Automated Dependent Surveillance-Broadcast (ADS-B) in development for aircraft	• Fully automated GN&C architectures being developed for UAVs • ADS-B in development for aircraft	• TRL 6-8	JSC Engineering Directorate Advanced Guidance, Navigation and Control Development Laboratory
Reliability	• Critical factor for the success of the PTP mission	• Propulsion system reliability approaching that of modern gas turbines • Robust TPS and materials requiring minimal maintenance and with health mgmt • Reusable airframe designed for harsh hypersonic flight environments	• Little to no reliability assessments exist for operational engine systems of this type • Some material reliability testing by not primary focus • STS, X-15 and SR-71 airframe design philosophies exist, but no best practices exist for future vehicles	• Prop Sys: TRL 2-3 • Materials: TRL 5-6 • Airframe: TRL 7-8 • GN&C: TRL 6-8	JSC Engineering Directorate Relex Reliability Prediction Tool
In-Flight Safety/Crew and Passenger Safety	• Maximize potential for safe abort through entire flight regime	• Detailed FMECA and incremental flight test and developing controls • Technology, abort options, elimination of failure modes	• Principally based on civil (NASA) manned spaceflight • Need to achieve significant improvements in control/accommodation of failure modes	• Principally an analytical activity (TRL is Not Applicable)	JSC Flight Crew Operations Directorate
Space Radiation	• Not a concern for short duration flights • The vehicle materials and cargo packaging would likely be sufficient to protect payload	•	•	•	NASA Space Radiation Analysis Group at JSC
Space Debris	• Only a concern if vehicle trajectory crosses through spacecraft orbit altitudes • Even so, launch window timing could mitigate concern	• Very unlikely for non-global P2P • Even so, launch window timing could mitigate concern	•	•	NASA Orbital Debris Program Office at JSC.
Pilot & Crew Requirements	• Training, Medical, and Human Factors (including interior cockpit & cabin) requirements need to be defined	• Defining training requirements is principally analytical not a technology	•	• Principally an analytical activity (TRL is Not Applicable)	JSC Flight Crew Operations Directorate JSC Mission Operations Directorate

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TECHNOLOGY AREA	DESCRIPTION (RELEVANCE FOR P2P)	TECHNOLOGY ISSUES TO OVERCOME	CURRENT DEVELOPMENT STATUS FOR P2P	TRL	JSC CAPABILITY: LAB/TEST ENVIRONMENT / DIRECTORATE
	• FAA, NASA, and/or Military air and space requirements as basis?				
ECLSS	• Maximize protection against cabin leak • Highly reliable life support/accommodations	• Decision whether or not to have closed loop atmosphere • Defining redundancy requirements for life support systems	•	• TRL 6-8	JSC Engineering Directorate JSC Mission Operations Directorate

Prepared by: XSC, 2013

[Preliminary Draft for Discussion Purposes Only]

Appendix E Spaceport Facilities Database

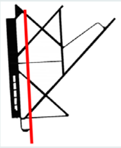
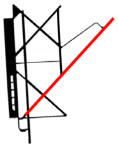
[Preliminary Draft for Discussion Purposes Only]

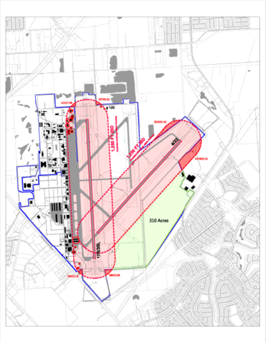
E.1 Facilities Database

[Preliminary Draft for Discussion Purposes Only]

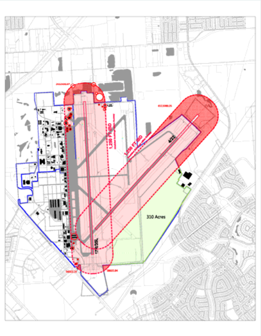
E.2 Runway Extension Options

Table 10-A: Runway Extension Options

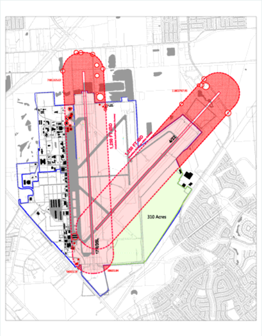
RUNWAY	WIND	VEHICLE CLASS RUNWAY REQUIRMENT	RUNWAY	LENGTH (FT)	WIDTH (FT)	ADDED PAVING AREA (FT2)	PAVING COST ($/FT2)	PAVING TOTAL ($M)
17R/35L 	Prevailing winds, preferable for glider return	• Firehawk - 3,500 ft. (trainer) • Lynx II - 7,900 ft. • Pegasus - 7,949 ft • Go2 - 8,000 ft. • Sidereus - 8,500 ft.	Current	9,001	150	0	$0.00	**$0**
		• VG WK2/SS2 (maybe) • VG Launcher One (maybe)	Extension 1	10,000	150	149,850	$90.16	**$14**
		• Stratolaunch requires 12,500 ft	Extension 2	12,000	200	1,049,850	$90.16	**$95**
4/22 	Glide return problem on cross wind situation	• Firehawk - 3,500 ft. (trainer) • Lynx II - 7,900 ft. • Pegasus - 7,949 ft • Go2 - 8,000 ft. • Sidereus - 8,500 ft.	Current	8,001	150	0	$0.00	**$0**
		• VG WK2/SS2 (maybe) • VG Launcher One (maybe)	Extension 1	10,000	150	299,850	$90.16	**$27**
		• Stratolaunch requires 12,500 ft	Extension 2	12,000	200	1,199,850	$90.16	**$108**



Current



10,000 ft.



12,000 ft.

Source: XSC, 2013

Appendix E

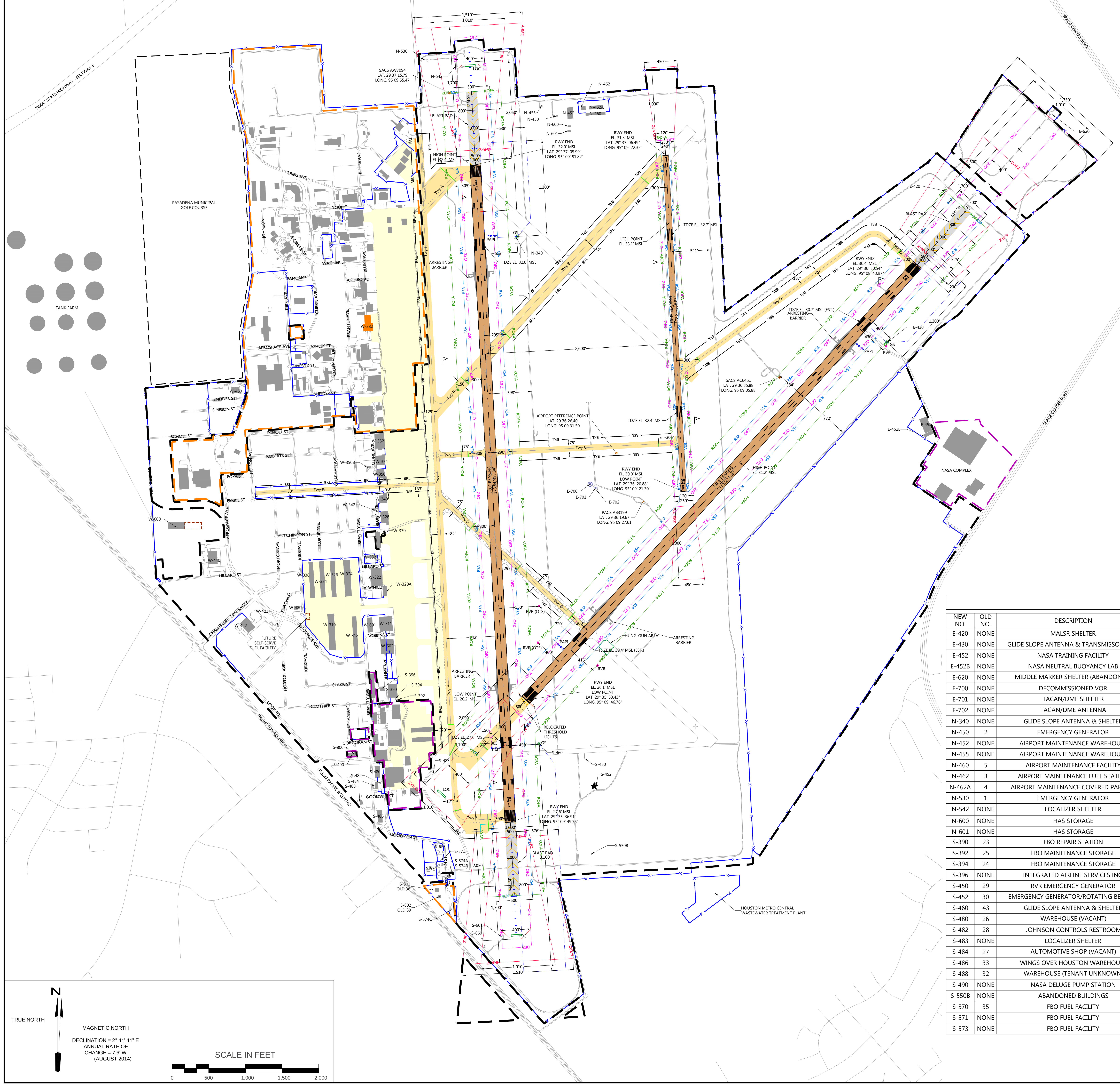
Pavement Conditions Assessment

HAS Pavement Condition Assessment
EFD Pavements

Network ID	Branch ID	Branch Name	Section ID	CIP Project Year	Planning Horizon	Priority	Near Term	Long Term	CIP Project Work	CIP Project Costs W/Soft Costs	CIP Project Cost	Acutal Condition Index (ACI)	Facility Condition Index (FCI)	Section Condition Index (FCI)	Section Replacement Value (CRV) W/Soft Costs	Section Replacement Value (CRV)	Section Deferred Maintenance Costs (DM) W/Soft Costs	Section Deferred Maintenance Costs (DM)	PAVER M&R Section Maint Costs W/Soft Costs	PAVER M&R Section Maint Costs	Remaining Structural Life, yrs	2014 PCI	2019 PCI	2024 PCI	True Area (SqFt)	Pavement Type	PCC Type
EFD	100	TAXIWAY A	105	-	-	-	-	-	-	-	-	10.00	0.00	0.00	$ 1,468,149	$ 965,887	$ 220	$ 145	$ 220	$ 145	>20	98	96	94	49,609	PCC	Non-CRCP
EFD	100	TAXIWAY A	110	-	-	-	-	-	-	-	-	10.00	0.00	0.00	$ 3,159,557	$ 2,078,656	$ -	$ -	$ -	$ -	>20	100	98	96	106,762	PCC	Non-CRCP
EFD	100	TAXIWAY A	120	-	-	-	-	-	-	-	-	10.00	0.00	0.00	$ 747,229	$ 491,598	$ 220	$ 145	$ 220	$ 145	>20	98	96	94	25,249	PCC	Non-CRCP
EFD	200	TAXIWAY B	205	-	-	-	-	-	-	-	-	10.00	0.01	0.00	$ 1,374,216	$ 904,089	$ 4,821	$ 3,172	$ 4,821	$ 3,172	>20	97	95	93	46,435	PCC	Non-CRCP
EFD	200	TAXIWAY B	210	-	-	-	-	-	-	-	-	10.00	0.01	0.00	$ 1,500,347	$ 987,071	$ 440	$ 290	$ 440	$ 290	>20	98	96	94	50,697	PCC	Non-CRCP
EFD	200	TAXIWAY B	220	-	-	-	-	-	-	-	-	10.00	0.01	0.01	$ 1,116,597	$ 734,603	$ 9,381	$ 6,172	$ 9,381	$ 6,172	>20	91	89	87	37,730	PCC	Non-CRCP
EFD	200	TAXIWAY B	225	-	-	-	-	-	-	-	-	10.00	0.01	0.01	$ 1,658,914	$ 1,091,391	$ 14,864	$ 9,779	$ 14,864	$ 9,779	>20	94	92	90	56,055	PCC	Non-CRCP
EFD	200	TAXIWAY B	233	2022	Long Term	-	-	$ 6,984,646	PCC RECON	$6,984,646	$4,595,162	3.00	1.00	1.00	$ 5,990,794	$ 3,941,312	$ 5,990,794	$ 3,941,312	$ 123,898	$ 81,512	<5	58	56	54	202,430	PCC	Non-CRCP
EFD	200	TAXIWAY B	235	2023	Long Term	-	-	$ 8,906,449	PCC RECON	$8,906,449	$5,859,506	3.00	1.00	1.00	$ 7,639,143	$ 5,025,752	$ 7,639,143	$ 5,025,752	$ 153,649	$ 101,085	<5	75	73	71	258,128	PCC	Non-CRCP
EFD	300	TAXIWAY C	305	-	-	-	-	-	-	-	-	10.00	0.01	0.00	$ 1,167,825	$ 768,306	$ 92	$ 60	$ 92	$ 60	>20	93	91	89	39,461	PCC	Non-CRCP
EFD	300	TAXIWAY C	306	-	-	-	-	-	-	-	-	10.00	0.01	0.00	$ 301,153	$ 198,127	$ -	$ -	$ -	$ -	>20	100	98	96	10,176	PCC	Non-CRCP
EFD	300	TAXIWAY C	307	-	-	-	-	-	-	-	-	10.00	0.01	0.01	$ 303,343	$ 199,568	$ 2,660	$ 1,750	$ 2,660	$ 1,750	>20	94	92	90	10,250	PCC	Non-CRCP
EFD	300	TAXIWAY C	310	-	-	-	-	-	-	-	-	10.00	0.01	0.00	$ 5,213,054	$ 3,429,641	$ 2,613	$ 1,719	$ 2,613	$ 1,719	>20	90	88	86	176,150	PCC	Non-CRCP
EFD	400	TAXIWAY D	405	-	-	-	-	-	-	-	-	10.00	0.01	0.00	$ 1,328,345	$ 873,911	$ -	$ -	$ -	$ -	>20	99	97	95	44,885	PCC	Non-CRCP
EFD	400	TAXIWAY D	410	-	-	-	-	-	-	-	-	10.00	0.01	0.00	$ 698,990	$ 459,862	$ -	$ -	$ -	$ -	>20	98	96	94	23,619	PCC	Non-CRCP
EFD	400	TAXIWAY D	415	-	-	-	-	-	-	-	-	10.00	0.01	0.01	$ 213,612	$ 140,534	$ 2,327	$ 1,531	$ 2,327	$ 1,531	>20	87	85	83	7,218	PCC	Non-CRCP
EFD	400	TAXIWAY D	417	-	-	-	-	-	-	-	-	10.00	0.01	0.00	$ 594,877	$ 391,366	$ -	$ -	$ -	$ -	>20	99	97	95	20,101	PCC	Non-CRCP
EFD	400	TAXIWAY D	425	-	-	-	-	-	-	-	-	10.00	0.01	0.00	$ 2,887,674	$ 1,899,785	$ 9,382	$ 6,173	$ 9,382	$ 6,173	>20	92	90	88	97,575	PCC	Non-CRCP
EFD	400	TAXIWAY D	435	-	-	-	-	-	-	-	-	10.00	0.01	0.00	$ 1,248,351	$ 821,284	$ 183	$ 121	$ 183	$ 121	>20	99	97	95	42,182	PCC	Non-CRCP
EFD	500	TAXIWAY E	505	-	-	-	-	-	-	-	-	10.00	0.02	0.00	$ 172,802	$ 113,685	$ 220	$ 145	$ 220	$ 145	>20	82	80	78	5,839	PCC	Non-CRCP
EFD	500	TAXIWAY E	510	-	-	-	-	-	-	-	-	10.00	0.02	0.00	$ 865,192	$ 569,205	$ 220	$ 145	$ 220	$ 145	>20	94	92	90	29,235	PCC	Non-CRCP
EFD	500	TAXIWAY E	515	-	-	-	-	-	-	-	-	10.00	0.02	0.00	$ 1,457,495	$ 958,878	$ -	$ -	$ -	$ -	>20	97	95	93	49,249	PCC	Non-CRCP
EFD	500	TAXIWAY E	520	-	-	-	-	-	-	-	-	10.00	0.02	0.00	$ 1,417,897	$ 932,827	$ -	$ -	$ -	$ -	>20	98	96	94	47,911	PCC	Non-CRCP
EFD	500	TAXIWAY E	545	-	-	-	-	-	-	-	-	10.00	0.02	0.02	$ 1,559,033	$ 1,025,680	$ 26,075	$ 17,155	$ 26,075	$ 17,155	>20	82	80	78	52,680	PCC	Non-CRCP
EFD	600	TAXIWAY F	610	-	-	-	-	-	-	-	-	10.00	0.00	0.00	$ 1,950,271	$ 1,283,073	$ 275	$ 181	$ 275	$ 181	>20	96	94	92	65,900	PCC	Non-CRCP
EFD	600	TAXIWAY F	620	-	-	-	-	-	-	-	-	10.00	0.00	0.00	$ 1,218,017	$ 801,327	$ 6,034	$ 3,970	$ 6,034	$ 3,970	>20	98	96	94	41,157	PCC	Non-CRCP
EFD	600	TAXIWAY F	630	-	-	-	-	-	-	-	-	10.00	0.00	0.00	$ 868,980	$ 571,698	$ 3,910	$ 2,572	$ 3,910	$ 2,572	>20	90	88	86	29,363	PCC	Non-CRCP
EFD	600	TAXIWAY F	635	-	-	-	-	-	-	-	-	10.00	0.00	0.00	$ 1,579,779	$ 1,039,328	$ -	$ -	$ -	$ -	>20	99	97	95	53,381	PCC	Non-CRCP
EFD	700	TAXIWAY G	705	2020	Near Term	-	$ 9,840,404	-	PCC RECON	$9,840,404	$6,473,950	5.00	1.00	1.00	$ 8,440,205	$ 5,552,766	$ 8,440,205	$ 5,552,766	$ 41,956	$ 27,603	<5	86	84	82	285,196	PCC	Non-CRCP
EFD	700	TAXIWAY G	709	2020	Near Term	-	$ 196,638	-	PCC RECON	$196,638	$129,367	5.00	1.00	1.00	$ 168,658	$ 110,960	$ 168,658	$ 110,960	$ -	$ -	<5	93	91	89	5,699	PCC	Non-CRCP
EFD	700	TAXIWAY G	710	2021	Near Term	-	$ 269,373	-	PCC RECON	$269,373	$177,219	5.00	1.00	1.00	$ 231,043	$ 152,002	$ 231,043	$ 152,002	$ 36	$ 23	<5	88	86	84	7,807	PCC	Non-CRCP
EFD	800	TAXIWAY H	813	-	-	-	-	-	-	-	-	10.00	0.00	0.00	$ 818,818	$ 538,696	$ -	$ -	$ -	$ -	>20	94	92	90	27,668	PCC	Non-CRCP
EFD	800	TAXIWAY H	814	-	-	-	-	-	-	-	-	10.00	0.00	0.00	$ 527,609	$ 347,111	$ -	$ -	$ -	$ -	>20	94	92	90	17,828	PCC	Non-CRCP
EFD	800	TAXIWAY H	815	-	-	-	-	-	-	-	-	10.00	0.00	0.00	$ 4,293,733	$ 2,824,824	$ 183	$ 121	$ 183	$ 121	>20	98	96	94	145,086	PCC	Non-CRCP
EFD	800	TAXIWAY H	820	-	-	-	-	-	-	-	-	10.00	0.00	0.00	$ 3,912,942	$ 2,574,304	$ 587	$ 386	$ 587	$ 386	>20	94	92	90	132,219	PCC	Non-CRCP
EFD	800	TAXIWAY H	823	-	-	-	-	-	-	-	-	10.00	0.00	0.00	$ 283,662	$ 186,620	$ 312	$ 205	$ 312	$ 205	>20	83	81	79	9,585	PCC	Non-CRCP
EFD	800	TAXIWAY H	825	-	-	-	-	-	-	-	-	10.00	0.00	0.00	$ 2,928,070	$ 1,926,362	$ 183	$ 121	$ 183	$ 121	>20	96	94	92	98,940	PCC	Non-CRCP
EFD	800	TAXIWAY H	830	-	-	-	-	-	-	-	-	10.00	0.00	0.00	$ 5,092,160	$ 3,350,106	$ 275	$ 181	$ 275	$ 181	>20	95	93	91	172,065	PCC	Non-CRCP
EFD	9100	RUNWAY 17R-35L	9103	-	-	-	-	-	-	-	-	10.00	0.00	0.00	$ 1,464,923	$ 963,765	$ 312	$ 205	$ 312	$ 205	>20	99	98	98	49,500	PCC	Non-CRCP
EFD	9100	RUNWAY 17R-35L	9106	-	-	-	-	-	-	-	-	10.00	0.00	0.00	$ 1,845,033	$ 1,213,838	$ -	$ -	$ -	$ -	>20	99	98	98	62,344	PCC	Non-CRCP
EFD	9100	RUNWAY 17R-35L	9109	-	-	-	-	-	-	-	-	10.00	0.00	0.00	$ 2,929,846	$ 1,927,530	$ 1,284	$ 845	$ 1,284	$ 845	>20	98	98	97	99,000	PCC	Non-CRCP
EFD	9100	RUNWAY 17R-35L	9112	-	-	-	-	-	-	-	-	10.00	0.00	0.00	$ 3,693,647	$ 2,430,031	$ 8,600	$ 5,658	$ 8,600	$ 5,658	>20	96	94	92	124,809	PCC	Non-CRCP
EFD	9100	RUNWAY 17R-35L	9115	-	-	-	-	-	-	-	-	10.00	0.00	0.00	$ 1,464,923	$ 963,765	$ 4,146	$ 2,728	$ 4,146	$ 2,728	>20	97	96	94	49,500	PCC	Non-CRCP
EFD	9100	RUNWAY 17R-35L	9118	-	-	-	-	-	-	-	-	10.00	0.00	0.00	$ 2,174,153	$ 1,430,364	$ 495	$ 326	$ 495	$ 326	>20	99	98	98	73,465	PCC	Non-CRCP
EFD	9100	RUNWAY 17R-35L	9121	-	-	-	-	-	-	-	-	10.00	0.00	0.00	$ 488,308	$ 321,255	$ -	$ -	$ -	$ -	>20	98	98	97	16,500	PCC	Non-CRCP
EFD	9100	RUNWAY 17R-35L	9124	-	-	-	-	-	-	-	-	10.00	0.00	0.00	$ 615,593	$ 404,995	$ -	$ -	$ -	$ -	>20	96	94	92	20,801	PCC	Non-CRCP
EFD	9100	RUNWAY 17R-35L	9127	-	-	-	-	-	-	-	-	10.00	0.00	0.00	$ 1,660,246	$ 1,092,267	$ 92	$ 60	$ 92	$ 60	>20	99	98	98	56,100	PCC	Non-CRCP
EFD	9100	RUNWAY 17R-35L	9130	-	-	-	-	-	-	-	-	10.00	0.00	0.00	$ 2,094,484	$ 1,377,950	$ 183	$ 121	$ 183	$ 121	>20	99	98	98	70,773	PCC	Non-CRCP
EFD	9100	RUNWAY 17R-35L	9133	-	-	-	-	-	-	-	-	10.00	0.00	0.00	$ 1,757,907	$ 1,156,518	$ 92	$ 60	$ 92	$ 60	>20	99	98	98	59,400	PCC	Non-CRCP
EFD	9100	RUNWAY 17R-35L	9136	-	-	-	-	-	-	-	-	10.00	0.00	0.00	$ 2,218,219	$ 1,459,354	$ 1,193	$ 785	$ 1,193	$ 785	>20	98	98	97	74,954	PCC	Non-CRCP
EFD	9100	RUNWAY 17R-35L	9139	-	-	-	-	-	-	-	-	10.00	0.00	0.00	$ 976,615	$ 642,510	$ 220	$ 145	$ 220	$ 145	>20	98	98	97	33,000	PCC	Non-CRCP
EFD	9100	RUNWAY 17R-35L	9142	-	-	-	-	-	-	-	-	10.00	0.00	0.00	$ 1,231,689	$ 810,322	$ 183	$ 121	$ 183	$ 121	>20	99	98	98	41,619	PCC	Non-CRCP
EFD	9100	RUNWAY 17R-35L	9145	-	-	-	-	-	-	-	-	10.00	0.00	0.00	$ 1,562,584	$ 1,028,016	$ 1,101	$ 724	$ 1,101	$ 724	>20	98	98	97	52,800	PCC	Non-CRCP
EFD	9100	RUNWAY 17R-35L	9148	-	-	-	-	-	-	-	-	10.00	0.00	0.00	$ 1,973,710	$ 1,298,493	$ 752	$ 495	$ 752	$ 495	>20	98	98	97	66,692	PCC	Non-CRCP
EFD	9100	RUNWAY 17R-35L	9151	-	-	-	-	-	-	-	-	10.00	0.00	0.00	$ 2,638,578	$ 1,735,906	$ 275	$ 181	$ 275	$ 181	>20	98	98	97	89,158	PCC	Non-CRCP
EFD	9100	RUNWAY 17R-35L	9154	-	-	-	-	-	-	-	-	10.00	0.00	0.00	$ 2,663,496	$ 1,752,300	$ 716	$ 471	$ 716	$ 471	>20	97	96	94	90,000	PCC	Non-CRCP
EFD	9100	RUNWAY 17R-35L	9157	-	-	-	-	-	-	-	-	10.00	0.00	0.00	$ 442,969	$ 291,427	$ -	$ -	$ -	$ -	>20	97	96	94	14,968	PCC	Non-CRCP
EFD	9100	RUNWAY 17R-35L	9160	-	-	-	-	-	-	-	-	10.00	0.00	0.00	$ 886,175	$ 583,010	$ -	$ -	$ -	$ -	>20	96	94	92	29,944	PCC	Non-CRCP
EFD	9100	RUNWAY 17R-35L	9163	-	-	-	-	-	-	-	-	10.00	0.00	0.00	$ 2,887,881	$ 1,899,922	$ 661	$ 435	$ 661	$ 435	>20	98	98	97	97,582	PCC	Non-CRCP
EFD	9100	RUNWAY 17R-35L	9166	-	-	-	-	-	-	-	-	10.00	0.00	0.00	$ 2,961,837	$ 1,948,577	$ 404	$ 266	$ 404	$ 266	>20	98	98	97	100,081	PCC	Non-CRCP
EFD	9200	RUNWAY 4-22	9205	-	-	-	-	-	-	-	-	7.00	0.00	0.00	$ 1,679,482	$ 1,104,923	$ -	$ -	$ -	$ -	>20	98	98	97	56,750	PCC	Non-CRCP
EFD	9200	RUNWAY 4-22	9210	-	-	-	-	-	-	-	-	7.00	0.00	0.00	$ 3,387,523	$ 2,228,634	$ 844	$ 555	$ 844	$ 555	>20	96	94	92	114,465	PCC	Non-CRCP
EFD	9200	RUNWAY 4-22	9215	-	-	-	-	-	-	-	-	7.00	0.00	0.00	$ 2,367,286	$ 1,557,425	$ -	$ -	$ -	$ -	>20	100	99	98	79,991	PCC	Non-CRCP
EFD	9200	RUNWAY 4-22	9220	-	-	-	-	-	-	-	-	7.00	0.00	0.00	$ 2,395,933	$ 1,576,272	$ -	$ -	$ -	$ -	>20	98	98	97	80,959	PCC	Non-CRCP
EFD	9200	RUNWAY 4-22	9225	-	-	-	-	-	-	-	-	7.00	0.00	0.00	$ 2,888,561	$ 1,900,369	$ -	$ -	$ -	$ -	>20	98	98	97	97,605	PCC	Non-CRCP
EFD	9200	RUNWAY 4-22	9230	-	-	-	-	-	-	-	-	7.00	0.00	0.00	$ 2,934,285	$ 1,930,451	$ 220	$ 145	$ 220	$ 145	>20	98	98	97	99,150	PCC	Non-CRCP
EFD	9200	RUNWAY 4-22	9235	-	-	-	-	-	-	-	-	7.00	0.00	0.00	$ 2,649,587	$ 1,743,149	$ -	$ -	$ -	$ -	>20	97	96	94	89,530	PCC	Non-CRCP
EFD	9200	RUNWAY 4-22	9240	2016	Priority	$ 613,135	-	-	PCC CPR	$613,135	$403,378	7.00	0.00	0.00	$ 2,600,815	$ 1,711,063	$ 9,360	$ 6,158	$ 9,360	$ 6,158	>20	62	58	54	87,882	PCC	Non-CRCP
EFD	9200	RUNWAY 4-22	9242	-	-	-	-	-	-	-	-	7.00	0.00	0.00	$ 2,663,496	$ 1,752,300	$ 92	$ 60	$ 92	$ 60	>20	96	94	92	90,000	PCC	Non-CRCP
EFD	9200	RUNWAY 4-22	9245	-	-	-	-	-	-	-	-	7.00	0.00	0.00	$ 5,353,627	$ 3,522,123	$ -	$ -	$ -	$ -	>20	99	98	98	180,900	PCC	Non-CRCP
EFD	9200	RUNWAY 4-22	9250	2016	Priority	$ 631,051	-	-	PCC CPR	$631,051	$415,165	7.00	0.00	0.00	$ 2,676,813	$ 1,761,062	$ 4,497	$ 2,959	$ 4,497	$ 2,959	>20	65	61	57	90,450	PCC	Non-CRCP
EFD	9200	RUNWAY 4-22	9255	-	-	-	-	-	-	-	-	7.00	0.00	0.00	$ 2,388,268	$ 1,571,229	$ -	$ -	$ -	$ -	>20	97	96	94	80,700	PCC	Non-CRCP
EFD	9200	RUNWAY 4-22	9260	2016	Priority	$ 240,072	-	-	PCC CPR	$240,072	$157,942	7.00	0.00	0.00	$ 1,018,343	$ 669,963	$ 2,219	$ 1,460	$ 2,219	$ 1,460	>20	65	61	57	34,410	PCC	Non-CRCP
EFD	9200	RUNWAY 4-22	9262	-	-	-	-	-	-	-	-	7.00	0.00	0.00	$ 160,165	$ 105,372	$ -	$ -	$ -	$ -	>20	87	83	78	5,412	PCC	Non-CRCP
EFD	9300	RUNWAY 17L-35R	9315	2020	Near Term	-	$ 1,418,978	-	PCC RECON	$1,418,978	$933,538	3.00	1.00	1.00	$ 1,217,070	$ 800,704	$ 1,217,070	$ 800,704	$ 217,069	$ 142,809	>20	34	30	26	41,125	PCC	Non-CRCP
EFD	9300	RUNWAY 17L-35R	9320	2020	Near Term	-	$ 525,669	-	PCC RECON	$525,669	$345,835	3.00	1.00	1.00	$ 450,871	$ 296,625	$ 450,871	$ 296,625	$ 72,963	$ 48,002	>20	44	40	36	15,235	PCC	Non-CRCP
EFD	9300	RUNWAY 17L-35R	9323	2019	Near Term	-	$ 35,504	-	PCC RECON	$35,504	$23,358	3.00	1.00	1.00	$ 30,453	$ 20,035	$ 30,453	$ 20,035	$ 6,511	$ 4,283	<5	57	53	49	1,029	PCC	Non-CRCP
EFD	9300	RUNWAY 17L-35R	9325	2019	Near Term	-	$ 2,070,033	-	PCC RECON	$2,070,033	$1,361,864	3.00	1.00	1.00	$ 1,775,486	$ 1,168,083	$ 1,775,486	$ 1,168,083	$ 4,434	$ 2,917	<5	87	83	78	59,994	PCC	Non-CRCP
EFD	9300	RUNWAY 17L-35R	9327	2019	Near Term	-	$ 198,121	-	PCC RECON	$198,121	$130,343	3.00	1.00	1.00	$ 169,931	$ 111,797	$ 169,931	$ 111,797	$ 239	$ 157	<5	84	79	74	5,742	PCC	Non-CRCP
EFD	9300	RUNWAY 17L-35R	9329	2019	Near Term	-	$ 124,146	-	PCC RECON	$124,146	$81,675	3.00	1.00	1.00	$ 106,481	$ 70,053	$ 106,481	$ 70,053	$ 45	$ 30	<5	51	47	43	3,598	PCC	Non-CRCP
EFD	9300	RUNWAY 17L-35R	9330	2019	Near Term	-	$ 862,393	-	PCC RECON	$862,393	$567,364	3.00	1.00	1.00	$ 739,682	$ 486,633	$ 739,682	$ 486,633	$ 54,468	$ 35,834	<5	56	52	48	24,994	PCC	Non-CRCP
EFD	9300	RUNWAY 17L-35R	9331	2019	Near Term	-	$ 27,086	-	PCC RECON	$27,086	$17,820	3.00	1.00	1.00	$ 23,232	$ 15,284	$ 23,232	$ 15,284	$ 1,678	$ 1,104	<5	39	35	31	785	PCC	Non-CRCP
EFD	9300	RUNWAY 17L-35R	9332	2019	Near Term	-	$ 179,421	-	PCC RECON	$179,421	$118,040	3.00	1.00	1.00	$ 153,891	$ 101,244	$ 153,891	$ 101,244	$ -	$ -	<5	82	77	72	5,200	PCC	Non-CRCP
EFD	9300	RUNWAY 17L-35R	9333	2018	Near Term	-	$ 1,310,290	-	PCC RECON	$1,310,290	$862,033	3.00	1.00	1.00	$ 1,123,847	$ 739,373	$ 1,123,847	$ 739,373	$ 10,260	$ 6,750	<5	64	60	56	37,975	PCC	Non-CRCP
EFD	9300	RUNWAY 17L-35R	9334	2019	Near Term	-	$ 115,933	-	PCC RECON	$115,933	$76,272	3.00	1.00	1.00	$ 99,437	$ 65,419	$ 99,437	$ 65,419	$ -	$ -	<5	98	98	97	3,360	PCC	Non-CRCP
EFD	9300	RUNWAY 17L-35R	9335	2018	Near Term	-	$ 2,971,139	-	PCC RECON	$2,971,139	$1,954,697	3.00	1.00	1.00	$ 2,548,374	$ 1,676,562	$ 2,548,374	$ 1,676,562	$ 4,494	$ 2,957	<5	73	68	63	86,110	PCC	Non-CRCP
EFD	9300	RUNWAY 17L-35R	9337	2017	Priority	$ 2,005,546	-	-	PCC RECON	$2,005,546	$1,319,438	3.00	1.00	1.00	$ 1,720,175	$ 1,131,694	$ 1,720,175	$ 1,131,694	$ 8,455	$ 5,562	<5	55	51	47	58,125	PCC	Non-CRCP
EFD	9300	RUNWAY 17L-35R	9338	2017	Priority	$ 94,128	-	-	PCC RECON	$94,128	$61,926	3.00	1.00	1.00	$ 80,734	$ 53,114	$ 80,734	$ 53,114	$ 6,511	$ 4,283	<5	50	46	42	2,728	PCC	Non-CRCP
EFD	9300	RUNWAY 17L-35R	9340	2017	Priority	$ 2,187,554	-	-	PCC RECON	$2,187,554	$1,439,180	3.00	1.00	1.00	$ 1,876,285	$ 1,234,398	$ 1,876,285	$ 1,234,398	$ 66,274	$ 43,601	<5	69	64	60	63,400	PCC	Non-CRCP
EFD	9300	RUNWAY 17L-35R	9350	2017	Priority	$ 671,379	-	-	PCC RECON	$671,379	$441,697	3.00	1.00	1.00	$ 575,848	$ 378,847	$ 575,848	$ 378,847	$ 6,630	$ 4,362	<5	74	69	64	19,458	PCC	Non-CRCP
						$ 6,442,864	**$ 20,145,130**	**$ 15,891,095**	**TOTALS**	**$ 42,479,089**	$ 27,946,769				$ 164,887,330	$ 108,478,507	**$ 35,285,062**	$ 23,213,857	$ 902,992	$ 594,074					5,571,572		
											Average	7.97	0.24	0.23													
									Filter Subtotal	**$ 42,479,089**	St Dev	2.83	0.42	0.42		**Filter Subtotal**	**$ 35,285,062**										
											C.O.V.	35.5%	179.6%	181.3%													

Appendix F

Airport Layout Plan



LEGEND

▨	RUNWAY PAVEMENT
▨	TAXIWAY PAVEMENT
▨	APRON PAVEMENT
▨	BUILDING
▨	AIRCRAFT RESCUE & FIRE FIGHTING (ARFF)
— — —	EXISTING AIRPORT PROPERTY LINE
— x —	FENCE (8' AGL)
— A-RPZ —	APPROACH RUNWAY PROTECTION ZONE
— D-RPZ —	DEPARTURE RUNWAY PROTECTION ZONE
— RSA —	RUNWAY SAFETY AREA (RSA)
— OFZ —	RUNWAY OBSTACLE FREE ZONE (OFZ)
— POFZ —	PRECISION RUNWAY OBSTACLE FREE ZONE (POFZ)
— ROFA —	RUNWAY OBJECT FREE AREA (ROFA)
— BRL —	BUILDING RESTRICTION LINE (BRL)
┼┼┼┼┼	RAILROAD
— — —	LOCALIZER CRITICAL AREA
- - - -	GLIDESLOPE CRITICAL AREA
—	HOLD BAR
—	ILS CRITICAL AREA HOLD BAR
— — —	NASA PROPERTY
— — —	MILITARY PROPERTY
— — —	GOLF COURSE BOUNDARY
⚐	WIND CONE
★	ROTATING BEACON

Notes:
1. All coordinates reference the North American Datum 1983 (NAD 83).
2. All elevations reference the North American Vertical Datum 1988 (NAVD 88).

AIRPORT BUILDING DATA TABLE

NEW NO.	OLD NO.	DESCRIPTION	ROOF ELEV.
E-420	NONE	MALSR SHELTER	36.1'
E-430	NONE	GLIDE SLOPE ANTENNA & TRANSMISSOMETER	36.1'
E-452	NONE	NASA TRAINING FACILITY	43.8'
E-452B	NONE	NASA NEUTRAL BUOYANCY LAB	70.6'
E-620	NONE	MIDDLE MARKER SHELTER (ABANDONED)	33.3'
E-700	NONE	DECOMMISSIONED VOR	42.2'
E-701	NONE	TACAN/DME SHELTER	38.4'
E-702	NONE	TACAN/DME ANTENNA	51.8'
N-340	NONE	GLIDE SLOPE ANTENNA & SHELTER	38.0'
N-450	2	EMERGENCY GENERATOR	43.4'
N-452	NONE	AIRPORT MAINTENANCE WAREHOUSE	59.1'
N-455	NONE	AIRPORT MAINTENANCE WAREHOUSE	44.1'
N-460	5	AIRPORT MAINTENANCE FACILITY	43.9'
N-462	3	AIRPORT MAINTENANCE FUEL STATION	56.0'
N-462A	4	AIRPORT MAINTENANCE COVERED PARKING	57.6'
N-530	1	EMERGENCY GENERATOR	42.9'
N-542	NONE	LOCALIZER SHELTER	41.5'
N-600	NONE	HAS STORAGE	51.3'
N-601	NONE	HAS STORAGE	44.8'
S-390	23	FBO REPAIR STATION	59.6'
S-392	25	FBO MAINTENANCE STORAGE	35.7'
S-394	24	FBO MAINTENANCE STORAGE	37.1'
S-396	NONE	INTEGRATED AIRLINE SERVICES INC.	43.6'
S-450	29	RVR EMERGENCY GENERATOR	33.6'
S-452	30	EMERGENCY GENERATOR/ROTATING BEACON	39.4'
S-460	43	GLIDE SLOPE ANTENNA & SHELTER	32.3'
S-480	26	WAREHOUSE (VACANT)	50.6'
S-482	28	JOHNSON CONTROLS RESTROOM	35.6'
S-483	NONE	LOCALIZER SHELTER	35.0'
S-484	27	AUTOMOTIVE SHOP (VACANT)	48.9'
S-486	33	WINGS OVER HOUSTON WAREHOUSE	50.3'
S-488	32	WAREHOUSE (TENANT UNKNOWN)	41.0'
S-490	NONE	NASA DELUGE PUMP STATION	39.6'
S-550B	NONE	ABANDONED BUILDINGS	39.5'
S-570	35	FBO FUEL FACILITY	37.6'
S-571	NONE	FBO FUEL FACILITY	34.0'
S-573	NONE	FBO FUEL FACILITY	35.1'

NEW NO.	OLD NO.	DESCRIPTION	ROOF ELEV.
S-574A	37	ANG FUEL PUMP STATION	37.1'
S-574B	NONE	ANG FUEL MAINTENANCE SHOP	35.2'
S-574C	40	ANG FUEL MAINTENANCE SHOP	40.1'
S-660	41	EMERGENCY GENERATOR (ABANDONED)	27.0'
S-661	42	LOCALIZER SHELTER	33.2'
S-760	34	EMERGENCY GENERATOR (ABANDONED)	25.3'
S-800	NONE	FUEL TANKS (ADJACENT TO S-490)	47.5'
S-801	38	ANG FUEL TANKS (2 HORIZONTAL)	34.9'
S-802	39	ANG FUEL STORAGE	36.9'
W-310	21	T-HANGAR A	50.8'
W-311	NONE	FBO HANGAR	69.2'
W-312	22	T-HANGAR B	57.6'
W-320A	12	FBO TERMINAL/FLYING TIGERS SCHOOL	61.0'
W-322	11	FBO HANGAR	61.0'
W-324	14	T-HANGAR C	56.3'
W-326	15	T-HANGAR D	49.2'
W-328	NONE	BK AIRPORT PROPERTIES - HANGAR	59.2'
W-330	9	OLD ARFF STATION (VACANT)	39.0'
W-332	10	AV FLIGHT SIMULATION	49.6'
W-334	16	T-HANGAR E	50.0'
W-336	17	T-HANGAR F	50.0'
W-340	7	BOMASADA FLIGHT OPERATIONS HANGAR	58.6'
W-342	8	AIR TRAFFIC CONTROL TOWER	80.4'
W-350	NONE	TEXAS FLYING LEGENDS	67.8'
W-350B	6	ELECTRICAL VAULT	42.2'
W-352	NONE	FBO HANGAR	70.6'
W-354	NONE	FBO HANGAR	58.6'
W-382	NONE	ANG ARFF FACILITY	53.0'
W-420	20	VACANT FACILITY	46.2'
W-421	NONE	GRUMMAN SECURITY GUARD POST	43.0'
W-422	19	GRUMMAN FACILITIES	92.8'
W-440	18	HAS ADMINISTRATIVE FACILITY	50.3'
W-460	44	SATELLITE COMMUNICATIONS BASE	55.9'
W-600	NONE	USCG FACILITY (UNDER CONSTRUCTION)	109.3'
W-601	NONE	FBO HANGAR	60.5'
W-602	NONE	FBO HANGAR	73.5'

RICONDO® & ASSOCIATES

REVISIONS

NO.	DATE	BY	DESCRIPTION	APP'D	NO.

ELLINGTON AIRPORT
Houston, Texas

EXISTING AIRPORT LAYOUT PLAN

HOUSTON AIRPORTS

APPROVED BY:

CITY OF HOUSTON
DEPARTMENT OF AVIATION

DATE: ______________ ______________________
DIRECTOR OF AVIATION

APPROVED BY:

CITY OF HOUSTON
DEPARTMENT OF AVIATION

DATE: ______________ ______________________
PLANNING MANAGER

APPROVED BY:

FEDERAL AVIATION ADMINISTRATION
SOUTHWEST REGION

☐ ALP APPROVED
☐ ALP APPROVED - SUBJECT TO CONDITIONS/COMMENTS IN LETTER DATED ____________________
☐ AERONAUTICAL STUDY NO. ____________________
☐ DISTRIBUTION: FTW FPO (3)
ASW-470 (1)
ASW-520 (2)
TXDOT (1)

DATE: ______________ ______________________
MANAGER, TX ADO

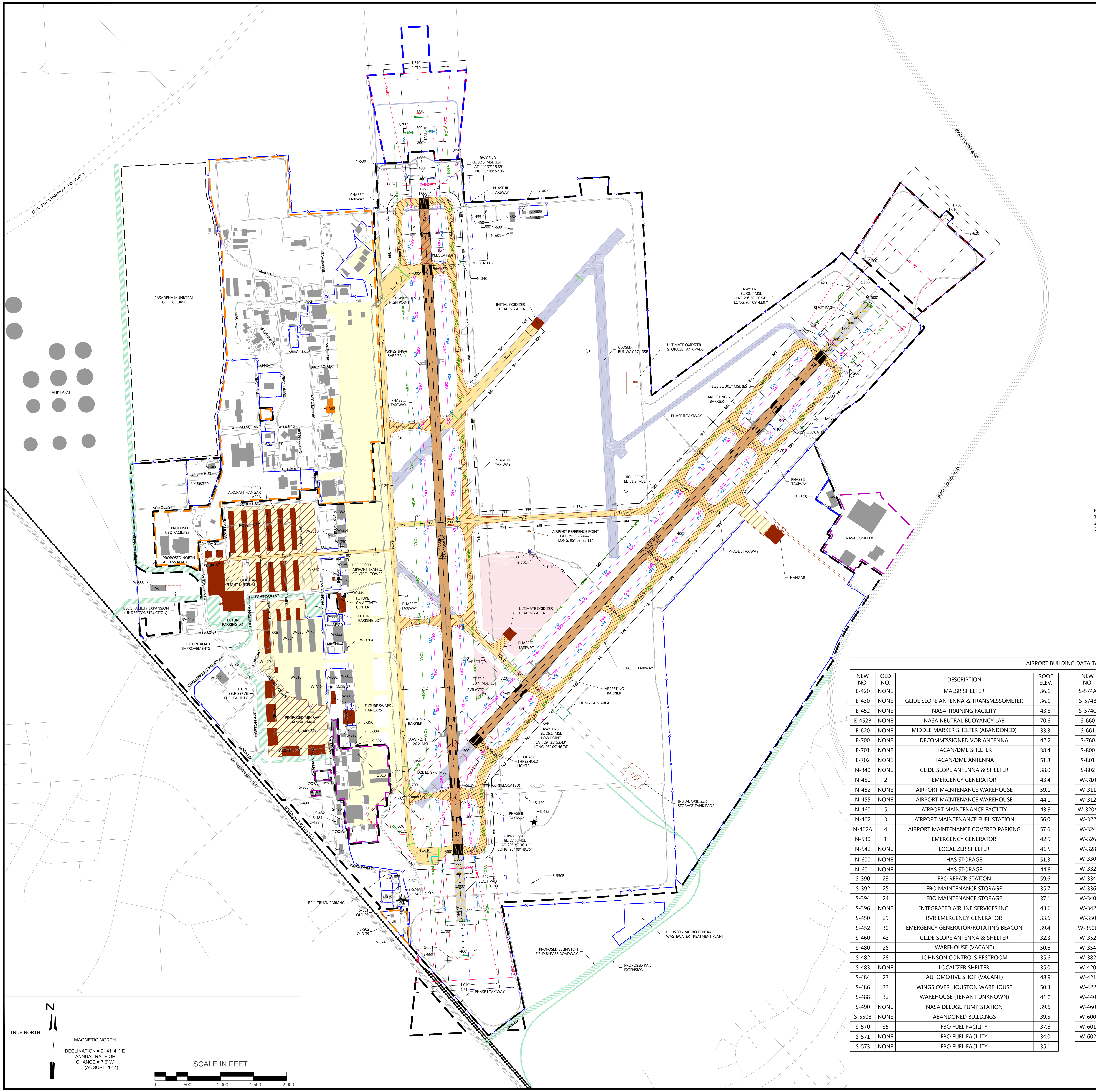
DRAWN BY: AFB

CHECKED BY: EMG

PREPARED BY:
Ricondo & Associates, Inc.

DATE: May 2015

Sheet 2 of 21



LEGEND

- ■ RUNWAY PAVEMENT
- ■ TAXIWAY PAVEMENT
- □ APRON PAVEMENT
- ■ BUILDING
- ■ AIRCRAFT RESCUE & FIRE FIGHTING (ARFF)
- ▨ PROPOSED RUNWAY EXTENSION PAVEMENT
- ▨ PROPOSED TAXIWAY PAVEMENT
- ▨ PROPOSED APRON PAVEMENT
- ■ PROPOSED BUILDING
- ▨ PROPOSED LANDSIDE DEVELOPMENT
- ■ PROPOSED PAVEMENT DECOMMISSION/DEMOLITION
- ■ INHABITED BUILDING DISTANCE
- — — EXISTING AIRPORT PROPERTY LINE
- — — PROPOSED AIRPORT PROPERTY LINE
- —x— FENCE (8' AGL)
- — A-RPZ — APPROACH RUNWAY PROTECTION ZONE
- — D-RPZ — DEPARTURE RUNWAY PROTECTION ZONE
- — RSA — RUNWAY SAFETY AREA (RSA)
- — OFZ — RUNWAY OBSTACLE FREE ZONE (OFZ)
- — POFZ — PRECISION RUNWAY OBSTACLE FREE ZONE (POFZ)
- — ROFA — RUNWAY OBJECT FREE AREA (ROFA)
- — BRL — BUILDING RESTRICTION LINE (BRL)
- ┼┼┼┼ RAILROAD
- ┼┼┼┼ PROPOSED RAILROAD
- — — LOCALIZER CRITICAL AREA
- — — GLIDESLOPE CRITICAL AREA
- — HOLD BAR
- — ILS CRITICAL AREA HOLD BAR
- — — NASA PROPERTY
- — — MILITARY PROPERTY
- — — GOLF COURSE BOUNDARY
- ⚐ WIND CONE
- ★ ROTATING BEACON

Notes:
1. All coordinates reference the North American Datum 1983 (NAD 83).
2. All elevations reference the North American Vertical Datum 1988 (NAVD 88).
3. Taxiway phases correspond to the following:
   - -Phase I: Short Term (2016-2020)
   - -Phase II: Medium Term (2021-2025)
   - -Phase III: Long Term (2026-2032)

AIRPORT BUILDING DATA TABLE

NEW NO.	OLD NO.	DESCRIPTION	ROOF ELEV.
E-420	NONE	MALSR SHELTER	36.1'
E-430	NONE	GLIDE SLOPE ANTENNA & TRANSMISSOMETER	36.1'
E-452	NONE	NASA TRAINING FACILITY	43.8'
E-452B	NONE	NASA NEUTRAL BUOYANCY LAB	70.6'
E-620	NONE	MIDDLE MARKER SHELTER (ABANDONED)	33.3'
E-700	NONE	DECOMMISSIONED VOR ANTENNA	42.2'
E-701	NONE	TACAN/DME SHELTER	38.4'
E-702	NONE	TACAN/DME ANTENNA	51.8'
N-340	NONE	GLIDE SLOPE ANTENNA & SHELTER	38.0'
N-450	2	EMERGENCY GENERATOR	43.4'
N-452	NONE	AIRPORT MAINTENANCE WAREHOUSE	59.1'
N-455	NONE	AIRPORT MAINTENANCE WAREHOUSE	44.1'
N-460	5	AIRPORT MAINTENANCE FACILITY	43.9'
N-462	3	AIRPORT MAINTENANCE FUEL STATION	56.0'
N-462A	4	AIRPORT MAINTENANCE COVERED PARKING	57.6'
N-530	1	EMERGENCY GENERATOR	42.9'
N-542	NONE	LOCALIZER SHELTER	41.5'
N-600	NONE	HAS STORAGE	51.3'
N-601	NONE	HAS STORAGE	44.8'
S-390	23	FBO REPAIR STATION	59.6'
S-392	25	FBO MAINTENANCE STORAGE	35.7'
S-394	24	FBO MAINTENANCE STORAGE	37.1'
S-396	NONE	INTEGRATED AIRLINE SERVICES INC.	43.6'
S-450	29	RVR EMERGENCY GENERATOR	33.6'
S-452	30	EMERGENCY GENERATOR/ROTATING BEACON	39.4'
S-460	43	GLIDE SLOPE ANTENNA & SHELTER	32.3'
S-480	26	WAREHOUSE (VACANT)	50.6'
S-482	28	JOHNSON CONTROLS RESTROOM	35.6'
S-483	NONE	LOCALIZER SHELTER	35.0'
S-484	27	AUTOMOTIVE SHOP (VACANT)	48.9'
S-486	33	WINGS OVER HOUSTON WAREHOUSE	50.3'
S-488	32	WAREHOUSE (TENANT UNKNOWN)	41.0'
S-490	NONE	NASA DELUGE PUMP STATION	39.6'
S-550B	NONE	ABANDONED BUILDINGS	39.5'
S-570	35	FBO FUEL FACILITY	37.6'
S-571	NONE	FBO FUEL FACILITY	34.0'
S-573	NONE	FBO FUEL FACILITY	35.1'
S-574A	37	ANG FUEL PUMP STATION	37.1'
S-574B	NONE	ANG FUEL MAINTENANCE SHOP	35.2'
S-574C	40	ANG FUEL MAINTENANCE SHOP	40.1'
S-660	41	EMERGENCY GENERATOR (ABANDONED)	27.0'
S-661	42	LOCALIZER SHELTER	33.2'
S-760	34	EMERGENCY GENERATOR (ABANDONED)	25.3'
S-800	NONE	FUEL TANKS (ADJACENT TO S-490)	47.5'
S-801	38	ANG FUEL TANKS (2 HORIZONTAL)	34.9'
S-802	39	ANG FUEL STORAGE	36.9'
W-310	21	T-HANGAR A	50.8'
W-311	NONE	FBO HANGAR	69.2'
W-312	22	T-HANGAR B	57.6'
W-320A	12	FBO TERMINAL/FLYING TIGERS SCHOOL	61.0'
W-322	11	FBO HANGAR	61.0'
W-324	14	T-HANGAR C	56.3'
W-326	15	T-HANGAR D	49.2'
W-328	NONE	BK AIRPORT PROPERTIES - HANGAR	59.2'
W-330	9	OLD ARFF STATION (VACANT)	39.0'
W-332	10	AV FLIGHT SIMULATION	49.6'
W-334	16	T-HANGAR E	50.0'
W-336	17	T-HANGAR F	50.0'
W-340	7	BOMASADA FLIGHT OPERATIONS HANGAR	58.6'
W-342	8	AIR TRAFFIC CONTROL TOWER	80.4'
W-350	NONE	TEXAS FLYING LEGENDS	67.8'
W-350B	6	ELECTRICAL VAULT	42.2'
W-352	NONE	FBO HANGAR	70.6'
W-354	NONE	FBO HANGAR	58.6'
W-382	NONE	ANG ARFF FACILITY	53.0'
W-420	20	VACANT FACILITY	46.2'
W-421	NONE	GRUMMAN SECURITY GUARD POST	43.0'
W-422	19	GRUMMAN FACILITIES	92.8'
W-440	18	HAS ADMINISTRATION FACILITY	50.3'
W-460	44	SATELLITE COMMUNICATIONS BASE	55.9'
W-600	NONE	USCG FACILITY	109.3'
W-601	NONE	FBO HANGAR	60.5'
W-602	NONE	FBO HANGAR	73.5'

RICONDO® & ASSOCIATES

REVISIONS

NO.	DATE	BY	DESCRIPTION	APP'D	NO.

ELLINGTON AIRPORT
Houston, Texas

FUTURE AIRPORT LAYOUT PLAN

HOUSTON AIRPORTS

APPROVED BY:

CITY OF HOUSTON
DEPARTMENT OF AVIATION

DATE: ______________ ______________________
DIRECTOR OF AVIATION

APPROVED BY:

CITY OF HOUSTON
DEPARTMENT OF AVIATION

DATE: ______________ ______________________
PLANNING MANAGER

APPROVED BY:

FEDERAL AVIATION ADMINISTRATION
SOUTHWEST REGION

☐ ALP APPROVED
☐ ALP APPROVED - SUBJECT TO CONDITIONS/COMMENTS IN LETTER DATED ______________
☐ AERONAUTICAL STUDY NO. ______________
☐ DISTRIBUTION: FTW FPO (3)
ASW-470 (1)
ASW-520 (2)
TXDOT (1)

DATE: ______________ ______________________
MANAGER, TX ADO

DRAWN BY: AFB

CHECKED BY: EMG

PREPARED BY:
Ricondo & Associates, Inc.

DATE: May 2015

Sheet 3 of 21

Appendix G

Self-Serve Fuel Assessment

1. Introduction

The Houston Airport System (HAS) is exploring the opportunity to install a self-serve fueling facility at Ellington Field Airport (EFD). The initial business assessment was conducted to determine the benefits of self-serve fuel in comparison to the overall costs associated with the installation, operation, and maintenance of a self-serve fuel facility.

Through this process, six tasks were conducted to determine the potential impacts of self-serve fuel on EFD's operations and finances. The six tasks are described as follows:

- Data Collection and Inventory
- Trends in General Aviation
- Comparable Airport Review
- Data Analysis and Assessment
- Costs Associated with a Self-Serve Fuel
- Potential Revenues from Self-Serve Fuels
- Business Assessment Overview

The following chapters will discuss each of the specific tasks in detail, the method of gathering the information, why the information is pertinent to the business assessment, and the incumbent impact of the task on EFD and its future self-serve fuel facility.

2. Data Collection and Inventory

Data Collection and Inventory provides an overview of the current operations and facilities at Ellington Field Airport (EFD) relative to based aircraft, operations, and existing forecast of future activity.

2.1 BASED AIRCRAFT

According to EFD's FAA Form 5010, Airport Master Record, dated 4/5/2012, EFD houses a total of 173 based aircraft. The fleet mix of EFD's based aircraft is as follows:

Table 2-A: EFD Based Aircraft, 2012

Single Engine	90
Multi Engine	24
Jet	56
Helicopters	3
Total	**173**

Source: Federal Aviation Administration TAF, Ricondo& Associates, Inc., January 2012

Of the 173 total based aircraft, 114 (90 single-engine piston and 24 multi-engine piston aircraft) or 66% of them are likely procurers of 100LL fuel from a self-serve fuel station in. Jet aircraft have been excluded from this study as because the self-serve fuel facility will not provide Jet A fuel service. Please note, piston-engine helicopters (100 LL) do exist, but are quite rare. For the purposes and practicality of this study, helicopters have also been excluded as potential users of the self-serve fueling facility.

Table 2-B provides the projected piston based aircraft at EFD through the forecasted period of 2030.

Table 2-B: EFD Projected Piston Based Aircraft, 2012-2030

	2012	2015	2020	2030
Single Engine	90	89	87	84
Multi Engine	24	24	23	23
Total	**114**	**113**	**110**	**107**

Source: Federal Aviation Administration TAF, Ricondo& Associates, Inc., January 2012

2.2 OPERATIONS

According to EFD's Master Plan – Aviation Activity Forecast, a larger portion of EFD's air traffic is comprised of itinerant operations. Local operations currently represent 35% and itinerant operations represent 65% of the total 76,968 total operations in 2011. Through the planning period, it is projected that the itinerant operations will increase to 70% and the local operations will decline to represent 30% of the total general aviation operations in the year 2030. *Table 2-C* presents projected general aviation operations by type at EFD through the year 2030.

Table 2-C: EFD Projected Operations by Type, 2012-2030

	2011 (65%/35%)	2015 (66%/34%)	2020 (67%/33%)	2030 (70%/30%)
Itinerant	50,029	51,862	54,170	60,193
Local	26,939	26,717	26,680	25,797
Total	**76,968**	**78,580**	**80,850**	**85,990**

Source: Ricondo&Associates, 2012

The 2004 EFD Master Plan estimated that approximately 63% of the operations at EFD are conducted by piston aircraft. *Table 2-D* identifies the number of operations by piston aircraft throughout the planning period.

Table 2-D: EFD Projected Operations by Piston Aircraft, 2012-2030

	2011	2015	2020	2030
Itinerant	31,517	32,673	34,126	37,921
Local	16,971	16,831	16,809	16,252
Total	**48,489**	**50,054**	**50,935**	**54,173**

Source: Ricondo & Associates, 2012 Draft Forecast of; 2004 EFD Master Plan, Leigh Fischer and Associates

In 2011, 63% of the general aviation operations at EFD were conducted by piston aircraft.

2.3 FBO FUEL FACILITIES

EFD currently operates one above ground fuel farm situated along State Highway 3 at the South end of the Airport. The fuel facility is maintained by HAS, but the FBO, Southwest Airport Services, provides aircraft fueling operations to based and itinerant general aviation and military aircraft on both the EFD and NASA aprons. Currently, trucks are used to transport all fuel to the aprons. In 2011, the monthly average fuel flowage at EFD was 296,878 gallons, totaling more than 3.5 million gallons, annually.

Typically, it is recommended that one FBO can service no more than 50,000 annual operations. Currently, EFD has more than 77,000 general aviation annual operations, and this number is projected to increase to more than 85,000 general aviation operations through the year 2030.

In 2011, more than 3.5 million gallons of fuel were sold at EFD.

3. Trends in General Aviation

The price of aviation fuel continues to be an important and uncertain factor affecting general aviation. Fluctuating fuel prices have caused corresponding variances in general aviation activity and costs. Consistency in pricing is important to the general aviation pilot.

Self-serve fuel equipment suppliers estimate that the demand for self-serve stations has increased by 20-25% in the past few years. They attribute the influx in demand to the combination of poor economic times and their desire to provide the best, most-affordable customer service to the general aviation population.

A struggling economy has resulted in airports having to reduce levels of staff, equipment, and hours of operation. All are required for the operation of a full-service FBO, but the self-service station relinquishes the necessity of these additional costs. The installation of self-serve facilities also allows FBO's to take care of higher capacity customers, as it often not cost effective to drive a truck and have a technician pump fuel into every general aviation aircraft in need of fuel.

Lastly, general aviation pilots appreciate the convenience of being able to fill their own aircraft on their own schedule.

Demand for self-serve stations has increased by 20-25% in the past few years

4. Comparable Airport Review

4.1 Houston Market Airports

There are 18 airports within 100 miles of EFD that offer self-serve 100LL fuel. Half of these airports provide both self-serve and full-service fueling options. Table 4-A below, provides the current per gallon and average fuel prices for both self-serve and full-serve full within the Houston market.

Table 4-A: Houston Market Fuel Prices

as of June 25, 2012

Airports within 100 Nautical Miles (NM) of EFD

Identifier	Airport	NM from EFD	SS Fuel Price	FS Fuel Price	% Discount for SS	SS Discount (FS-SS)
T00	Chambers County	28	$ 4.68	NA		
LBX	Texas Gulf Coast Regional	18	$ 4.90	$ 5.30	7.55%	$ 0.40
SGR	Sugar Land Regional	29	$ 5.02	$ 5.67	11.46%	$ 0.65
BYY	Bay City	80	$ 5.05	NA		
CXO	Lone Star Exec	70	$ 5.15	$ 5.41	4.81%	$ 0.26
HPY	Baytown	15	$ 5.20	NA		
PSX	Palacios	95	$ 5.25	NA		
DWH	David Wayne Hooks	73	$ 5.36	$ 5.61	4.46%	$ 0.25
T41	La Porte Municipal	6	$ 5.40	$ 5.90	8.47%	$ 0.50
54T	RWJ Airpark	19	$ 5.45	NA		
EYQ	Weiser Airpark	29	$ 5.50	NA		
00R	Livingston Municipal	70	$ 5.50	NA		
TME	Houston Executive	44	$ 5.55	$ 5.99	7.35%	$ 0.44
LVJ	Pearland Regional	4	$ 5.65	$ 5.90	4.24%	$ 0.25
9X1	North Houston Business	34	$ 5.65	NA		
BMT	Beaumont	90	$ 5.73	$ 5.93	3.37%	$ 0.20
1XS1	Dunham Field	21	$ 5.89	NA		
GLS	Galveston Scholes	19	$ 5.92	$ 6.22	4.82%	$ 0.30
	High	GLS	$ 5.92	$ 6.22		
	Low	LBX	$ 4.68	$ 5.30		
	Average		***$ 5.38***	***$ 5.77***	***6.75%***	***$ 0.36***
	Median		***$ 5.43***	***$ 5.90***	***8.05%***	***$ 0.30***

Source: www.airnav.com

SS - Self-Service

FS - Full-Service

EFD's 100LL fuel price is currently $5.71/gallon, which is 5% higher than the average price of fuel sold by other airports within the Houston market, but lower than the Southwest Region average of $5.93 per gallon. In addition, the range of savings for purchasing self-serve fuel over full-service fuel ranges from a high of 11.46% at Sugarland Regional to a low of 3.37% at Beaumont. The average discount for purchasing self-serve 100LL fuel instead of the full-service fuel within the Houston market is 6.75%.

4.2 MSA Comparable Airports

A telephone survey was conducted from four comparable airports to EFD. These airports are reliever and general aviation airports located in similar metropolitan statistical areas (MSA) to Houston. A representative from airports located within the metropolitan areas of Dallas, Phoenix, Denver, and Boise was interviewed as part of this assessment.

Overall, the respondents of the airport interview were excited and enthusiastic about the success of their self-serve fueling product. All of the airports interviewed have a large based aircraft fleet of primarily piston aircraft, a full-service FBO, and a self-serve fuel product. Each airport has experienced an increase in itinerant aircraft operations since the installation of self-serve fuel. Some attribute the additional traffic to cost competitiveness, while others believe it is the 24 hour convenience for pilots.

Airport Surveys provided the following data for use in this analysis:

- Range of 50-80% utilization of self-serve fuel for itinerant operations
- Range of 60-90% utilization of self-serve fuel for local operations
- Average self-serve fuel sale for piston aircraft is 24 gallons per transaction
- Average owner/operator mark-up on fuel sales is $.70 per gallon
- Itinerant operations increase by 8-10% annually following the installation of self-serve fuel

5. Intangible Benefits of Self-Serve Fuel

Intangible benefits refer to those that cannot be measured or analyzed with a dollar value, but contribute to increases in convenience, performance, and customer satisfaction. Ultimately, these “soft” benefits add to the overall value of making the investment.

Intangible Benefits associated with the investment of a self-serve fuel facility at EFD include:

- Providing the general aviation flying community with cost-effective 24 hours per day, 7 days per week fuel service;
- Providing pilots with a sense of independence in taking care of their own aircraft;
- Reducing the amount of time piston aircraft pilots wait to be serviced by an FBO fuel truck;
- Convenience and lower fuel costs will increase in itinerant general aviation by 10% annually.

Intangible benefits improve convenience, performance, and customer satisfaction.

6. Costs Associated with Self-Serve Fuel

The investment required to properly purchase and install a self-service fueling station at EFD has been quoted by a supplier at $90,000.

Comparable Airports to EFD have reported that maintenance costs associated with the self-serve fueling facility are minimal. They have cited the replacement of credit card readers as the most common maintenance occurrence. Other maintenance items include phone lines and fuel hoses, but overall, the self-serve fuel stations require very little maintenance. On average, annual costs associated with maintaining the fuel facilities totals $1,500.00.

TxDOT Aviation covers 50% of maintenance costs of self-serve fueling facility through their Routine Airport Maintenance Program or RAMP Grant. Please see Routine Airport Maintenance for a description of the RAMP Grant Program.

TxDOT RAMP Grants provide 50% funding for maintenance of self-serve fuel facilities

7. Potential Revenues From Self-Serve Fuel

Table 7-A, combines the forecasted operations data with the information provided by comparable airports with self-serve fuel to project the fuel sales resulting from the installation of a self-serve fuel facility at EFD. *Table 7-A* lists the total general aviation operations, calculates total piston general aviation operations (63% of total general aviation operations), and distributes the total general aviation piston operations into itinerant and local operations, based upon forecast year.

Once piston operations by type are identified, high and low utilization ranges are presented based on those provided by comparable airports with self-serve fuel. Low and high utilization scenarios are identified for both itinerant and local operations. As presented in *Section 4.2, MSA Comparable Airports*, a high utilization rates for itinerant and local operations were estimated to be 80% and 90%, respectively. 50% itinerant and 60% local are the low utilization rates for piston aircraft operations. This calculation identifies the likely number of fueling transactions under the identified utilization ranges. It is also estimated that there are two operations associated with each fueling operation, one take-off and one landing. Please note, that if there is a high concentration of touch-and-go operations for a period, this will increase the number of operations per transaction under the local operations category.

Table 7-A: Forecasted Self-Serve Fuel Transactions

	Total GA Operations	Total Piston Aircraft Operations (63% of Total GA Ops)	Piston Operations by Type	Estimated Self-Serve Fuel Transactions	
				Utilization Scenario	*Number of Transactions (2 operations per transaction)*
2011	76,968	**48,489**			
		65% Intinerant	31,517	*High =80%*	12,606
				Low = 50%	7,859
		35% Local	16,971	*High = 90%*	7,636
				Low = 60%	5,091
2015	78,580	**49,504**			
		66% Itinerant	32,673	*High =80%*	13,069
				Low = 50%	8,186
		34% Local	16,831	*High = 90%*	7,573
				Low = 60%	5,049
2020	80,850	**50,935**			
		67% Intinerant	34,126	*High =80%*	13,650
				Low = 50%	8,531
		33% Local	16,809	*High = 90%*	7,563
				Low = 60%	5,042
2030	85,990	**54,173**			
		70% Intinerant	37,921	*High =80%*	15,168
				Low = 50%	9,480
		30% Local	16,252	*High = 90%*	7,312
				Low = 60%	4,875

**It is estimated that one fuel purchase transaction yields two operations, although touch-and-go operations will reduce the operations per transaction for the local operations.*

Table 7-B, Projected Monthly Revenues, applies the number of projected self-serve fuel purchases (transactions) identified in *Table 7-A* and combines it with the average fuel purchase of AvGas by a piston aircraft, 24 gallons, to project monthly fuel sales in gallons. The number of gallons is then multiplied by the average owner/operator mark-up of fuel, $.70 per gallon, to estimate average monthly fuel revenues.

Table 7-B: Projected Monthly Revenue, Self-Serve Fuel

	High Utilization Scenario			*Low Utilization Scenario*		
Forecast Year	**No. of Fuel Purchases (monthly)**	**Total Gallons[1]**	**Projected Monthly Revenue at $.70/gal**	**No. of Fuel Purchases**	**Total Gallons[1]**	**Projected Monthly Revenue at $.70/gal**
Base - 2011	1,687	40,484	$ 28,339	1,079	25,900	$ 18,130
2015	1,771	42,510	$ 29,757	1,052	25,244	$ 17,671
2020	1,848	44,362	$ 31,053	1,050	25,210	$ 17,647
2030	2,054	49,296	$ 34,507	1,016	24,374	$ 17,062

[1] *Data Derived from Comparable Airport Surveys, the average fuel purchase of AvGas by a piston aircraft equals 24 gallons.*

8. Business Assessment Overview

It is anticipated that the installation of a self-serve fuel facility at Ellington Field Airport will be rewarding for both the general aviation community in terms of convenience and level of customer service and for the Houston Airport System with regards to limited investment and projected revenues.

Using the operations forecast prepared in 2012, data presented in the 2004 EFD Master Plan, and surveys of airports around the country that are comparable to EFD, monthly revenues for self-serve AvGas fuel are projected to be significant. It is recommended that pricing for self-serve fuel is discounted by 7-10% below full-service fuel to attract operators from the Houston regional market.

It is anticipated that a minimum of 25,000 gallons of self-serve fuel will be sold at EFD each month at EFD. If the Airport's mark-up on fuel is at least $.70 per gallon, this volume of fuel sales will generate more than $17,500 monthly for EFD and the Houston Airport System.

The upfront expense to install this system is estimated to equal $90,000. Annual maintenance expenses are most likely not to exceed $1,500, 50% of which should qualify to receive funding through the TxDOT RAMP Grant Program. Without assuming any finance costs, the pay-off period for a self-serve AvGas fuel system at EFD is approximately 5 months.

Appendix H

Traffic Analysis Report

ELLINGTON FIELD AIRPORT
MASTER PLAN UPDATE

TRAFFIC ANALYSIS REPORT

PREPARED FOR
RICONDO AND ASSOCIATES
AND
HOUSTON AIRPORT SYSTEM

PREPARED BY

GUNDA
CORPORATION
Engineers, Planners & Managers

MAY 2015

ELLINGTON FIELD AIRPORT
MASTER PLAN UPDATE

TRAFFIC ANALYSIS REPORT

Interim Review Only
Document Incomplete: Not Intended for Permit or Construction Engineer: **Mohan P. Atluri, P.E., PTOE** P.E. Serial No. 100251 Date: May 6, 2015 TBPE Firm Registration No. F-3531

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May 06, 2015

ELLINGTON FIELD AIRPORT MASTER PLAN UPDATE

TRAFFIC ANALYSIS REPORT

*****

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LIST OF TABLES

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INTRODUCTION

This report summarizes the data collection procedures, analysis, and results of a traffic study conducted by Gunda Corporation, LLC (GUNDA) in connection with the Ellington Field Airport Master Plan Update.

BACKGROUND

Houston Airport System (HAS) requested an analysis of Ellington Field Airport (EFD) as part of the EFD Master Plan Update. One of the goals of the project is to accommodate future aviation activity while balancing the capacity of the airfield, the passenger terminal, the ground transportation system, and support facilities at the airport. The plan that emerges from this study should be coordinated with the City of Houston and regional development projects. In order to achieve this goal an evaluation of intersections along primary roadways providing access to EFD was conducted for existing conditions, opening day, and design year.

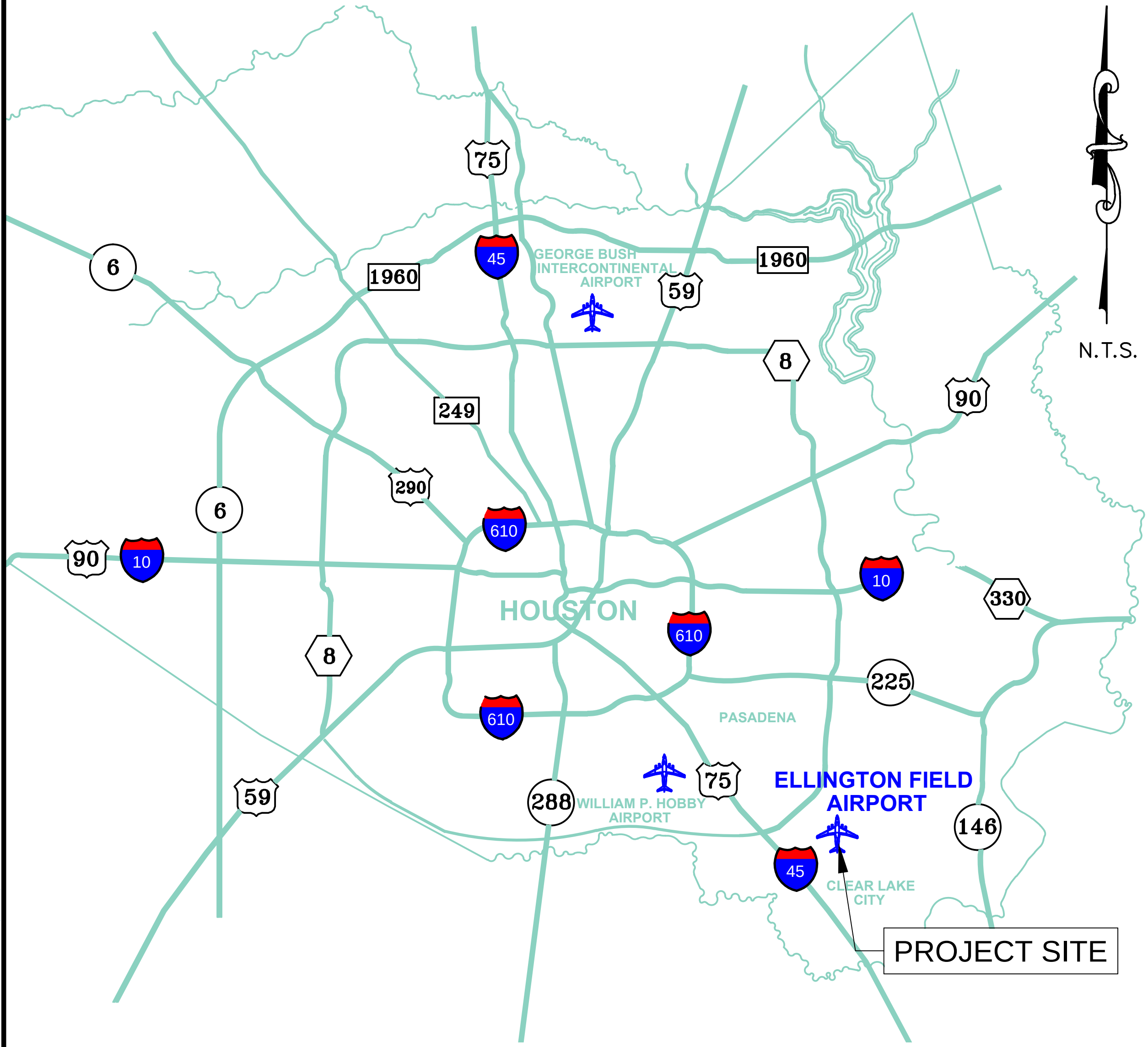
EXISTING CONDITIONS

The land use in the study area is primarily residential with single-family residences located on all four sides of the airport and some commercial establishments located on the east and west of the airport. The Project Location Map of the study area is illustrated in Figure 1 and an Aerial Map is presented in Figure 2.

SITE ACCESS

Regional access to the project site is provided by IH 45 to the west and, Sam Houston Tollway to the south. Old Galveston Road (SH 3), a north-south major thoroughfare, provides direct access to the airport. Currently, the primary access to the airport facilities is through the following intersections:

- Old Galveston Road at Hillard Street (Unsignalized);
- Old Galveston Road at Challenger Drive (Signalized);
- Old Galveston Road at Brantley Avenue (Signalized);



LEGEND

✈ AIRPORT LOCATIONS

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TBPE Registration Number: F-3531

PROJECT NAME:

ELLINGTON FIELD AIRPORT MASTER PLAN UPDATE

SHEET TITLE:

ELLINGTON FIELD LOCATION

PROJ. NO.: 11007-01

DATE: MAY 2015

SHEET NO.: FIGURE 1

GUNDA CORPORATION
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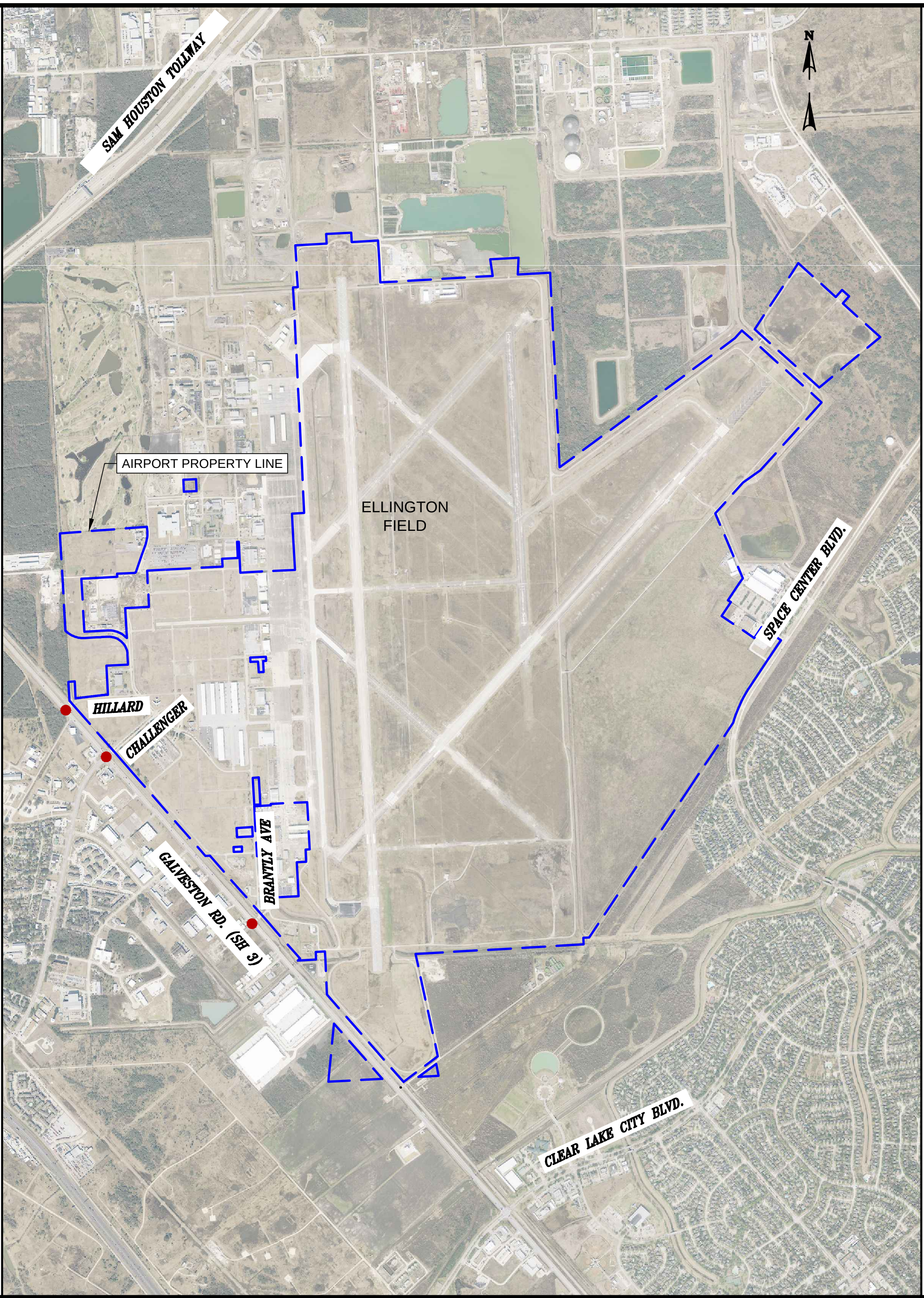

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PROJECT NAME:

ELLINGTON FIELD AIRPORT MASTER PLAN UPDATE

SHEET TITLE:

ELLINGTON FIELD AERIAL MAP

PROJ. NO.: 11007-01

DATE: MAY 2015

SHEET NO.: FIGURE 2

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PROGRAMMED AND PLANNED ROADWAY IMPROVEMENTS

The 2014 Major Thoroughfare and Freeway Plan (MTFP) amendment requests published by planning and development division of City of Houston were reviewed to identify any major changes to roadways in the vicinity of the Ellington Field Airport. No changes are proposed to the other major roadways in the vicinity of the Airport. A Wastewater Force Main Renewal and Replacement project along SH 3 in the vicinity of EFD Airport is programmed in City of Houston's Capital Improvement Program. The construction is anticipated to start in September 2017.

There are currently several Transportation Improvement Program projects in the study area as presented in the 2040 Regional Transportation Plan (RTP) developed by Houston-Galveston Area Council (H-GAC). Table 1 lists the project name, project type, and construction dates which are presented in RTP.

Table 1 – H-GAC Regional Transportation Plan 2040 Projects in the Vicinity of Ellington Field Airport

Number	Street	CSJ No.	Project Description	Location (From)	Location (To)	Project Status	Let Date
1	SH 3	0051-02-079	ADDITION OF RIGHT TURN LANE STORAGE, SIDEWALKS, RAILROAD PLANKING/SIGNALS WITH TRAFFIC SIGNALS	AT FM 2351 AND AT S SHAVER RD		LET	8/1/2013
2	IH 45 S	0500-03-550	WIDEN EXISTING PAVEMENT AND RESTRIPE FROM 6 TO 8 LANES	KURLAND DR	NYACK DR	LET	5/1/2011
3	IH 45 S	0500-03-462	WIDEN AND RECONSTRUCT TO 10 MAIN LANES, TWO 3-LANE FRONTAGE ROADS AND 1 HOV REVERSIBLE LANE	NYACK DR	0.7881 MILES S OF FM 1959	LET	5/1/2011
4	IH 45 S	0500-03-565	WIDEN AND RECONSTRUCT TO 10 MAIN LANES, TWO 3-LANE FRONTAGE ROADS AND 1 HOV REVERSIBLE LANE	0.7881 MILES S OF FM 1959	0.9884 MILES S OF FM 2351	LET	5/1/2011
5	IH 45 S	0500-03-043	WIDEN AND RECONSTRUCT TO 10 MAIN LANES, TWO 3-LANE FRONTAGE ROADS AND 1 HOV REVERSIBLE LANE	0.9884 MI S OF FM 2351	0.4808 MILES S OF EL DORADO BLVD	LET	11/1/2012
6	IH 45 S	0500-03-042	WIDEN AND RECONSTRUCT TO 10 MAIN LANES, TWO 3-LANE FRONTAGE ROADS AND 1 HOV REVERSIBLE LANE	0.4808 MILES S OF EL DORADO BLVD	S OF MEDICAL CENTER BLVD	LET	11/1/2012
7	PRESTON RD	0912-72-063	CONSTRUCT 4-LANE DIVIDED THOROUGHFARE	BW 8	GENOA RED BLUFF RD	TIP	1/1/2015
8	FM 1959	1844-01-027	ASPHALT CONCRETE PAVEMENT OVERLAY	IH 45	SH 3 (OLD GALVESTON ROAD)	TIP	10/1/2013
9	FM 2553	3058-01-006	CRACK SEAL (FY 2010 PROG CALL. CANCEL PER DISTRICT 10/20/2010)	IH 45	SH 3 (OLD GALVESTON ROAD)	LET	6/1/2011
10	BW 8	3256-01-089	WIDEN FROM 4 TO 8 MAIN LANES IN SECTIONS	SH 288	IH 45 S	TIP	1/1/2015
11	BW 8	3256-04-070	WIDEN FROM 4 TO 8 MAIN LANES IN SECTIONS	IH 10	W OF IH 45 S	SHORT	6/1/2017
12	CLEAR LAKE CITY BLVD	NULL	DESIGN, ACQUIRE ROW & CONSTRUCT 4-LANE DIVIDED ROADWAY & DRAINAGE INCLUDING SIGNALS	RED BLUFF RD	MIDDLEBROOK	SHORT	1/1/2019
13	CENTER ST	NULL	DESIGN, ACQUIRE ROW & CONSTRUCT 4-LANE DIVIDED ROADWAY INCLUDING DRAINAGE AND SIGNALS AT GENOA-RED BLUFF	FAIRMMONT PKWY	GENOA RED BLUFF RD	SHORT	1/1/2017
14	CRENSHAW RD	NULL	DESIGN & CONSTRUCT WESTBOUND ROADWAY	SPACE CENTER BLVD	HOLLY BAY CT	SHORT	1/1/2020
15	CRENSHAW RD	NULL	DESIGN, ACQUIRE ROW & EXTEND 4-LANE DIVIDED ROADWAY INCLUDING DRAINAGE AND SIGNALS AT CENTER	HOLLY BAY CT	CENTER ST	SHORT	10/1/2021
16	EL DORADO BLVD	NULL	WIDEN TO 4-LANE DIVIDED ROADWAY	FM 2351	HORSEPEN BAYOU	SHORT	1/1/2021
17	EL DORADO PARK & RIDE	NULL	EL DORAGO PARK & RIDE	IH 45 NEAR EL DORADO BLVD		TIP	1/1/2013
18	GENOA RED BLUFF RD	NULL	WIDEN TO 5-LANE CONCRETE PAVEMENT W/STORM SEWER	BW 8	BAYWOOD DR	LET	12/22/2009
19	GENOA RED BLUFF RD	NULL	WIDEN TO 5-LANE CONCRETE PAVEMENT W/STORM SEWER	BAYWOOD DR	RED BLUFF RD	LET	12/1/2010
20	NORTH ACCESS RD	NULL	CONSTRUCT 4-LANE DIVIDED EXTENSION CONNECTING ELLINGTON FIELD INTERIOR W/BW 8	AEROSPACE AVE	BW 8 (S) NB SERVICE ROAD	SHORT	1/1/2018
21	PINE ST	NULL	DESIGN & WIDEN TO 4-LANE UNDIVIDED W/DRAINAGE & SIGNALS AT RED BLUFF & LEFT TURN LANES AT JANA	BW 8	RANDOLPH ST	SHORT	9/1/2019
22	RANDOLPH ST	NULL	DESIGN AND CONSTRUCT EXTENSION OF 4-LANE DIVIDED INCLUDING DRAINAGE, INTERSECTION REDESIGN AND SIGNALS AT PINE & RED BLUFF RD	RED BLUFF RD	SPENCER HWY	TIP	8/1/2014
23	SH 3	NULL	GALVESTON COMMUTER RAIL TRANSIT (7 STATIONS)	METRO INTERMODAL TRANSIT TERMINAL	GALVESTON CRUISE TERMINAL	SHORT	9/1/2023

DATA COLLECTION

GUNDA Corporation conducted peak period turning movement counts for the study intersections during the month of April 2012. The traffic data collection effort included the following items:

- 24-Hour traffic volumes;
- Intersection turning movement counts;
- Existing roadway geometry and traffic control information; and
- Signal timing data requested from the City of Houston.

The 24-hour traffic counts are summarized in Table 2, below.

Table 2 Existing 24-Hour Traffic Volume

Ellington Field Airport Master Plan Update

LOCATIONS	DIRECTION	24-HOUR VOLUME
1. Hillard Drive just east of Old Galveston Road	Eastbound	973
1. Hillard Drive just east of Old Galveston Road	Westbound	866
2. Challenger Drive east of Old Galveston Road	Eastbound	1,455
2. Challenger Drive east of Old Galveston Road	Westbound	1,485
3. Brantly Drive just east of Old Galveston Road	Eastbound	545
3. Brantly Drive just east of Old Galveston Road	Westbound	684
4. Aerospace Avenue just north of Popa Avenue	Northbound	1,229
4. Aerospace Avenue just north of Popa Avenue	Southbound	1,717
5. Space Center Boulevard just north of Village Dale Avenue	Northbound	8,203
5. Space Center Boulevard just north of Village Dale Avenue	Southbound	9,171

Turning Movement Counts were collected during the AM peak period (07:00 to 09:00 AM) and PM peak period (4:00 to 6:00 PM) on typical weekdays (Tuesday-Thursday). Traffic volumes for all study intersections were compared to determine the study area peak hours within the peak periods. The overall peak hours determined from these counts are as follows:

- AM Peak Hour – 7:15 AM to 8:15 AM
- PM Peak Hour – 4:45 PM to 5:45 PM

The existing AM and PM peak hour intersection traffic turning movement counts are graphically illustrated in Figure 3 and Figure 4, as well as in Appendix A along with the traffic volumes estimated for various traffic analysis scenarios presented in the following sections of this report.

The project area field reconnaissance was conducted to gather information such as roadway geometry, intersection traffic control, and general traffic conditions in the study area.

The existing traffic signal timing information for the signalized intersections was obtained by contacting the City of Houston - Traffic Operations Division.

LEGEND

↑ DIRECTION

000 VOLUME

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TBPE Registration Number: F-3531

PROJECT NAME:

ELLINGTON FIELD AIRPORT MASTER PLAN UPDATE

SHEET TITLE:

EXISTING CONDITIONS AM PEAK HOUR TURNING MOVEMENT COUNTS

PROJ. NO.: 11007-01

DATE: MAY 2015

SHEET NO.: FIGURE 3

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LEGEND

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PROJECT NAME:

ELLINGTON FIELD AIRPORT MASTER PLAN UPDATE

SHEET TITLE:

EXISTING CONDITIONS PM PEAK HOUR TURNING MOVEMENT COUNTS

PROJ. NO.:
11007-01

DATE:
MAY 2015

SHEET NO.
FIGURE 4

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TRAFFIC ANALYSIS

Analysis Methodology

Intersection Level of Service (LOS) analyses were performed in accordance with the procedures set forth and recommended by the latest Highway Capacity Manual (HCM) Level of Service methodologies for evaluation of signalized and unsignalized intersections. The traffic analysis software SYNCHRO was used to evaluate the operations of the study intersections. The LOS criteria for signalized and unsignalized intersections are listed below in Table 3. The LOS is based on delay per vehicle.

LOS is a quantitative stratification of a performance measure or measures that represent quality of service. The Highway Capacity Manual defines six levels of service, ranging from A to F based on a quantitative value of performance measures. LOS 'A' is considered as best, free-flow conditions and LOS 'F' is considered failing conditions. A change of LOS indicates that roadway performance has transitioned from one given range of traveler-perceivable conditions to another range. LOS 'D' is considered acceptable during peak hours to the City of Houston.

Delay is defined as additional travel time experienced by a driver beyond that required to travel at the desired speed, and is measured in seconds per vehicle.

Table 3 - Level of Service (LOS) Criteria for Intersections

Ellington Field Airport Master Plan Update

LOS	SIGNALIZED INTERSECION	UNSIGNALIZED INTERSECION
	DELAY (SEC/VEH)	DELAY (SEC/VEH)
A	0-10	0-10
B	>10-20	>10-15
C	>20-35	>15-25
D	>35-55	>25-35
E	>55-80	>35-50
F	>80	>50

The base SYNCHRO model network was developed using the field collected data, which includes lane configuration, traffic control at the intersections, and speed limits on streets in the study area. The peak hour traffic volumes, pedestrian volumes, and peak hour factors were entered as input. The model was then calibrated based on observations made during the field visit. Variables, such as bus blockages, were adjusted in order to replicate the actual field conditions at study area intersections.

Existing Conditions

The existing AM and PM peak hour levels of service of the analysis intersections are summarized in Table 4, while detailed level of service analyses are included in Appendix B of this report. As presented in Table 4, the intersection of Old Galveston Road at Clearlake City Boulevard is operating at LOS F. The remaining intersections are operating at LOS D or better. The AM and PM peak hour levels of service are shown in Figure 5 and 6, respectively.

Table 4 - Intersections Level of Service – Existing Condition

Ellington Field Airport Master Plan Update

INTERSECTIONS	AM PEAK HOUR		PM PEAK HOUR	
	LOS	Delay[1]	LOS	Delay[1]
Old Galveston Road (SH 3) at Hillard Street[2, 3]	B	12.7	B	14.5
Old Galveston Road (SH 3) at Challenger Drive	C	27.1	D	48.9
Old Galveston Road (SH 3) at Brantly Avenue	A	3.4	B	11.3
Old Galveston Road (SH 3) at Clearlake City Blvd.	F	93.9	F	108.2

NOTES:
LOS – LEVEL OF SERVICE
[1] DELAY IS PRESENTED IN SECONDS PER VEHICLE
[2] DELAY SHOWN FOR CRITICAL MOVEMENT
[3] UNSIGNALIZED INTERSECTION

Figure 5: EFD Airport Study Area: Existing AM Peak Hour Level of Service

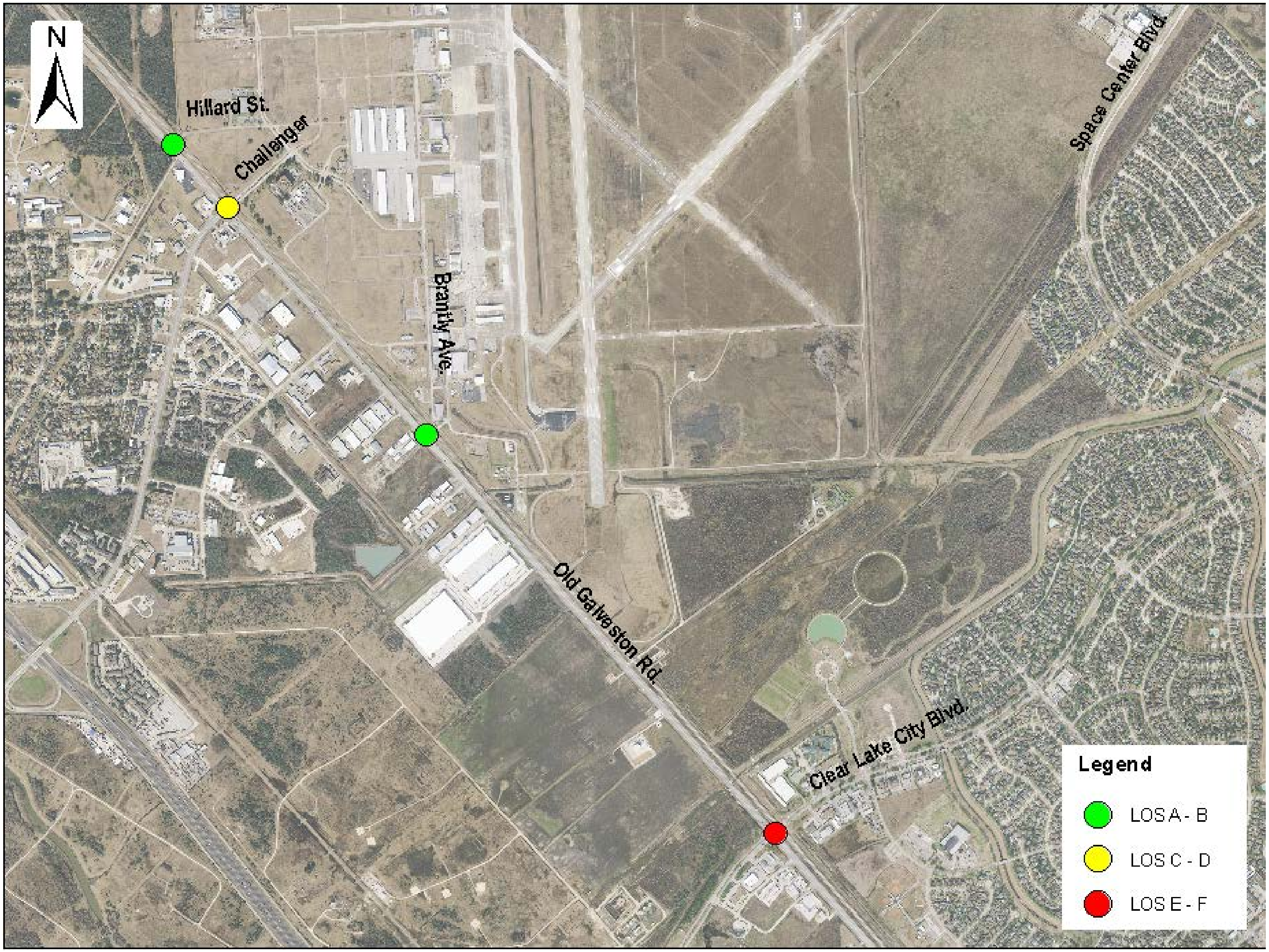
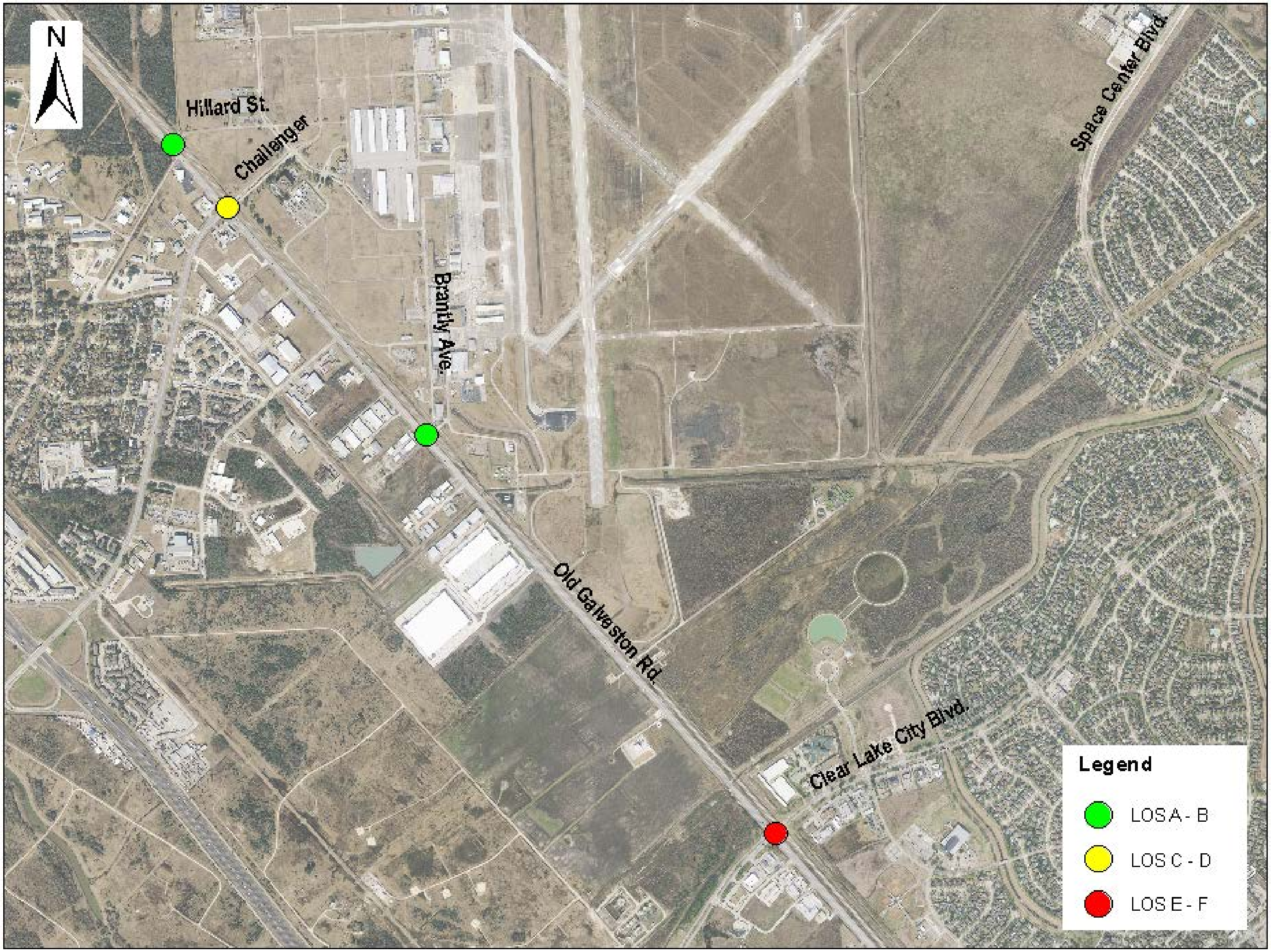


Figure 6: EFD Airport Study Area: Existing PM Peak Hour Level of Service



Year 2020 and Year 2030 Background Conditions (Without Airport Growth)

The existing (2012) traffic volumes at the study intersections were projected to future years (FY) 2020 and 2030. Based on the information provided in the technical memorandum summarizing the aviation activity forecast for Ellington Field Airport, it was determined that the annual growth rate of operations between 2012 and 2030 is 0.6%. Similarly, based on the Houston Consolidated Metropolitan Statistical Area (CMSA) data presented in Table 1-11 it was determined that the compound annual growth rate of population in the area between 2012 and 2030 is 2.0%. The non-airport traffic growth rate, which was estimated by comparing Year 2015 and Year 2025 utilizing data obtained from H-GAC, is also 2.0%. The same growth rate was applied to project the non-airport traffic at the study intersections to Year 2020 and Year 2030.

Utilizing the projected traffic data for the study intersections, the background AM and PM peak hour levels of service for the study intersections were calculated. The background AM and PM peak hour levels of service of the analysis intersections are summarized in Table 5 and 6, while detailed level of service analyses are included in Appendix B. As presented in Table 5, the intersections of Old Galveston Rd. at Challenger Dr. and at Clearlake City Blvd. are projected to operate at level of service F by 2020.

Table 5 - Intersections Level of Service – 2020 Background Condition

Ellington Field Airport Master Plan Update

INTERSECTIONS	**AM PEAK HOUR**		**PM PEAK HOUR**	
	LOS	**Delay[1]**	**LOS**	**Delay[1]**
Old Galveston Road (SH 3) at Hillard Street[2, 3]	B	14.3	C	15.8
Old Galveston Road (SH 3) at Challenger Drive	C	33.4	F	92.4
Old Galveston Road (SH 3) at Brantly Avenue	A	3.7	B	13.0
Old Galveston Road (SH 3) at Clearlake City Blvd.	F	147.1	F	173.4

NOTES:

LOS – LEVEL OF SERVICE

[1] DELAY IS PRESENTED IN SECONDS PER VEHICLE

[2] DELAY SHOWN FOR CRITICAL MOVEMENT

[3] UNSIGNALIZED INTERSECTION

As presented in Table 6, the intersections of Old Galveston Road at Challenger Drive and Clearlake City Boulevard are projected to operate at level of service F under Year 2030 traffic conditions.

Table 6 - Intersections Level of Service – 2030 Background Condition

Ellington Field Airport Master Plan Update

INTERSECTIONS	AM PEAK HOUR		PM PEAK HOUR	
	LOS	Delay[1]	LOS	Delay[1]
Old Galveston Road (SH 3) at Hillard Street[2, 3]	C	17.2	C	19.5
Old Galveston Road (SH 3) at Challenger Drive	D	42.5	F	150.7
Old Galveston Road (SH 3) at Brantly Avenue	A	4.3	B	16.1
Old Galveston Road (SH 3) at Clearlake City Blvd.	F	217.5	F	263.6

NOTES:
LOS – LEVEL OF SERVICE
[1] DELAY IS PRESENTED IN SECONDS PER VEHICLE
[2] DELAY SHOWN FOR CRITICAL MOVEMENT
[3] UNSIGNALIZED INTERSECTION

The AM and PM peak hour levels of service for Year 2020 Background Conditions are illustrated in Figure 7 and 8, respectively. The AM and PM peak hour levels of service for Year 2030 Background Conditions are illustrated in Figure 9 and 10, respectively.

Figure 7: EFD Airport Study Area: Background 2020 AM Peak Hour Level of Service

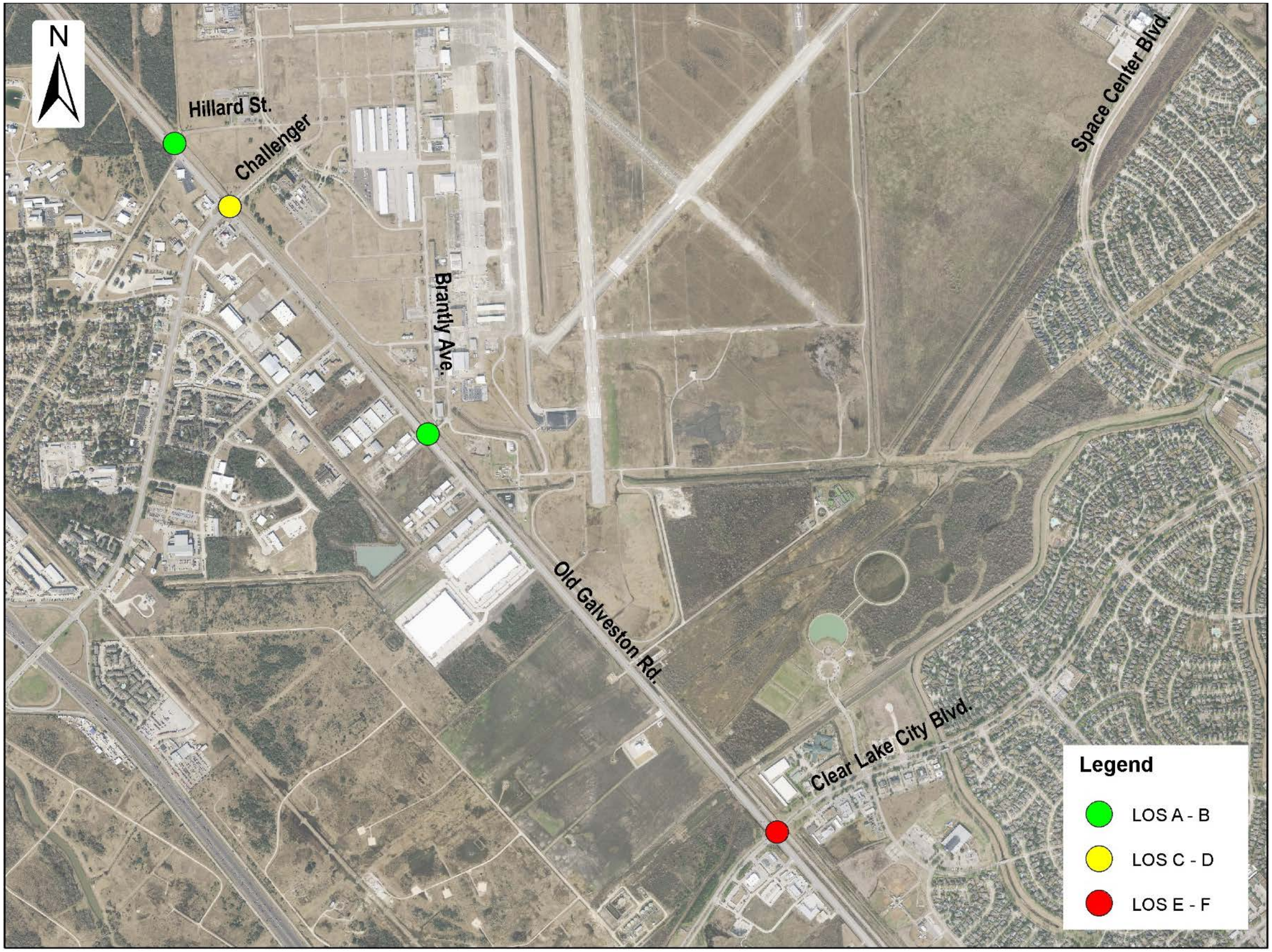


Figure 8: EFD Airport Study Area: Background 2020 PM Peak Hour Level of Service

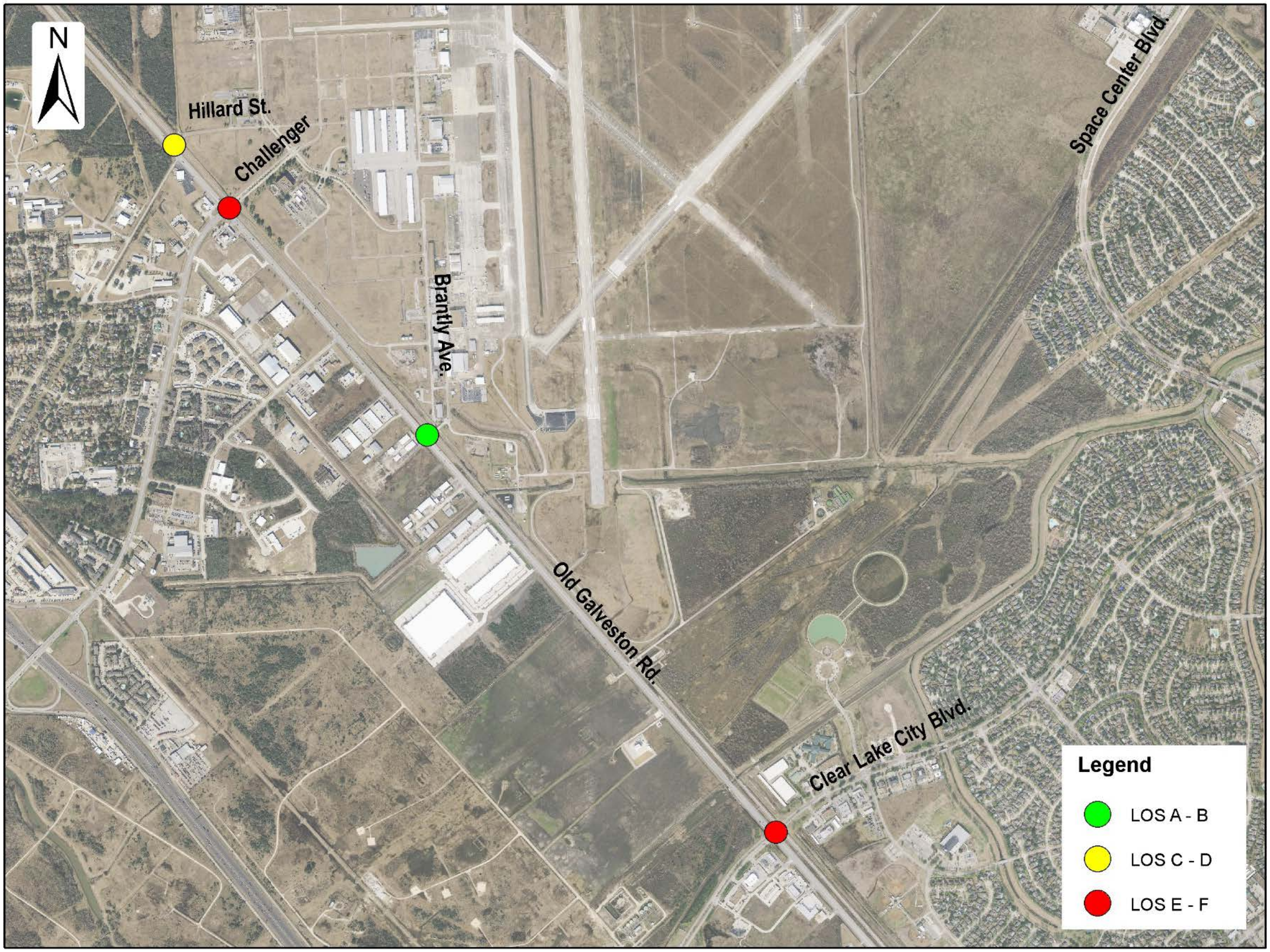


Figure 9: EFD Airport Study Area: Background 2030 AM Peak Hour Level of Service

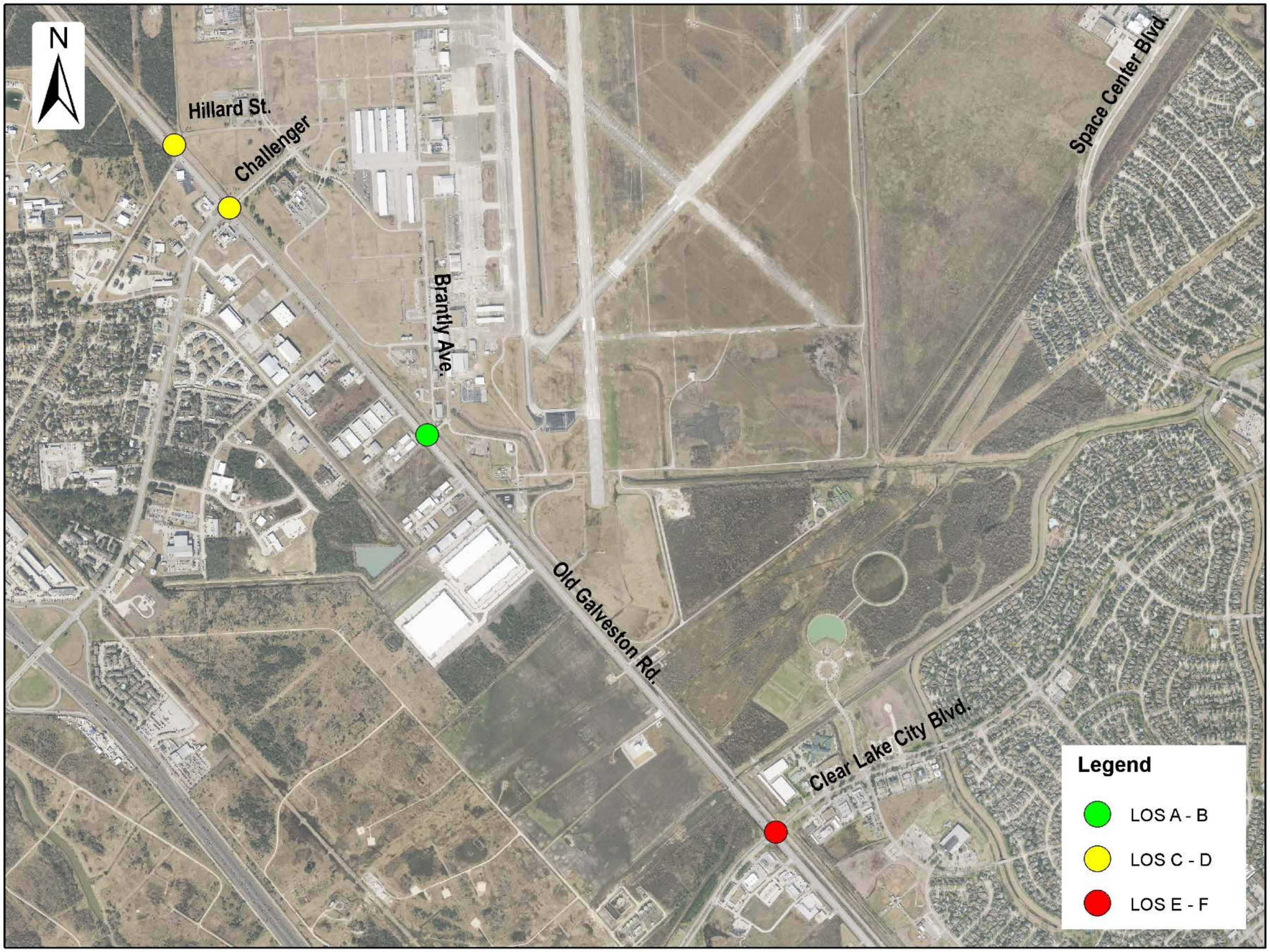
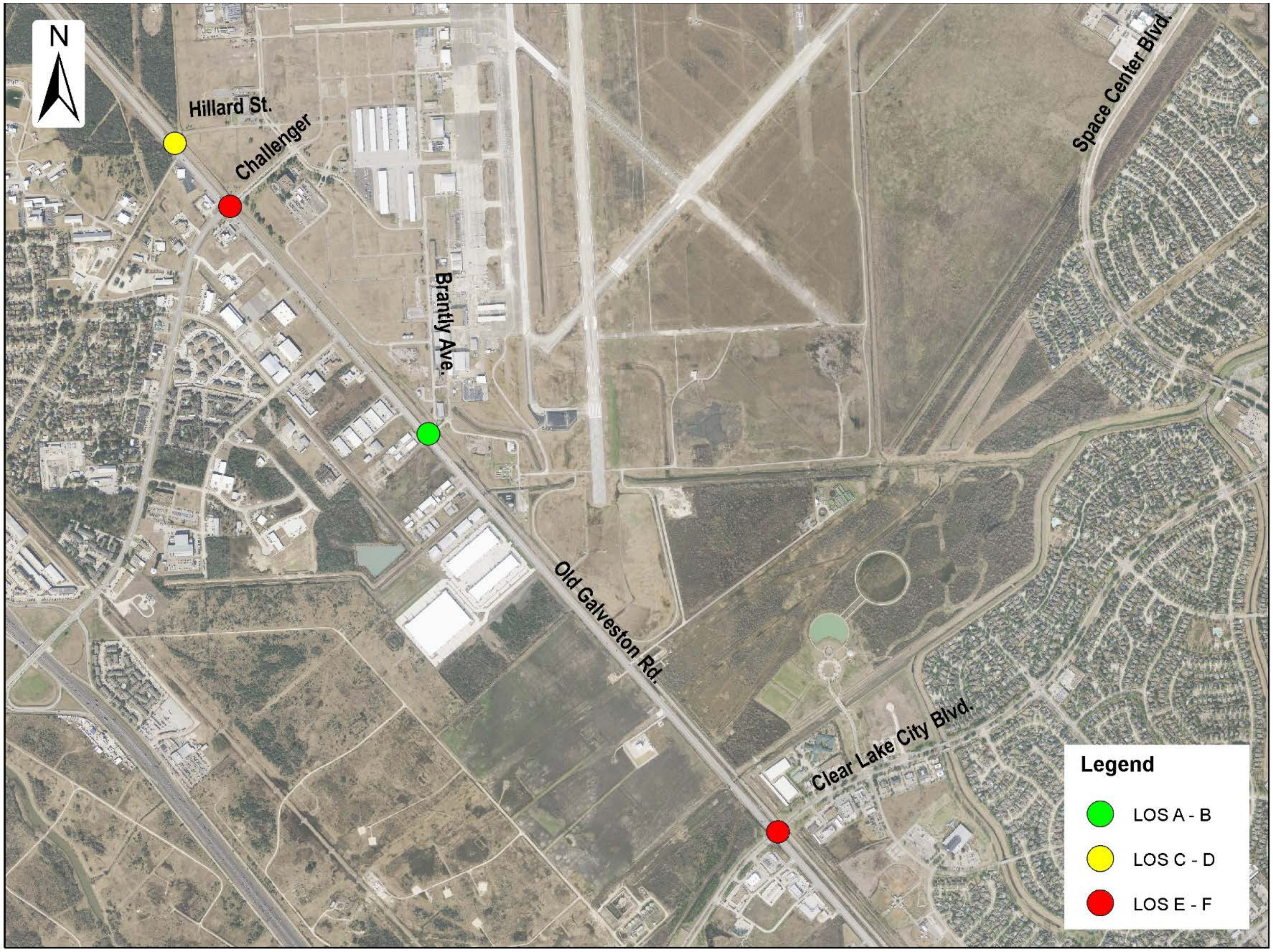


Figure 10: EFD Airport Study Area: Background 2030 PM Peak Hour Level of Service



Year 2020 and Year 2030 Project Conditions (With Airport Growth)

The purpose of this traffic analysis is to analyze traffic operations at the intersections along the primary roadways providing access to EFD in Year 2020 and Year 2030. Additionally, the analysis will determine the traffic impacts on adjacent roadway system and the study intersections in the vicinity of the project site resulting from the proposed development.

The traffic volumes for this scenario were developed by applying 0.6% to the airport oriented traffic and distributing them though the study intersections. Also, the trips anticipated to be generated by the proposed Lone Star Aviation Museum were assigned to appropriate movements.

Utilizing the traffic volumes developed for the project conditions, the AM and PM peak hour levels of service for the study intersections were calculated for both Year 2020 and Year 2030 Project Conditions, summarized in Table 7 and 8, respectively, while detailed level of service analyses are included in Appendix B. As presented in Tables 7 and 8, the intersections of Old Galveston Road at Challenger Drive and Clearlake City Boulevard are projected to operate at level of service F by 2020. In addition, there is a slight increase in delays at other study intersections.

The AM and PM peak hour levels of service for Year 2020 Project Conditions are illustrated in Figure 11 and 12, respectively. The AM and PM peak hour levels of service for Year 2030 Project Conditions are illustrated in Figure 13 and 14, respectively.

Table 7 - Intersections Level of Service – 2020 Project Condition

Ellington Field Airport Master Plan Update

INTERSECTIONS	AM PEAK HOUR		PM PEAK HOUR	
	LOS	Delay[1]	LOS	Delay[1]
Old Galveston Road (SH 3) at Hillard Street[2, 3]	B	14.7	C	16.5
Old Galveston Road (SH 3) at Challenger Drive	C	33.6	F	92.9
Old Galveston Road (SH 3) at Brantly Avenue	A	3.8	B	13.2
Old Galveston Road (SH 3) at Clearlake City Blvd.	F	149.4	F	174.5

NOTES:
LOS – LEVEL OF SERVICE
[1] DELAY IS PRESENTED IN SECONDS PER VEHICLE
[2] DELAY SHOWN FOR CRITICAL MOVEMENT
[3] UNSIGNALIZED INTERSECTION

Table 8 - Intersections Level of Service – 2030 Project Condition

Ellington Field Airport Master Plan Update

INTERSECTIONS	AM PEAK HOUR		PM PEAK HOUR	
	LOS	Delay[1]	LOS	Delay[1]
Old Galveston Road (SH 3) at Hillard Street[2, 3]	C	18.3	C	21.7
Old Galveston Road (SH 3) at Challenger Drive	D	42.6	F	150.4
Old Galveston Road (SH 3) at Brantly Avenue	A	4.5	B	17.9
Old Galveston Road (SH 3) at Clearlake City Blvd.	F	221.7	F	265.4

NOTES:
LOS – LEVEL OF SERVICE
[1] DELAY IS PRESENTED IN SECONDS PER VEHICLE
[2] DELAY SHOWN FOR CRITICAL MOVEMENT
[3] UNSIGNALIZED INTERSECTION

Figure 11: EFD Airport Study Area: 2020 Project AM Peak Hour Level of Service

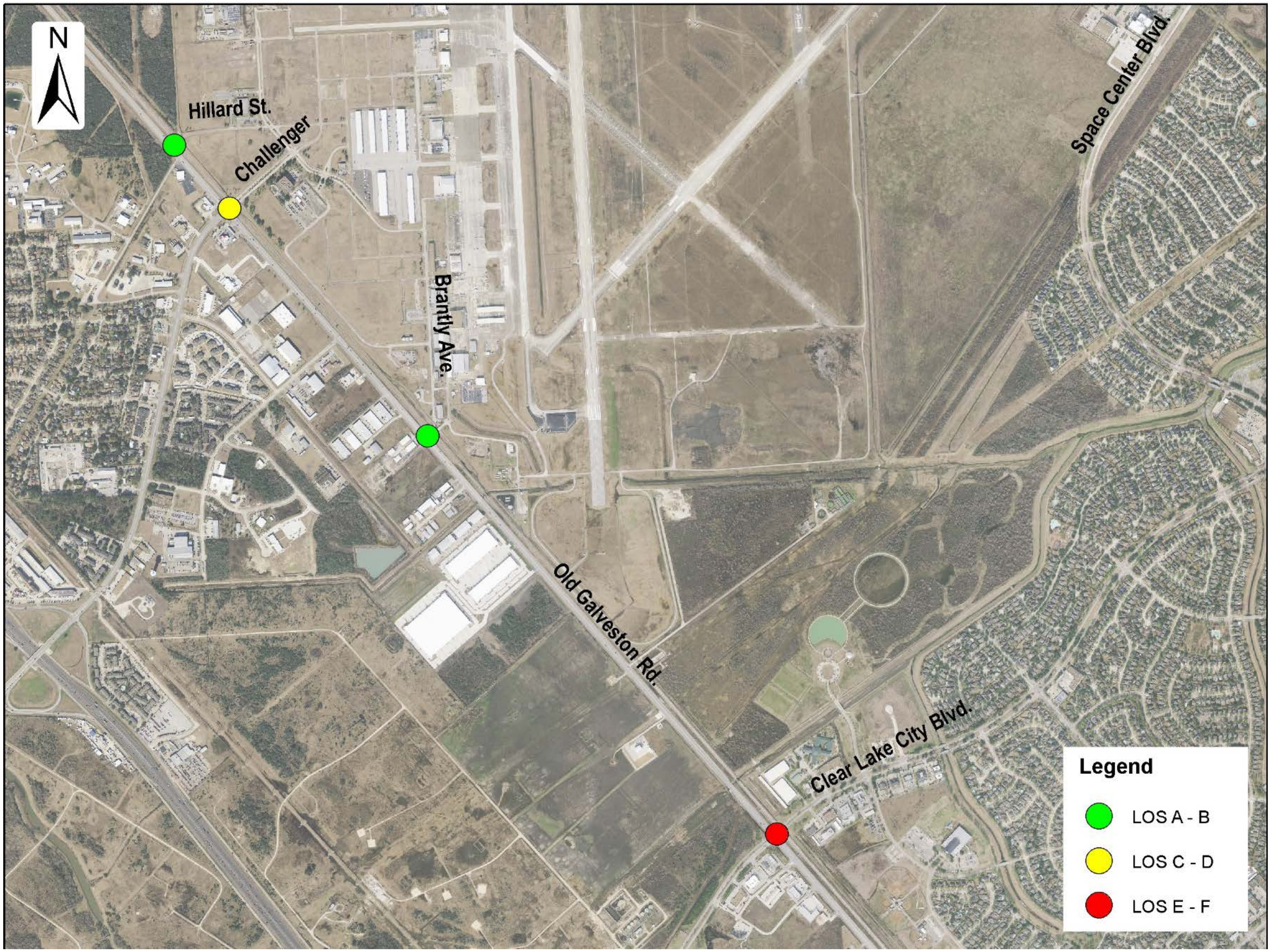


Figure 12: EFD Airport Study Area: 2020 Project PM Peak Hour Level of Service

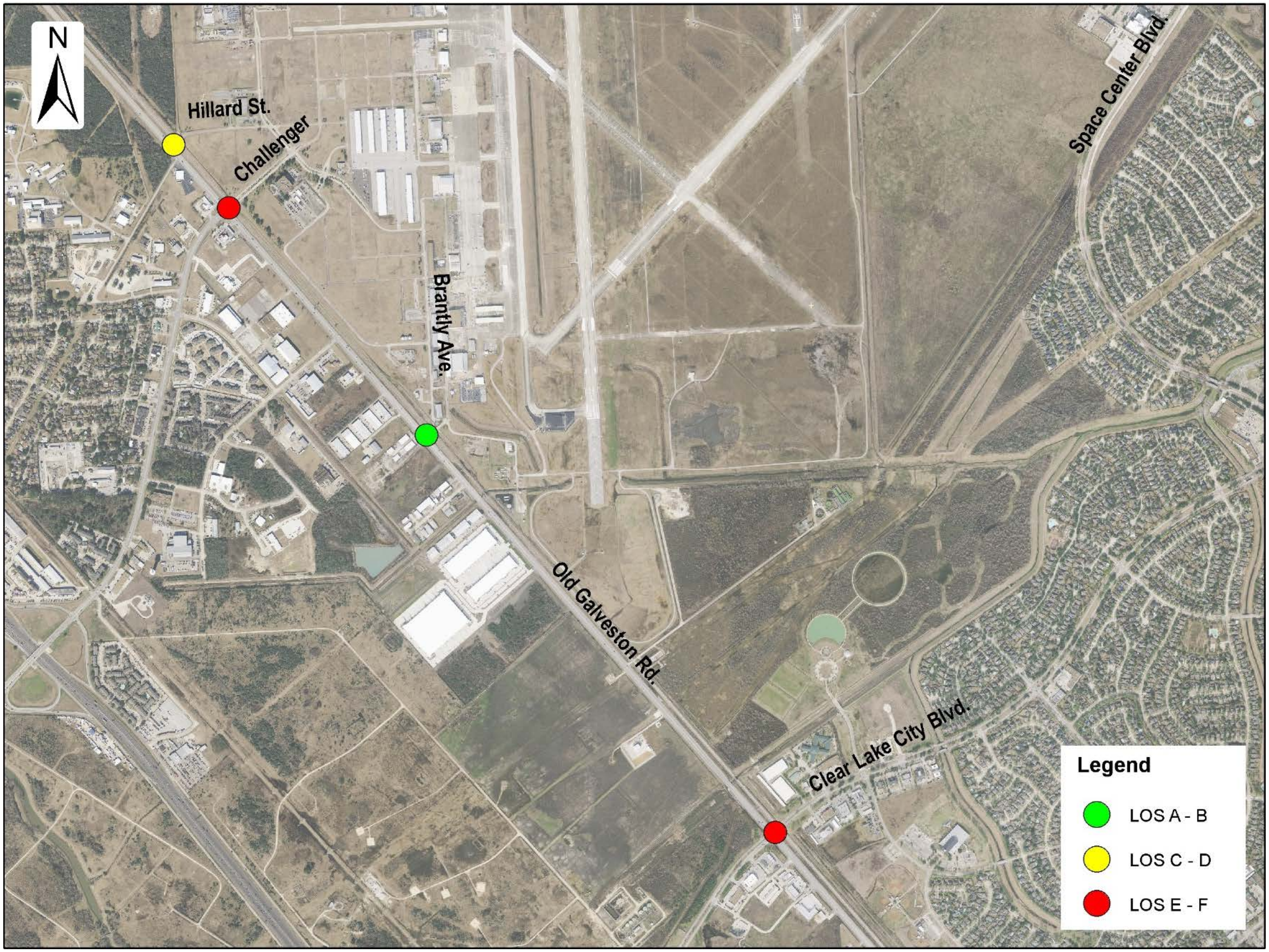


Figure 13: EFD Airport Study Area: 2030 Project AM Peak Hour Level of Service

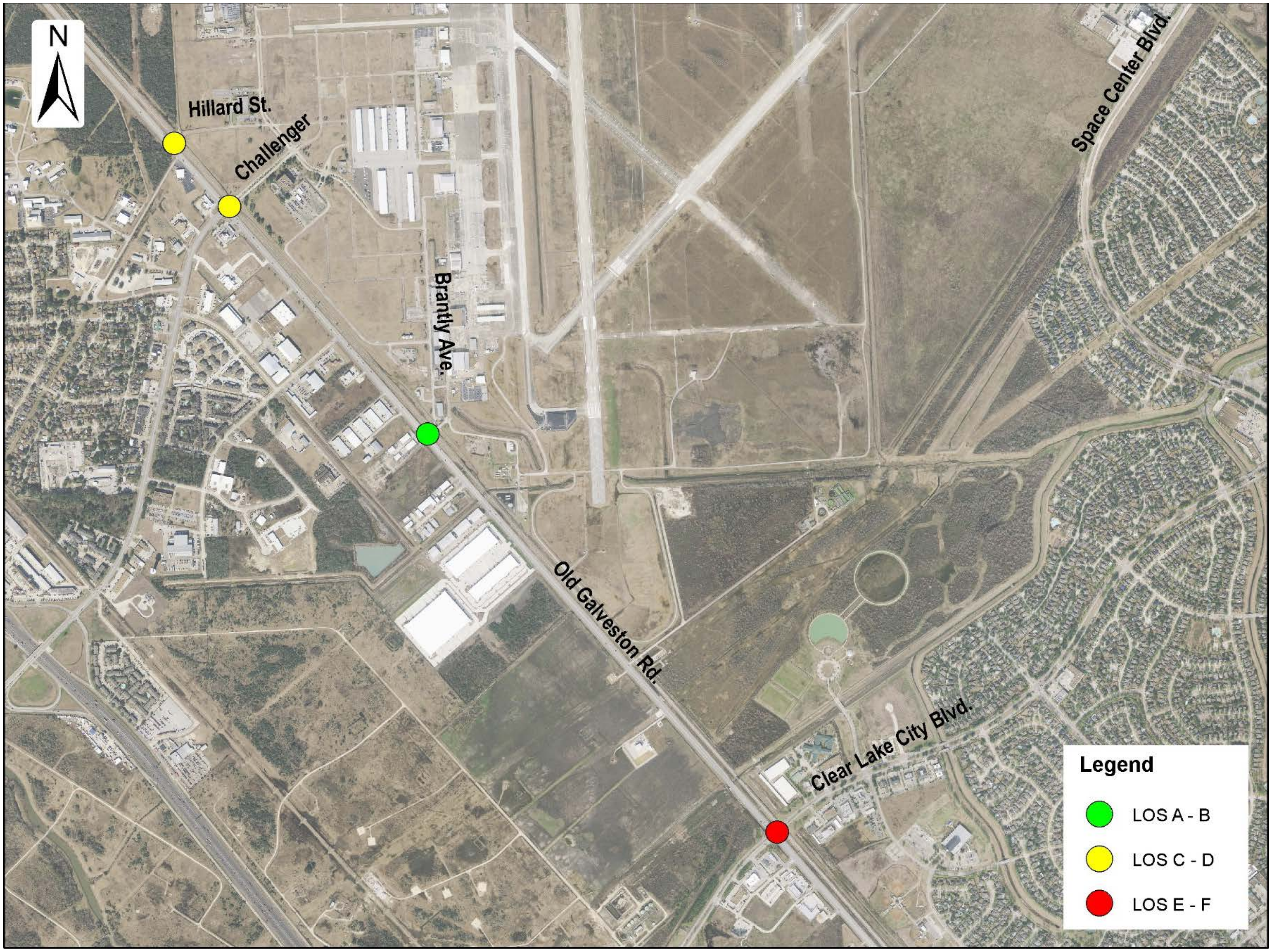
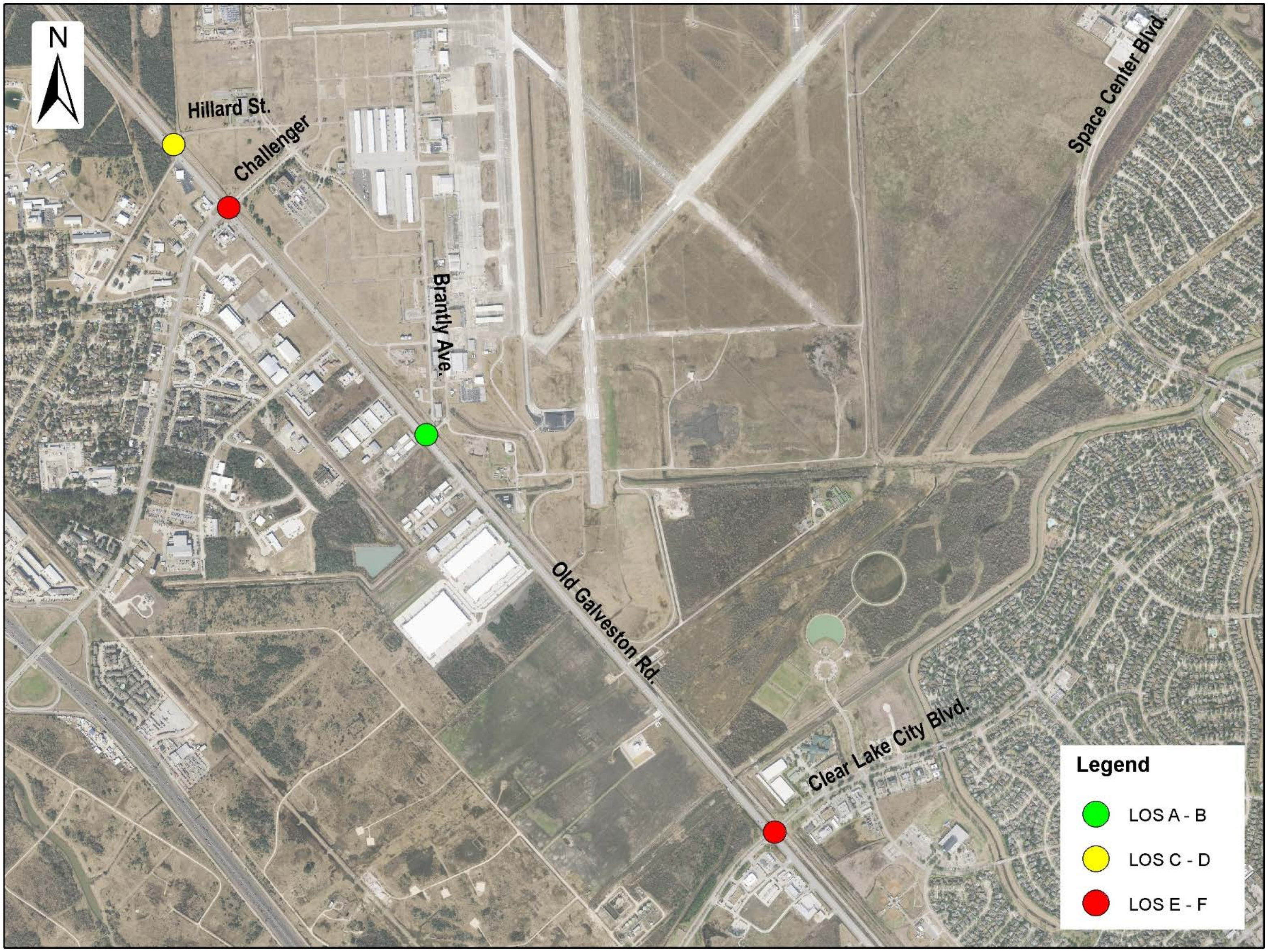


Figure 14: EFD Airport Study Area: 2030 Project PM Peak Hour Level of Service



MITIGATED PROJECT CONDITIONS

As indicated in the previous sections, by conducting traffic analysis for future conditions for both Year 2020 and 2030 scenarios, was determined that the intersections of Old Galveston Road at Challenger Drive and Clearlake City Boulevard are projected to operate at level of service F by Year 2020.

The following roadway improvements are recommended to improve the traffic operations at those two intersections:

- Old Galveston Road at Challenger Drive
    - Add additional south/eastbound right turn bay (200’)
- Old Galveston Road at Clearlake City Boulevard
    - Add additional south/eastbound left turn bay (300’)
    - Add additional north/westbound left turn bay (300’)
    - Add additional south/westbound left turn bay (125’)
    - Add additional north/eastbound left turn bay (315’)
    - Add south/eastbound right turn bay (300’)
    - Add north/westbound right turn bay (300’)
    - Add south/westbound right turn bay (250’)

The availability of right-of-way to implement the above mentioned improvement measures need to be field verified.

Following the implementation of improvement measures, the study intersections are anticipated to operate at LOS D or better under Year 2020 traffic conditions. The mitigated conditions level of service for Year 2020 are summarized in Table 9 and are graphically illustrated in Figure 16 and Figure 17, for AM and PM peak hours, respectively.

Table 9 - Intersections Level of Service – 2020 Mitigated Project Condition

Ellington Field Airport Master Plan Update

INTERSECTIONS	AM PEAK HOUR		PM PEAK HOUR	
	LOS	Delay[1]	LOS	Delay[1]
Old Galveston Road (SH 3) at Hillard Street2, 3	B	14.2	C	10.4
Old Galveston Road (SH 3) at Challenger Drive	C	23.0	C	34.3
Old Galveston Road (SH 3) at Brantly Avenue	A	3.8	A	7.1
Old Galveston Road (SH 3) at Clearlake City Blvd.	D	43.3	D	54.9

NOTES:
LOS – LEVEL OF SERVICE
[1] DELAY IS PRESENTED IN SECONDS PER VEHICLE
[2] DELAY SHOWN FOR CRITICAL MOVEMENT
[3] UNSIGNALIZED INTERSECTION

However, with the recommended improvements, the intersection of Old Galveston Road at Clearlake City Boulevard would operate at LOS E under Year 2030 traffic conditions. The mitigated conditions level of service for Year 2030 are summarized in Table 10 and are graphically illustrated in Figure 17 and Figure 18 for AM and PM peak hour, respectively.

As part of the EFD Masterplan Update it has been identified that significant development opportunities exist within EFD boundaries. Some of them include Aircraft Manufacturing facilities, Aerospace research and design laboratories, additional air cargo operations facilities, additional office space. These developments may require access and roadway connectivity improvements in addition to the intersection improvements presented for Year 2020 and Year 2030 traffic conditions.

A Rail Spur to Southeast Quadrant is proposed to support the proposed developments anticipated to be completed by Year 2030. Additionally, the following potential access improvements are identified in the masterplan update:

- A bypass road connecting Old Galveston Road and Space Center Boulevard
- Beltway 8 connector to north

The implementation of these improvements would improve the operation of the intersection of Old Galveston Road at Clearlake City Boulevard. A significant portion of the traffic currently on Clearlake City Boulevard would be diverted to the proposed bypass road connecting to Space Center Boulevard.

The recommended improvement measures are illustrated in Figure 19 and the proposed long term access improvements are graphically illustrated in Figure 20.

Table 10 - Intersections Level of Service – 2030 Mitigated Project Condition

Ellington Field Airport Master Plan Update

INTERSECTIONS	AM PEAK HOUR		PM PEAK HOUR	
	LOS	Delay1	LOS	Delay1
Old Galveston Road (SH 3) at Hillard Street2, 3	C	17.6	D	11.5
Old Galveston Road (SH 3) at Challenger Drive	C	27.3	D	48.9
Old Galveston Road (SH 3) at Brantly Avenue	A	4.5	A	9.4
Old Galveston Road (SH 3) at Clearlake City Blvd.	E	59.8	F	91.7

NOTES:

LOS – LEVEL OF SERVICE

[1] DELAY IS PRESENTED IN SECONDS PER VEHICLE

[2] DELAY SHOWN FOR CRITICAL MOVEMENT

[3] UNSIGNALIZED INTERSECTION

Figure 15: EFD Airport Study Area: Mitigated Year 2020 Project AM Peak Hour Level of Service

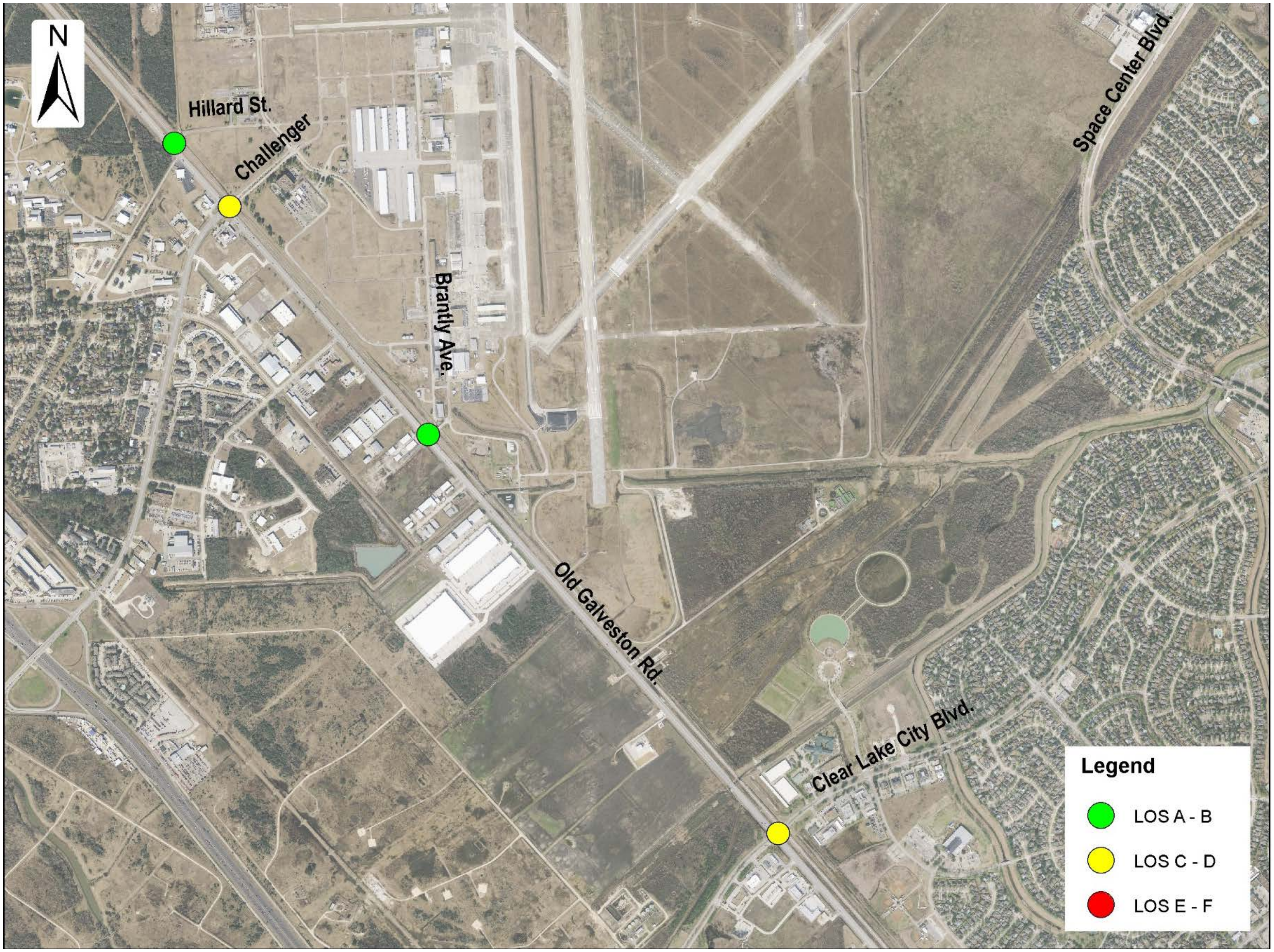


Figure 16: EFD Airport Study Area: Mitigated Year 2020 Project PM Peak Hour Level of Service

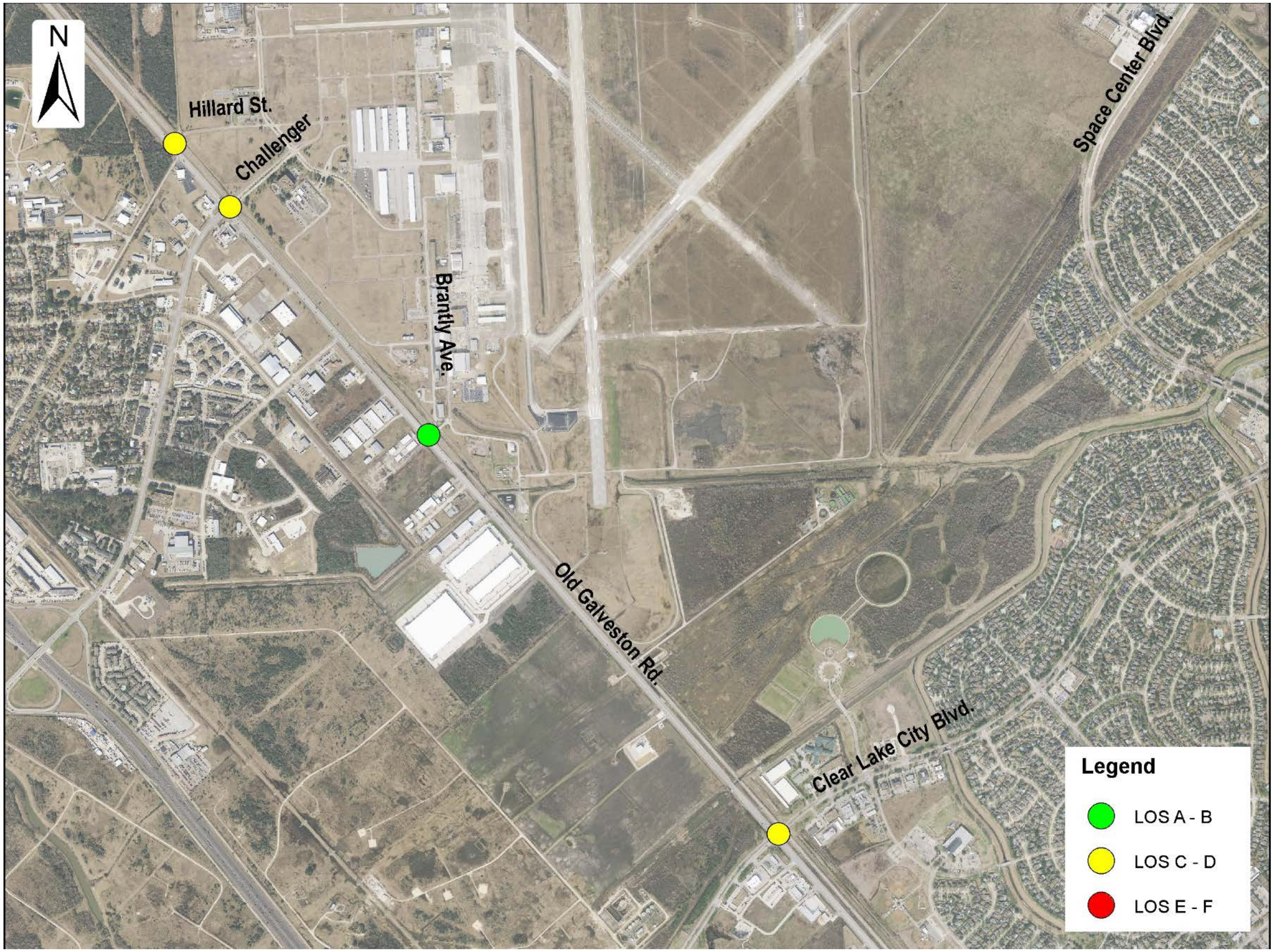


Figure 17: EFD Airport Study Area: Mitigated Year 2030 Project AM Peak Hour Level of Service

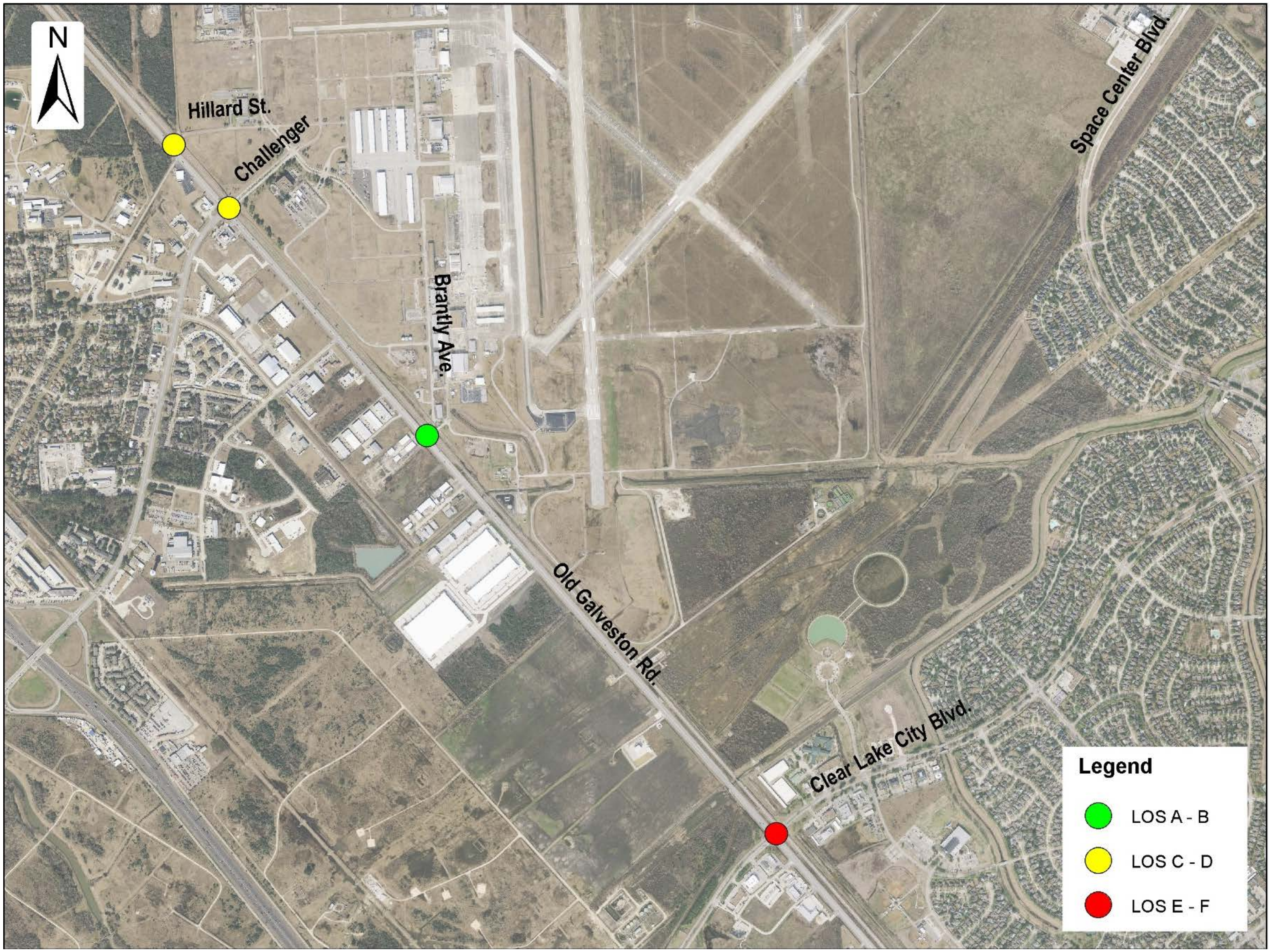
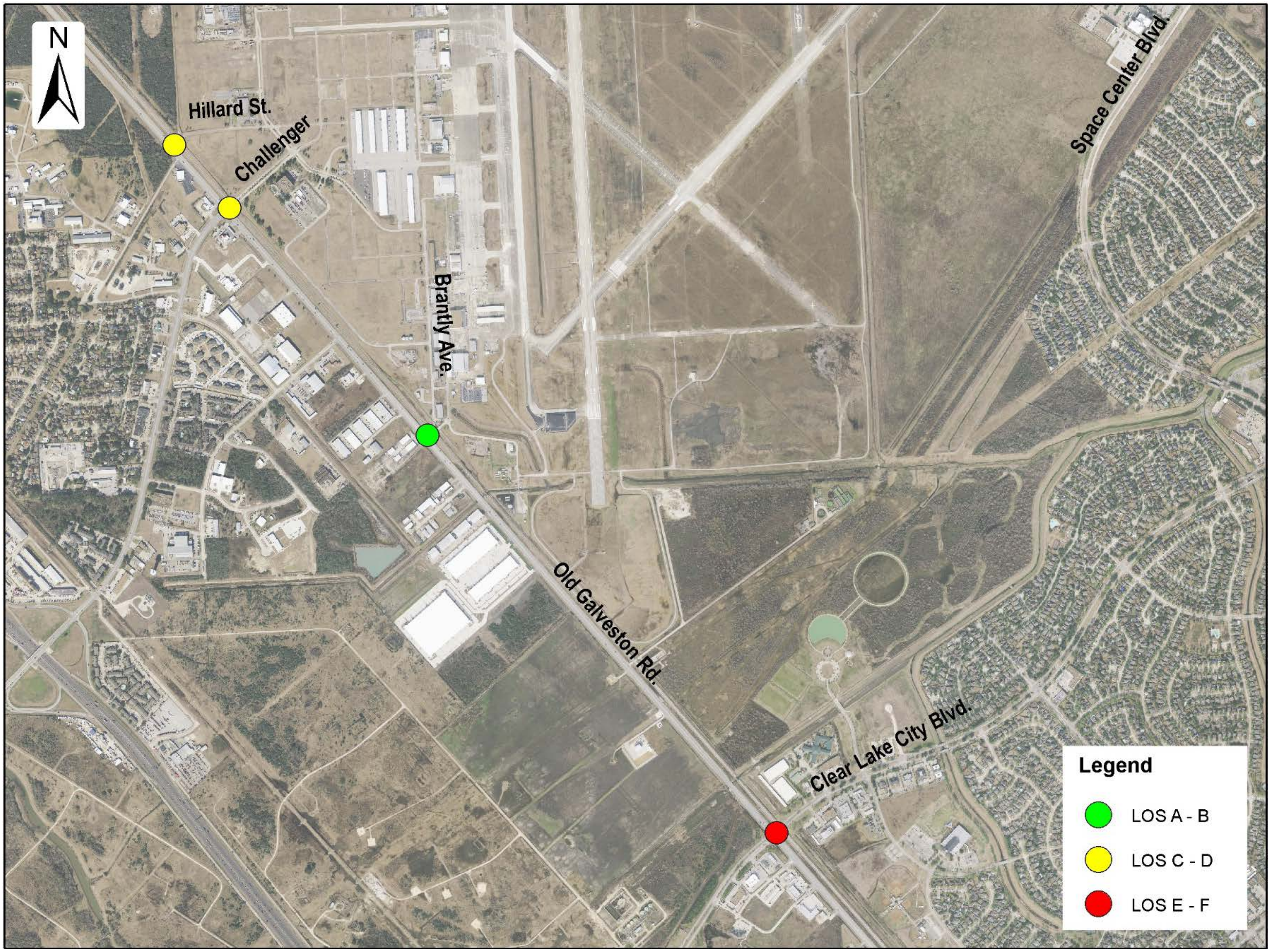
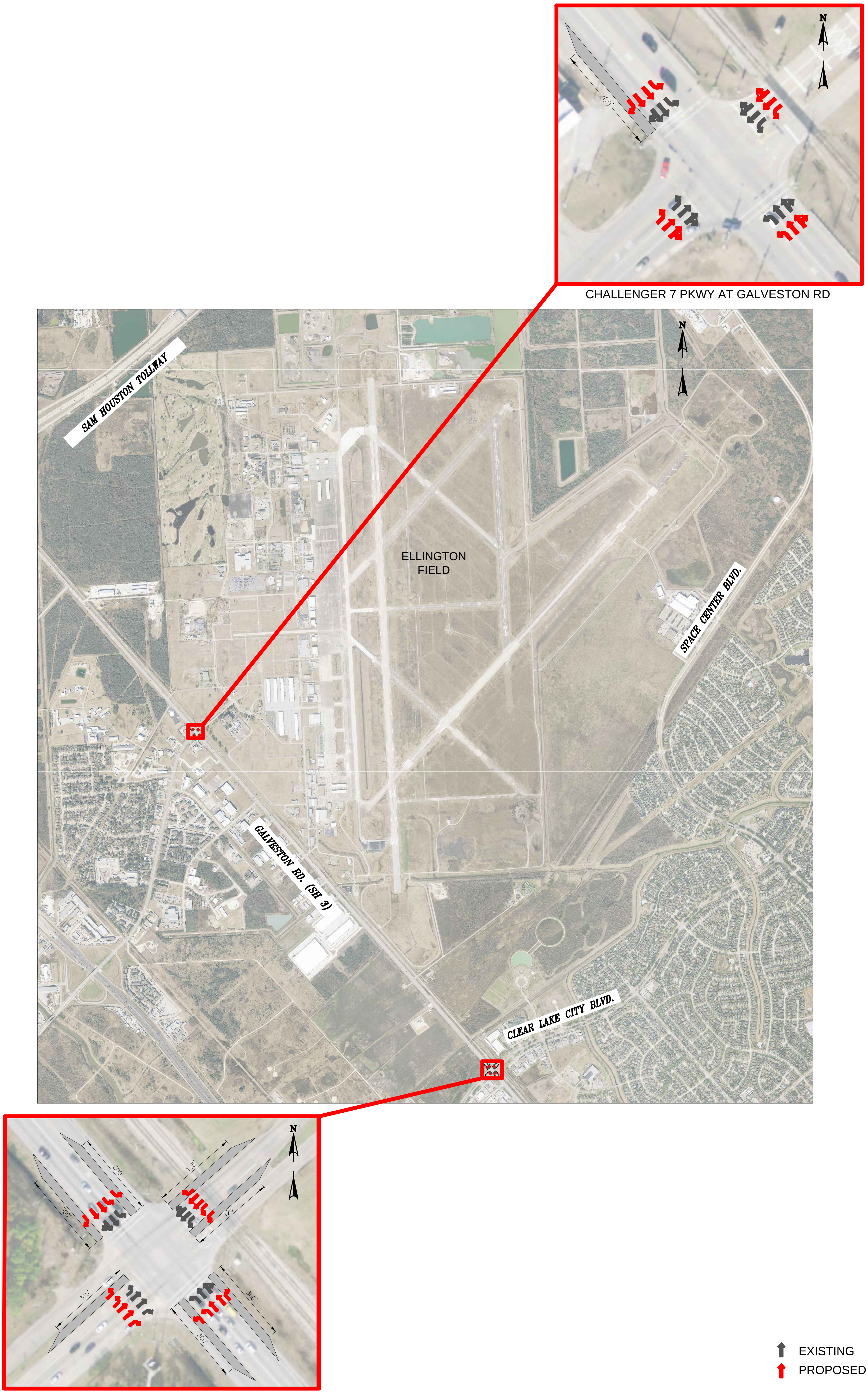


Figure 18: EFD Airport Study Area: Mitigated Year 2030 Project PM Peak Hour Level of Service





CLEAR LAKE CITY BLVD AT GALVESTON RD

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TBPE Registration Number: F-3531

PROJECT NAME:

ELLINGTON FIELD AIRPORT MASTER PLAN UPDATE

SHEET TITLE:

ELLINGTON FIELD AERIAL MAP

PROJ. NO.: 11007-01

DATE: MAY 2015

SHEET NO. FIGURE 19

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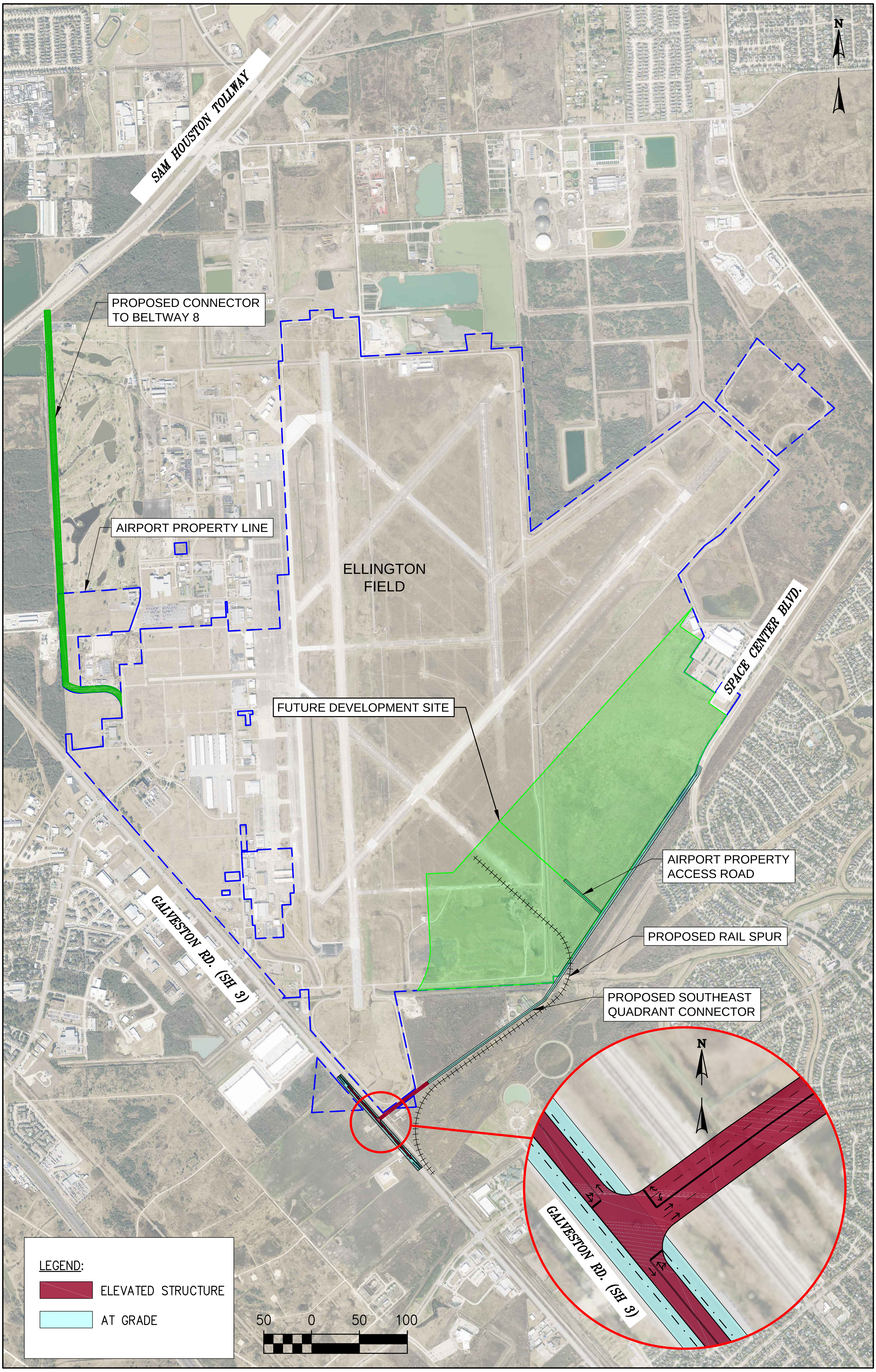

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PROJECT NAME:

ELLINGTON FIELD AIRPORT MASTER PLAN UPDATE

SHEET TITLE:

ELLINGTON FIELD AERIAL MAP

PROJ. NO.: 11007-01

DATE: MAY 2015

SHEET NO.: FIGURE 20

FINDINGS AND CONCLUSION

Based on the results of the traffic analysis conducted for the study area intersections in the vicinity of the EFD Airport, the following is a summary of our findings.

- Under the existing conditions, the intersections of Old Galveston Road at Hillard Street, Challenger Drive and Brantley Avenue are operating at level of service D or better. The intersection of Old Galveston Road at Clearlake City Boulevard is operating at level of service F, during both AM and PM peak hours.

- Under Year 2020 and 2030 background conditions, increase in the delays for the study intersections was observed. The intersection of Old Galveston Road at Challenger Drive is expected to deteriorate to LOS F during PM peak hour.

- Under Year 2020 and 2030 traffic conditions with airport traffic, delays continue to increase for the study intersections, but the study intersections would operate at the same acceptable levels of service as under background conditions. However, they will experience only a minor increase in the delay. The airport traffic alone is not anticipated to create level of service F condition but this is due to existing and background growth expected.

- The study intersections are anticipated to operate at LOS D or better following the implementation of recommended mitigation measures under Year 2020 traffic conditions. However, under Year 2030 traffic conditions, the intersection of Old Galveston Road at Clearlake City Boulevard is projected to operate at level of service F, during both AM and PM peak hours.

- The following long term access improvements which are included in the masterplan update are anticipated to alleviate the delays to the traffic movements on the roadways and intersections providing access to Ellington Field Airport:

  1. Sam Houston Tollway Connector and
  2. Bypass Road Connecting Space Center Boulevard

The study concludes that the public roadway system, following the implementation of intersection improvements presented in this report as well as the access improvements considered as part of masterplan development, can accommodate the anticipated traffic volumes generated by the proposed developments at Ellington Field Airport during the Year 2020 and Year 2030.

APPENDIX A

TRAFFIC VOLUMES

LEGEND

↑ DIRECTION

000 VOLUME

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TBPE Registration Number: F-3531

PROJECT NAME:

ELLINGTON FIELD AIRPORT MASTER PLAN UPDATE

SHEET TITLE:

EXISTING CONDITION AM PEAK HOUR TURNING MOVEMENT COUNTS

PROJ. NO.:
11007-01

DATE:
MAY 2015

SHEET NO.
EXHIBIT A-1

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LEGEND

↑ DIRECTION

000 VOLUME

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TBPE Registration Number: F-3531

PROJECT NAME:

ELLINGTON FIELD AIRPORT MASTER PLAN UPDATE

SHEET TITLE:

EXISTING CONDITIONS PM PEAK HOUR TURNING MOVEMENT COUNTS

PROJ. NO.: 11007-01

DATE: MAY 2015

SHEET NO. EXHIBIT A-2

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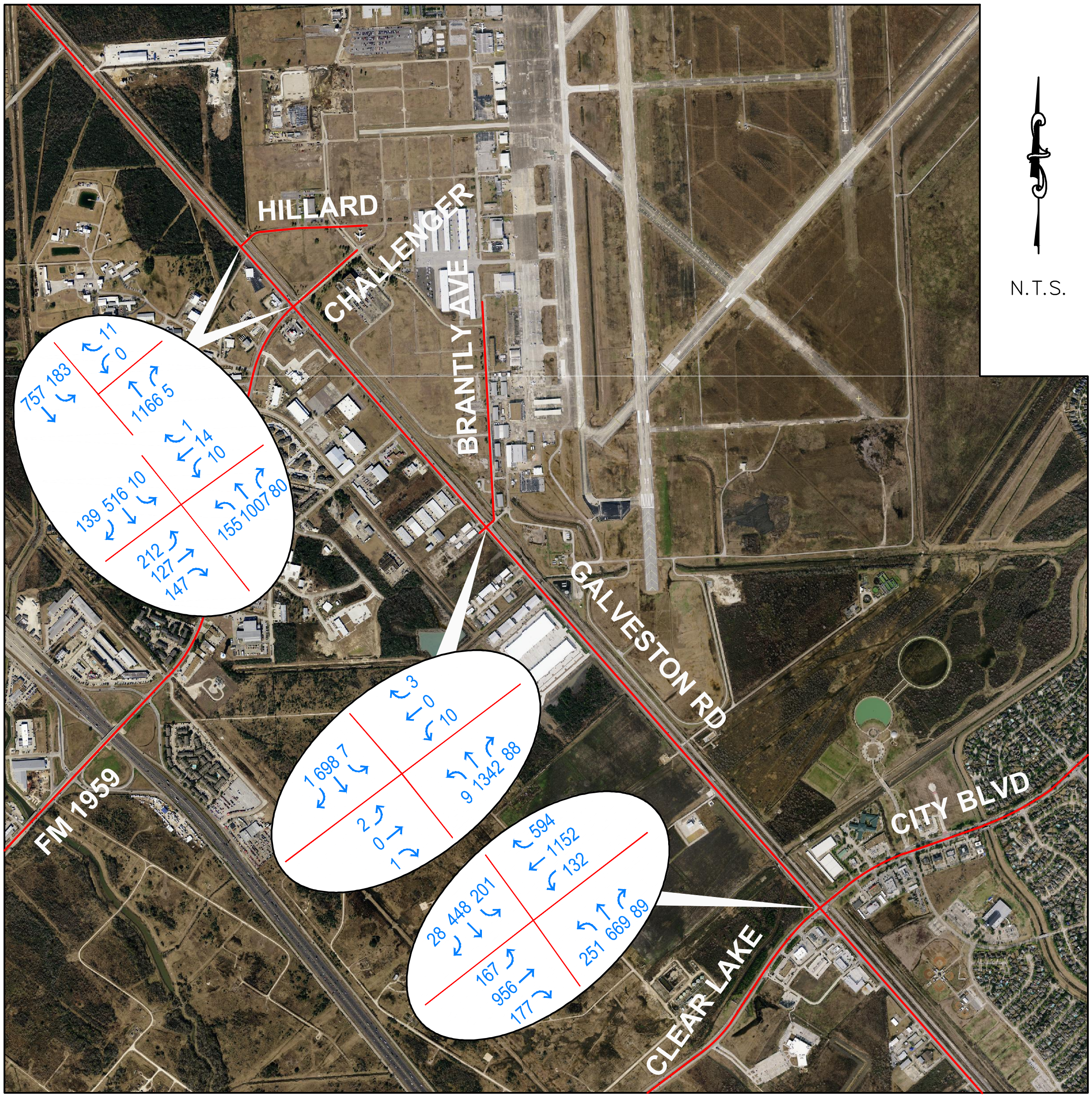

LEGEND

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TBPE Registration Number: F-3531

PROJECT NAME:

ELLINGTON FIELD AIRPORT MASTER PLAN UPDATE

SHEET TITLE:

2020 BACKGROUND AM PEAK HOUR TURNING MOVEMENT COUNTS

PROJ. NO.: **11007-01**

DATE: **MAY 2015**

SHEET NO.

EXHIBIT A-3

GUNDA CORPORATION

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TBPE Registration Number: F-3531

PROJECT NAME:

ELLINGTON FIELD AIRPORT MASTER PLAN UPDATE

SHEET TITLE:

2020 BACKGROUND PM PEAK HOUR TURNING MOVEMENT COUNTS

PROJ. NO.: 11007-01

DATE: MAY 2015

SHEET NO.: EXHIBIT A-4

GUNDA CORPORATION
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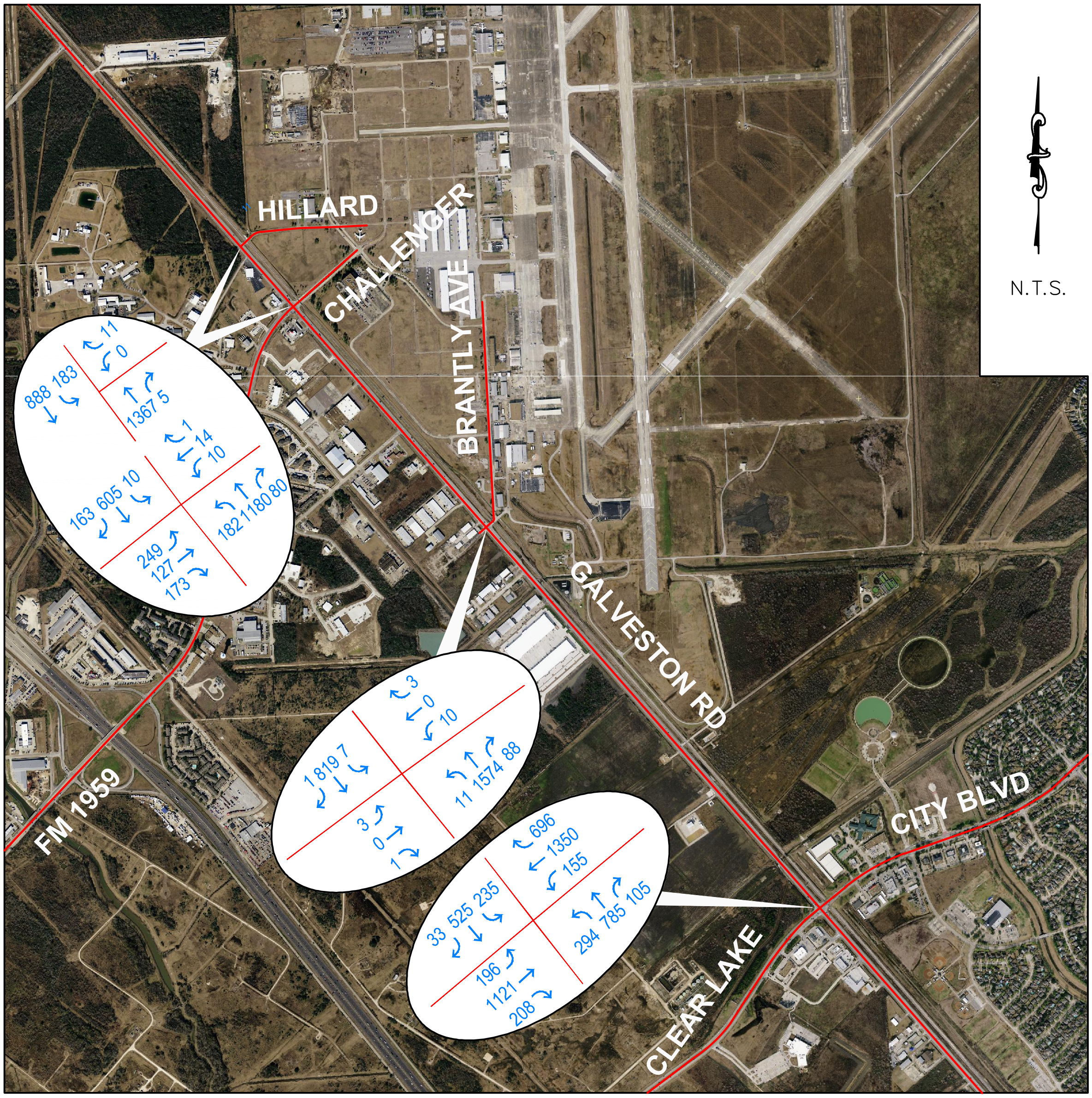

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PROJECT NAME:

ELLINGTON FIELD AIRPORT MASTER PLAN UPDATE

SHEET TITLE:

2030 BACKGROUND AM PEAK HOUR TURNING MOVEMENT COUNTS

PROJ. NO.: 11007-01

DATE: MAY 2015

SHEET NO.: EXHIBIT A-5

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PROJECT NAME:

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SHEET TITLE:

2030 BACKGROUND PM PEAK HOUR TURNING MOVEMENT COUNTS

PROJ. NO.:
11007-01

DATE:
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SHEET NO.
EXHIBIT A-6

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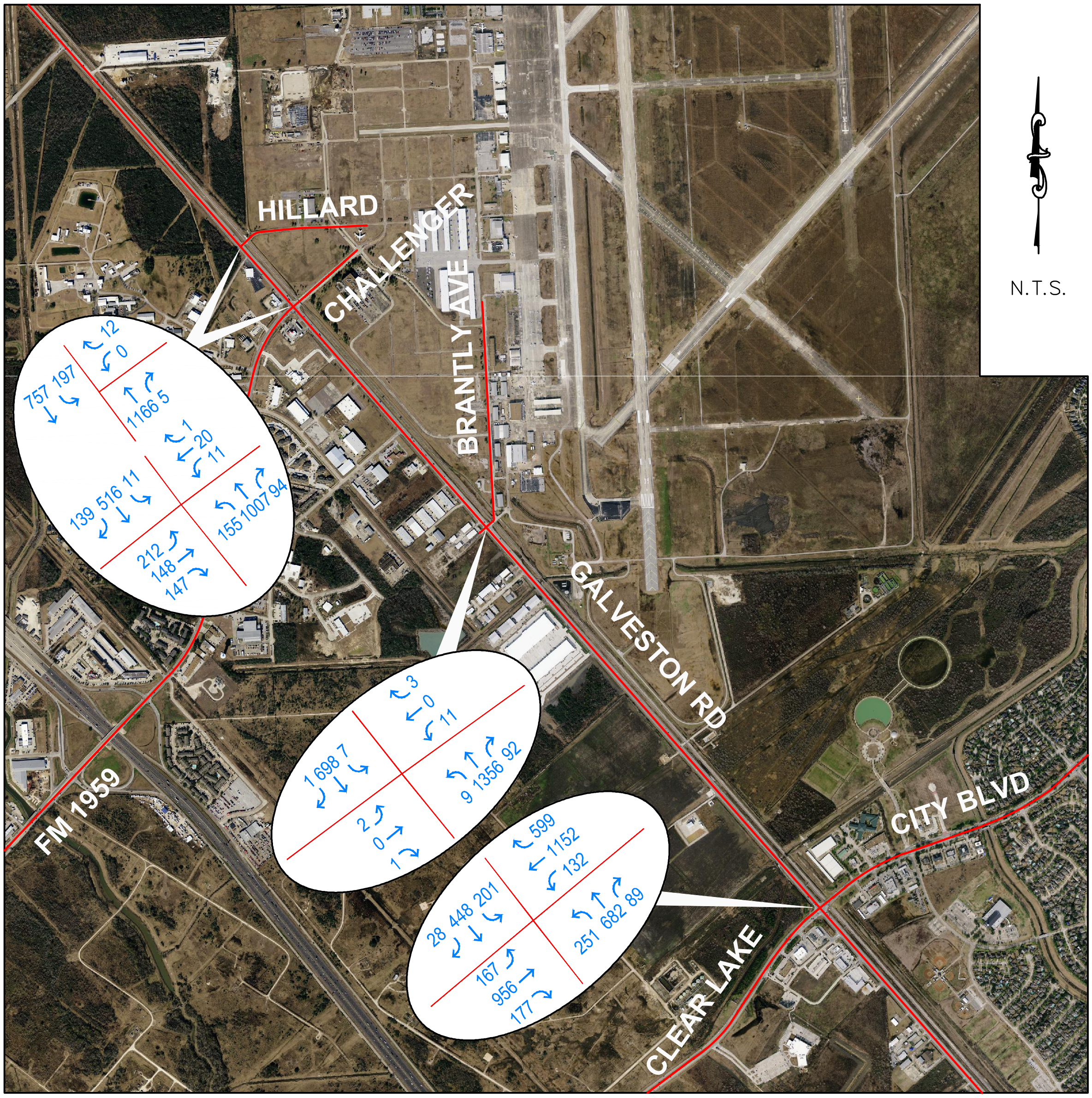

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PROJECT NAME:

ELLINGTON FIELD AIRPORT MASTER PLAN UPDATE

SHEET TITLE:

2020 BUILD AM PEAK HOUR TURNING MOVEMENT COUNTS

PROJ. NO.: 11007-01

DATE: MAY 2015

SHEET NO.: EXHIBIT A-7

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PROJECT NAME:

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SHEET TITLE:

2020 BUILD PM PEAK HOUR TURNING MOVEMENT COUNTS

PROJ. NO.: 11007-01

DATE: MAY 2015

SHEET NO.: EXHIBIT A-8

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PROJECT NAME:

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SHEET TITLE:

2030 BUILD AM PEAK HOUR TURNING MOVEMENT COUNTS

PROJ. NO.:
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DATE:
MAY 2015

SHEET NO.
EXHIBIT A-9

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LEGEND

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PROJECT NAME:

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SHEET TITLE:

2030 BUILD PM PEAK HOUR TURNING MOVEMENT COUNTS

PROJ. NO.: 11007-01

DATE: MAY 2015

SHEET NO.: EXHIBIT A-10

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APPENDIX B

INTERSECTION LEVEL OF SERVICE ANALYSIS REPORTS

Movement	SEL	SET	NWT	NWR	SWL	SWR
Lane Configurations	↰	↑↑	↑↱		↰↱	
Volume (veh/h)	183	653	1005	5	0	11
Sign Control		Free	Free		Stop	
Grade		0%	0%		0%	
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92
Hourly flow rate (vph)	199	823	1267	5	0	12
Pedestrians						
Lane Width (ft)						
Walking Speed (ft/s)						
Percent Blockage						
Right turn flare (veh)						
Median type		None	None			
Median storage veh)						
Upstream signal (ft)			968			
pX, platoon unblocked	0.84				0.84	0.84
vC, conflicting volume	1273				2079	636
vC1, stage 1 conf vol						
vC2, stage 2 conf vol						
vCu, unblocked vol	955				1910	202
tC, single (s)	4.2				6.8	6.9
tC, 2 stage (s)						
tF (s)	2.3				3.5	3.3
p0 queue free %	66				100	98
cM capacity (veh/h)	584				33	680

Direction, Lane #	SE 1	SE 2	SE 3	NW 1	NW 2	SW 1
Volume Total	199	412	412	845	428	12
Volume Left	199	0	0	0	0	0
Volume Right	0	0	0	0	5	12
cSH	584	1700	1700	1700	1700	680
Volume to Capacity	0.34	0.24	0.24	0.50	0.25	0.02
Queue Length 95th (ft)	38	0	0	0	0	1
Control Delay (s)	14.3	0.0	0.0	0.0	0.0	10.4
Lane LOS	B					B
Approach Delay (s)	2.8			0.0		10.4
Approach LOS						B

Intersection Summary			
Average Delay	1.3		
Intersection Capacity Utilization	55.9%	ICU Level of Service	B
Analysis Period (min)	15		

Lane Group	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations	↰	↑↑↱		↰	↑↑↱		↰	↑↑	↱	↰	↑↑↱	
Volume (vph)	173	386	24	216	577	77	144	824	153	114	993	512
Satd. Flow (prot)	1703	3375	0	1703	3344	0	1770	3539	1583	1770	3359	0
Flt Permitted	0.950			0.950			0.950			0.950		
Satd. Flow (perm)	1703	3375	0	1703	3344	0	1770	3539	1583	1770	3359	0
Satd. Flow (RTOR)		4			10				193		92	
Lane Group Flow (vph)	218	517	0	272	825	0	182	1039	193	144	1898	0
Turn Type	Prot	NA		Prot	NA		Prot	NA	Perm	Prot	NA	
Protected Phases	7	4		3	8		5	2		1	6	
Permitted Phases									2			
Total Split (s)	23.0	23.0		25.0	25.0		17.0	52.0	52.0	20.0	55.0	
Total Lost Time (s)	5.5	6.5		5.5	6.5		5.0	6.5	6.5	5.0	6.5	
Act Effct Green (s)	17.1	16.5		19.5	18.9		12.0	47.3	47.3	13.2	48.5	
Actuated g/C Ratio	0.14	0.14		0.16	0.16		0.10	0.39	0.39	0.11	0.40	
v/c Ratio	0.90	1.11		0.99	1.54		1.03	0.75	0.26	0.74	1.34	
Control Delay	88.2	121.3		101.2	287.2		128.3	35.6	4.4	73.9	189.6	
Queue Delay	0.0	0.0		0.0	0.0		0.0	0.0	0.0	0.0	0.0	
Total Delay	88.2	121.3		101.2	287.2		128.3	35.6	4.4	73.9	189.6	
LOS	F	F		F	F		F	D	A	E	F	
Approach Delay		111.4			241.0			43.3			181.5	
Approach LOS		F			F			D			F	

Intersection Summary

Cycle Length: 120

Actuated Cycle Length: 120

Offset: 60 (50%), Referenced to phase 2:NET and 6:SWT, Start of Green

Control Type: Actuated-Coordinated

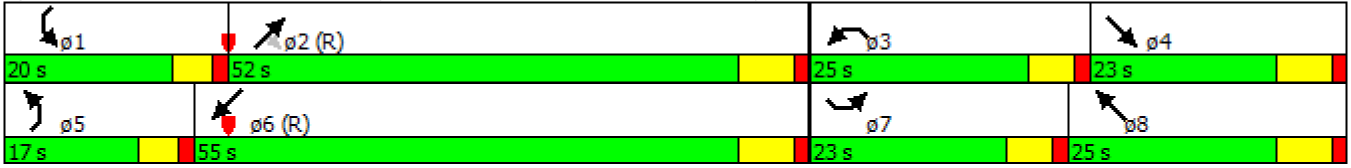
Maximum v/c Ratio: 1.54

Intersection Signal Delay: 147.1 Intersection LOS: F

Intersection Capacity Utilization 112.2% ICU Level of Service H

Analysis Period (min) 15

Splits and Phases: 3: Clear Lake City Blvd. / Clear Lake City Blvd. & Old Galveston Rd. /Old Galveston Rd.



Lane Group	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations	↰	↑↱		↰	↑↱		↰	↑↱		↰	↑↱	
Volume (vph)	10	445	120	134	868	80	183	127	127	10	14	1
Satd. Flow (prot)	1703	3297	0	1703	3368	0	1770	3253	0	1770	3507	0
Flt Permitted	0.950			0.950			0.950			0.950		
Satd. Flow (perm)	1703	3297	0	1703	3368	0	1770	3253	0	1770	3507	0
Satd. Flow (RTOR)		40			10			160			1	
Lane Group Flow (vph)	11	712	0	169	1181	0	231	298	0	11	16	0
Turn Type	Prot	NA		Prot	NA		Prot	NA		Prot	NA	
Protected Phases	5	2		1	6		7	4		3	8	
Permitted Phases												
Total Split (s)	15.0	45.0		15.0	45.0		15.0	25.0		15.0	25.0	
Total Lost Time (s)	5.5	5.5		5.5	5.5		5.0	5.0		5.0	5.0	
Act Effct Green (s)	5.5	51.5		17.6	72.1		10.0	12.7		5.4	6.0	
Actuated g/C Ratio	0.06	0.52		0.18	0.72		0.10	0.13		0.05	0.06	
v/c Ratio	0.12	0.41		0.57	0.49		1.31	0.54		0.11	0.08	
Control Delay	47.4	16.3		42.0	10.4		209.7	22.1		47.3	42.2	
Queue Delay	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Total Delay	47.4	16.3		42.0	10.4		209.7	22.1		47.3	42.2	
LOS	D	B		D	B		F	C		D	D	
Approach Delay		16.8			14.4			104.0			44.3	
Approach LOS		B			B			F			D	

Intersection Summary

Cycle Length: 100
Actuated Cycle Length: 100
Offset: 40 (40%), Referenced to phase 2:SET and 6:NWT, Start of Green
Control Type: Actuated-Coordinated
Maximum v/c Ratio: 1.31
Intersection Signal Delay: 33.4 Intersection LOS: C
Intersection Capacity Utilization 66.3% ICU Level of Service C
Analysis Period (min) 15

Splits and Phases: 8: Dixie Farm Rd. / Challenger & Old Galveston Rd. /Old Galveston Rd.

11: Old Galveston Rd. / Old Galveston Rd. & Brantly Ave.

Lane Group	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations	↰	↑↱		↰	↑↱			✥			↰↑	↱
Volume (vph)	7	602	1	8	1157	88	2	0	1	10	0	3
Satd. Flow (prot)	1703	3406	0	1703	3375	0	0	1735	0	0	1770	1583
Flt Permitted	0.950			0.950								
Satd. Flow (perm)	1703	3406	0	1703	3375	0	0	1799	0	0	1863	1583
Satd. Flow (RTOR)					12			109				109
Lane Group Flow (vph)	8	760	0	10	1555	0	0	4	0	0	11	3
Turn Type	Prot	NA		Prot	NA		Perm	NA		Perm	NA	Perm
Protected Phases	5	2		1	6			4			8	
Permitted Phases							4			8		8
Total Split (s)	18.0	65.0		18.0	65.0		17.0	17.0		17.0	17.0	17.0
Total Lost Time (s)	6.5	6.5		6.5	6.0			5.0			5.5	5.5
Act Effct Green (s)	6.1	89.8		6.2	90.1			5.8			5.6	5.6
Actuated g/C Ratio	0.06	0.90		0.06	0.90			0.06			0.06	0.06
v/c Ratio	0.08	0.25		0.10	0.51			0.02			0.11	0.02
Control Delay	42.6	1.7		45.8	4.0			0.2			46.5	0.0
Queue Delay	0.0	0.0		0.0	0.0			0.0			0.0	0.0
Total Delay	42.6	1.7		45.8	4.0			0.2			46.5	0.0
LOS	D	A		D	A			A			D	A
Approach Delay		2.1			4.3			0.3			36.5	
Approach LOS		A			A			A			D	

Intersection Summary

Cycle Length: 100
Actuated Cycle Length: 100
Offset: 90 (90%), Referenced to phase 2:SET and 6:NWT, Start of Green
Control Type: Actuated-Coordinated
Maximum v/c Ratio: 0.51
Intersection Signal Delay: 3.7 Intersection LOS: A
Intersection Capacity Utilization 62.0% ICU Level of Service B
Analysis Period (min) 15

Splits and Phases: 11: Old Galveston Rd. / Old Galveston Rd. & Brantly Ave.

1: Old Galveston Rd. & Hillard St.

Movement	SEL	SET	NWT	NWR	SWL	SWR
Lane Configurations	↰	↑↑	↑↱		↰↱	
Volume (veh/h)	183	653	1005	5	0	11
Sign Control		Free	Free		Stop	
Grade		0%	0%		0%	
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92
Hourly flow rate (vph)	199	965	1486	5	0	12
Pedestrians						
Lane Width (ft)						
Walking Speed (ft/s)						
Percent Blockage						
Right turn flare (veh)						
Median type		None	None			
Median storage veh)						
Upstream signal (ft)			968			
pX, platoon unblocked	0.78				0.78	0.78
vC, conflicting volume	1491				2369	746
vC1, stage 1 conf vol						
vC2, stage 2 conf vol						
vCu, unblocked vol	1054				2186	93
tC, single (s)	4.2				6.8	6.9
tC, 2 stage (s)						
tF (s)	2.3				3.5	3.3
p0 queue free %	59				100	98
cM capacity (veh/h)	491				18	734

Direction, Lane #	SE 1	SE 2	SE 3	NW 1	NW 2	SW 1
Volume Total	199	483	483	990	501	12
Volume Left	199	0	0	0	0	0
Volume Right	0	0	0	0	5	12
cSH	491	1700	1700	1700	1700	734
Volume to Capacity	0.41	0.28	0.28	0.58	0.29	0.02
Queue Length 95th (ft)	49	0	0	0	0	1
Control Delay (s)	17.2	0.0	0.0	0.0	0.0	10.0
Lane LOS	C					A
Approach Delay (s)	2.9			0.0		10.0
Approach LOS						A

Intersection Summary			
Average Delay	1.3		
Intersection Capacity Utilization	61.4%	ICU Level of Service	B
Analysis Period (min)	15		

2020 Background PM Peak Hour

3: Clear Lake City Blvd. / Clear Lake City Blvd. & Old Galveston R

Lane Group	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations	↰	↑↱		↰	↑↱		↰	↑↑	↱	↰	↑↱	
Volume (vph)	392	1002	226	204	584	117	40	873	254	118	1043	229
Satd. Flow (prot)	1703	3310	0	1703	3321	0	1770	3539	1583	1770	3444	0
Flt Permitted	0.950			0.950			0.950			0.950		
Satd. Flow (perm)	1703	3310	0	1703	3321	0	1770	3539	1583	1770	3444	0
Satd. Flow (RTOR)		22			16				259		20	
Lane Group Flow (vph)	494	1548	0	257	884	0	50	1101	320	149	1604	0
Turn Type	Prot	NA		Prot	NA		Prot	NA	Perm	Prot	NA	
Protected Phases	7	4		3	8		5	2		1	6	
Permitted Phases									2			
Total Split (s)	40.0	54.0		20.0	34.0		12.0	37.0	37.0	24.0	49.0	
Total Lost Time (s)	5.5	6.5		5.5	6.5		5.0	6.5	6.5	5.0	6.5	
Act Effct Green (s)	34.5	47.5		14.5	27.5		6.7	34.0	34.0	15.5	44.9	
Actuated g/C Ratio	0.26	0.35		0.11	0.20		0.05	0.25	0.25	0.11	0.33	
v/c Ratio	1.14	1.31		1.41	1.28		0.57	1.24	0.54	0.73	1.39	
Control Delay	130.9	183.2		257.2	180.5		88.1	158.0	13.6	78.2	213.7	
Queue Delay	0.0	0.0		0.0	0.0		0.0	0.0	0.0	0.0	0.0	
Total Delay	130.9	183.2		257.2	180.5		88.1	158.0	13.6	78.2	213.7	
LOS	F	F		F	F		F	F	B	E	F	
Approach Delay		170.6			197.7			124.2			202.2	
Approach LOS		F			F			F			F	

Intersection Summary

Cycle Length: 135

Actuated Cycle Length: 135

Offset: 67 (50%), Referenced to phase 2:NET and 6:SWT, Start of Green

Control Type: Actuated-Coordinated

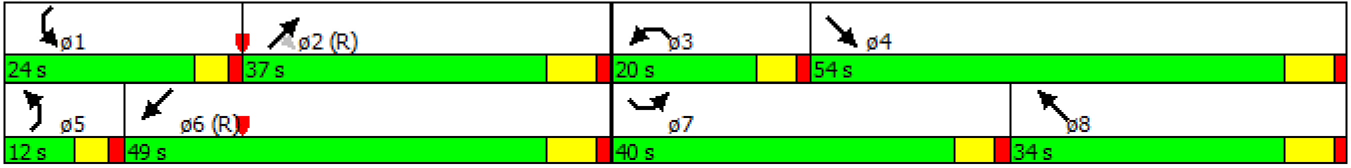
Maximum v/c Ratio: 1.41

Intersection Signal Delay: 173.4 Intersection LOS: F

Intersection Capacity Utilization 119.3% ICU Level of Service H

Analysis Period (min) 15

Splits and Phases: 3: Clear Lake City Blvd. / Clear Lake City Blvd. & Old Galveston Rd. /Old Galveston Rd.



8: Dixie Farm Rd. / Challenger & Old Galveston Rd. /Old Galveston Rd.

Lane Group	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations	↰	↑↱		↰	↑↱		↰	↑↱		↰	↑↱	
Volume (vph)	3	1199	311	183	700	11	138	17	192	93	149	15
Satd. Flow (prot)	1703	3300	0	1703	3399	0	1770	3044	0	1770	3493	0
Flt Permitted	0.950			0.950			0.950			0.950		
Satd. Flow (perm)	1703	3300	0	1703	3399	0	1770	3044	0	1770	3493	0
Satd. Flow (RTOR)		42			2			242			8	
Lane Group Flow (vph)	3	1904	0	231	895	0	174	260	0	101	178	0
Turn Type	Prot	NA		Prot	NA		Prot	NA		Prot	NA	
Protected Phases	5	2		1	6		7	4		3	8	
Permitted Phases												
Total Split (s)	20.0	50.0		20.0	50.0		15.0	15.0		15.0	15.0	
Total Lost Time (s)	5.5	5.5		5.5	5.5		5.0	5.0		5.0	5.0	
Act Effct Green (s)	5.1	45.2		15.0	63.6		10.0	12.1		8.8	8.7	
Actuated g/C Ratio	0.05	0.45		0.15	0.64		0.10	0.12		0.09	0.09	
v/c Ratio	0.03	1.26		0.91	0.41		0.98	0.45		0.65	0.57	
Control Delay	46.0	147.6		81.2	10.3		110.3	9.9		63.1	49.1	
Queue Delay	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Total Delay	46.0	147.6		81.2	10.3		110.3	9.9		63.1	49.1	
LOS	D	F		F	B		F	A		E	D	
Approach Delay		147.5			24.8			50.2			54.2	
Approach LOS		F			C			D			D	

Intersection Summary	
Cycle Length: 100	
Actuated Cycle Length: 100	
Offset: 40 (40%), Referenced to phase 2:SET and 6:NWT, Start of Green	
Control Type: Actuated-Coordinated	
Maximum v/c Ratio: 1.26	
Intersection Signal Delay: 92.4	Intersection LOS: F
Intersection Capacity Utilization 92.7%	ICU Level of Service F
Analysis Period (min) 15	

Splits and Phases: 8: Dixie Farm Rd. / Challenger & Old Galveston Rd. /Old Galveston Rd.

11: Old Galveston Rd. / Old Galveston Rd. & Brantly Ave.

Lane Group	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations	↰	↑↱		↰	↑↱			✥			↰	↱
Volume (vph)	2	1558	1	1	894	11	2	0	5	90	0	12
Satd. Flow (prot)	1703	3406	0	1703	3399	0	0	1668	0	0	1770	1583
Flt Permitted	0.950			0.950				0.902			0.752	
Satd. Flow (perm)	1703	3406	0	1703	3399	0	0	1529	0	0	1401	1583
Satd. Flow (RTOR)					2			109				109
Lane Group Flow (vph)	2	1965	0	1	1139	0	0	9	0	0	98	13
Turn Type	Prot	NA		Prot	NA		Perm	NA		Perm	NA	Perm
Protected Phases	5	2		1	6			4			8	
Permitted Phases							4			8		8
Total Split (s)	20.0	60.0		20.0	60.0		20.0	20.0		20.0	20.0	20.0
Total Lost Time (s)	6.5	6.5		6.5	6.0			5.0			5.5	5.5
Act Effct Green (s)	5.0	78.4		5.0	78.8			11.1			10.9	10.9
Actuated g/C Ratio	0.05	0.78		0.05	0.79			0.11			0.11	0.11
v/c Ratio	0.02	0.74		0.01	0.43			0.03			0.64	0.05
Control Delay	35.5	14.8		46.0	5.9			0.2			61.1	0.3
Queue Delay	0.0	0.0		0.0	0.0			0.0			0.0	0.0
Total Delay	35.5	14.8		46.0	5.9			0.2			61.1	0.3
LOS	D	B		D	A			A			E	A
Approach Delay		14.9			5.9			0.3			53.9	
Approach LOS		B			A			A			D	

Intersection Summary	
Cycle Length: 100	
Actuated Cycle Length: 100	
Offset: 90 (90%), Referenced to phase 2:SET and 6:NWT, Start of Green	
Control Type: Actuated-Coordinated	
Maximum v/c Ratio: 0.74	
Intersection Signal Delay: 13.0	Intersection LOS: B
Intersection Capacity Utilization 71.6%	ICU Level of Service C
Analysis Period (min) 15	

Splits and Phases: 11: Old Galveston Rd. / Old Galveston Rd. & Brantly Ave.

1: Old Galveston Rd. & Hillard St.

Movement	SEL	SET	NWT	NWR	SWL	SWR
Lane Configurations	↰	↑↑	↑↱		↰↱	
Volume (veh/h)	183	653	1005	5	0	11
Sign Control		Free	Free		Stop	
Grade		0%	0%		0%	
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92
Hourly flow rate (vph)	199	965	1486	5	0	12
Pedestrians						
Lane Width (ft)						
Walking Speed (ft/s)						
Percent Blockage						
Right turn flare (veh)						
Median type		None	None			
Median storage veh)						
Upstream signal (ft)			968			
pX, platoon unblocked	0.78				0.78	0.78
vC, conflicting volume	1491				2369	746
vC1, stage 1 conf vol						
vC2, stage 2 conf vol						
vCu, unblocked vol	1054				2186	93
tC, single (s)	4.2				6.8	6.9
tC, 2 stage (s)						
tF (s)	2.3				3.5	3.3
p0 queue free %	59				100	98
cM capacity (veh/h)	491				18	734

Direction, Lane #	SE 1	SE 2	SE 3	NW 1	NW 2	SW 1
Volume Total	199	483	483	990	501	12
Volume Left	199	0	0	0	0	0
Volume Right	0	0	0	0	5	12
cSH	491	1700	1700	1700	1700	734
Volume to Capacity	0.41	0.28	0.28	0.58	0.29	0.02
Queue Length 95th (ft)	49	0	0	0	0	1
Control Delay (s)	17.2	0.0	0.0	0.0	0.0	10.0
Lane LOS	C					A
Approach Delay (s)	2.9			0.0		10.0
Approach LOS						A

Intersection Summary			
Average Delay	1.3		
Intersection Capacity Utilization	61.4%	ICU Level of Service	B
Analysis Period (min)	15		

Lane Group	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations	↰	↑↱		↰	↑↱		↰	↑↑	↱	↰	↑↱	
Volume (vph)	173	386	24	216	577	77	144	824	153	114	993	512
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Storage Length (ft)	300		0	300		0	315		315	125		0
Storage Lanes	1		0	1		0	1		1	1		0
Taper Length (ft)	25			25			25			25		
Satd. Flow (prot)	1703	3375	0	1703	3344	0	1770	3539	1583	1770	3359	0
Flt Permitted	0.950			0.950			0.950			0.950		
Satd. Flow (perm)	1703	3375	0	1703	3344	0	1770	3539	1583	1770	3359	0
Right Turn on Red			Yes			Yes			Yes			Yes
Satd. Flow (RTOR)		4			10				226		92	
Link Speed (mph)		30			30			30			30	
Link Distance (ft)		6101			1008			1045			2119	
Travel Time (s)		138.7			22.9			23.8			48.2	
Lane Group Flow (vph)	256	606	0	319	967	0	213	1218	226	169	2225	0
Turn Type	Prot	NA		Prot	NA		Prot	NA	Perm	Prot	NA	
Protected Phases	7	4		3	8		5	2		1	6	
Permitted Phases									2			
Total Split (s)	23.0	23.0		25.0	25.0		17.0	52.0	52.0	20.0	55.0	
Total Lost Time (s)	5.5	6.5		5.5	6.5		5.0	6.5	6.5	5.0	6.5	
Act Effct Green (s)	17.5	16.5		19.5	18.5		12.0	46.5	46.5	14.0	48.5	
Actuated g/C Ratio	0.15	0.14		0.16	0.15		0.10	0.39	0.39	0.12	0.40	
v/c Ratio	1.03	1.30		1.16	1.85		1.20	0.89	0.30	0.82	1.58	
Control Delay	116.0	190.1		147.8	418.8		178.8	44.0	4.3	80.8	289.9	
Queue Delay	0.0	0.0		0.0	0.0		0.0	0.0	0.0	0.0	0.0	
Total Delay	116.0	190.1		147.8	418.8		178.8	44.0	4.3	80.8	289.9	
LOS	F	F		F	F		F	D	A	F	F	
Approach Delay		168.1			351.6			55.9			275.1	
Approach LOS		F			F			E			F	

Intersection Summary

Area Type: Other

Cycle Length: 120

Actuated Cycle Length: 120

Offset: 60 (50%), Referenced to phase 2:NET and 6:SWT, Start of Green

Control Type: Actuated-Coordinated

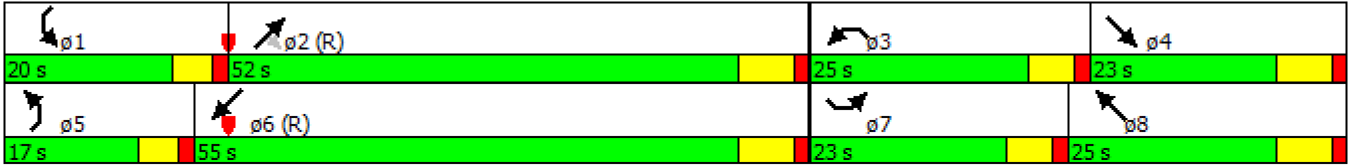
Maximum v/c Ratio: 1.85

Intersection Signal Delay: 217.5 Intersection LOS: F

Intersection Capacity Utilization 128.1% ICU Level of Service H

Analysis Period (min) 15

Splits and Phases: 3: Clear Lake City Blvd. / Clear Lake City Blvd. & Old Galveston Rd. /Old Galveston Rd.



2030 Background AM Peak Hour
8: Dixie Farm Rd. / Challenger & Old Galveston Rd. /Old Galveston Rd.

Lane Group	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations	↰	↑↱		↰	↑↱		↰	↑↱		↰	↑↱	
Volume (vph)	10	445	120	134	868	80	183	127	127	10	14	1
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Storage Length (ft)	200		0	200		0	150		0	200		0
Storage Lanes	1		0	1		0	1		0	1		0
Taper Length (ft)	25			25			25			25		
Satd. Flow (prot)	1703	3297	0	1703	3372	0	1770	3231	0	1770	3507	0
Flt Permitted	0.950			0.950			0.950			0.950		
Satd. Flow (perm)	1703	3297	0	1703	3372	0	1770	3231	0	1770	3507	0
Right Turn on Red			Yes			Yes			Yes			Yes
Satd. Flow (RTOR)		40			8			188			1	
Link Speed (mph)		30			30			30			30	
Link Distance (ft)		968			3524			1823			652	
Travel Time (s)		22.0			80.1			41.4			14.8	
Lane Group Flow (vph)	11	835	0	198	1370	0	271	326	0	11	16	0
Turn Type	Prot	NA		Prot	NA		Prot	NA		Prot	NA	
Protected Phases	5	2		1	6		7	4		3	8	
Permitted Phases												
Total Split (s)	15.0	45.0		15.0	45.0		15.0	25.0		15.0	25.0	
Total Lost Time (s)	5.5	5.5		5.5	5.5		5.0	5.0		5.0	5.0	
Act Effct Green (s)	5.5	47.9		21.1	72.1		10.0	12.7		5.4	6.0	
Actuated g/C Ratio	0.06	0.48		0.21	0.72		0.10	0.13		0.05	0.06	
v/c Ratio	0.12	0.52		0.55	0.56		1.53	0.57		0.11	0.08	
Control Delay	47.4	19.5		38.3	11.6		298.3	20.8		47.3	42.0	
Queue Delay	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Total Delay	47.4	19.5		38.3	11.6		298.3	20.8		47.3	42.0	
LOS	D	B		D	B		F	C		D	D	
Approach Delay		19.9			14.9			146.8			44.2	
Approach LOS		B			B			F			D	

Intersection Summary

Area Type: Other
Cycle Length: 100
Actuated Cycle Length: 100
Offset: 40 (40%), Referenced to phase 2:SET and 6:NWT, Start of Green
Control Type: Actuated-Coordinated
Maximum v/c Ratio: 1.53
Intersection Signal Delay: 42.5 Intersection LOS: D
Intersection Capacity Utilization 73.1% ICU Level of Service D
Analysis Period (min) 15

Splits and Phases: 8: Dixie Farm Rd. / Challenger & Old Galveston Rd. /Old Galveston Rd.

11: Old Galveston Rd. / Old Galveston Rd. & Brantly Ave.

Lane Group	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations	↰	↑↱		↰	↑↱			✥			↰↑	↱
Volume (vph)	7	602	1	8	1157	88	2	0	1	10	0	3
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Storage Length (ft)	280		0	200		0	0		0	0		0
Storage Lanes	1		0	1		0	0		0	0		1
Taper Length (ft)	25			25			25			25		
Satd. Flow (prot)	1703	3406	0	1703	3378	0	0	1735	0	0	1770	1583
Flt Permitted	0.950			0.950								
Satd. Flow (perm)	1703	3406	0	1703	3378	0	0	1799	0	0	1863	1583
Right Turn on Red			Yes			Yes			Yes			Yes
Satd. Flow (RTOR)					10			109				109
Link Speed (mph)		30			30			30			30	
Link Distance (ft)		3524			6101			140			183	
Travel Time (s)		80.1			138.7			3.2			4.2	
Lane Group Flow (vph)	8	891	0	12	1806	0	0	4	0	0	11	3
Turn Type	Prot	NA		Prot	NA		Perm	NA		Perm	NA	Perm
Protected Phases	5	2		1	6			4			8	
Permitted Phases							4			8		8
Total Split (s)	18.0	65.0		18.0	65.0		17.0	17.0		17.0	17.0	17.0
Total Lost Time (s)	6.5	6.5		6.5	6.0			5.0			5.5	5.5
Act Effct Green (s)	6.1	89.8		6.3	90.1			5.8			5.6	5.6
Actuated g/C Ratio	0.06	0.90		0.06	0.90			0.06			0.06	0.06
v/c Ratio	0.08	0.29		0.11	0.59			0.02			0.11	0.02
Control Delay	40.7	1.8		45.9	4.9			0.2			46.5	0.0
Queue Delay	0.0	0.0		0.0	0.0			0.0			0.0	0.0
Total Delay	40.7	1.8		45.9	4.9			0.2			46.5	0.0
LOS	D	A		D	A			A			D	A
Approach Delay		2.1			5.2			0.3			36.5	
Approach LOS		A			A			A			D	

Intersection Summary

Area Type: Other

Cycle Length: 100

Actuated Cycle Length: 100

Offset: 90 (90%), Referenced to phase 2:SET and 6:NWT, Start of Green

Control Type: Actuated-Coordinated

Maximum v/c Ratio: 0.59

Intersection Signal Delay: 4.3 Intersection LOS: A

Intersection Capacity Utilization 68.4% ICU Level of Service C

Analysis Period (min) 15

Splits and Phases: 11: Old Galveston Rd. / Old Galveston Rd. & Brantly Ave.

Movement	SEL	SET	NWT	NWR	SWL	SWR
Lane Configurations	↰	↑↑	↑↱		Y	
Volume (veh/h)	20	1563	850	1	4	209
Sign Control		Free	Free		Stop	
Grade		0%	0%		0%	
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92
Hourly flow rate (vph)	22	2311	1257	1	4	227
Pedestrians						
Lane Width (ft)						
Walking Speed (ft/s)						
Percent Blockage						
Right turn flare (veh)						
Median type		None	None			
Median storage veh)						
Upstream signal (ft)			968			
pX, platoon unblocked	0.83				0.83	0.83
vC, conflicting volume	1258				2456	629
vC1, stage 1 conf vol						
vC2, stage 2 conf vol						
vCu, unblocked vol	892				2342	132
tC, single (s)	4.2				6.8	6.9
tC, 2 stage (s)						
tF (s)	2.3				3.5	3.3
p0 queue free %	96				82	69
cM capacity (veh/h)	604				24	739

Direction, Lane #	SE 1	SE 2	SE 3	NW 1	NW 2	SW 1
Volume Total	22	1155	1155	838	420	232
Volume Left	22	0	0	0	0	4
Volume Right	0	0	0	0	1	227
cSH	604	1700	1700	1700	1700	476
Volume to Capacity	0.04	0.68	0.68	0.49	0.25	0.49
Queue Length 95th (ft)	3	0	0	0	0	65
Control Delay (s)	11.2	0.0	0.0	0.0	0.0	19.5
Lane LOS	B					C
Approach Delay (s)	0.1			0.0		19.5
Approach LOS						C

Intersection Summary			
Average Delay	1.2		
Intersection Capacity Utilization	78.6%	ICU Level of Service	D
Analysis Period (min)	15		

3: Clear Lake City Blvd. / Clear Lake City Blvd. & Old Galveston R

Lane Group	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations	↰	↑↱		↰	↑↱		↰	↑↑	↱	↰	↑↱	
Volume (vph)	392	1002	226	204	584	117	40	873	254	118	1043	229
Satd. Flow (prot)	1703	3310	0	1703	3321	0	1770	3539	1583	1770	3444	0
Flt Permitted	0.950			0.950			0.950			0.950		
Satd. Flow (perm)	1703	3310	0	1703	3321	0	1770	3539	1583	1770	3444	0
Satd. Flow (RTOR)		22			16				259		20	
Lane Group Flow (vph)	579	1815	0	302	1036	0	59	1291	375	174	1881	0
Turn Type	Prot	NA		Prot	NA		Prot	NA	Perm	Prot	NA	
Protected Phases	7	4		3	8		5	2		1	6	
Permitted Phases									2			
Total Split (s)	40.0	54.0		20.0	34.0		12.0	37.0	37.0	24.0	49.0	
Total Lost Time (s)	5.5	6.5		5.5	6.5		5.0	6.5	6.5	5.0	6.5	
Act Effct Green (s)	34.5	47.5		14.5	27.5		6.8	32.8	32.8	16.7	44.9	
Actuated g/C Ratio	0.26	0.35		0.11	0.20		0.05	0.24	0.24	0.12	0.33	
v/c Ratio	1.33	1.54		1.66	1.50		0.67	1.50	0.65	0.80	1.62	
Control Delay	203.6	279.4		356.0	270.8		96.7	267.7	20.1	82.6	315.8	
Queue Delay	0.0	0.0		0.0	0.0		0.0	0.0	0.0	0.0	0.0	
Total Delay	203.6	279.4		356.0	270.8		96.7	267.7	20.1	82.6	315.8	
LOS	F	F		F	F		F	F	C	F	F	
Approach Delay		261.0			290.0			208.0			296.1	
Approach LOS		F			F			F			F	

Intersection Summary

Cycle Length: 135

Actuated Cycle Length: 135

Offset: 67 (50%), Referenced to phase 2:NET and 6:SWT, Start of Green

Control Type: Actuated-Coordinated

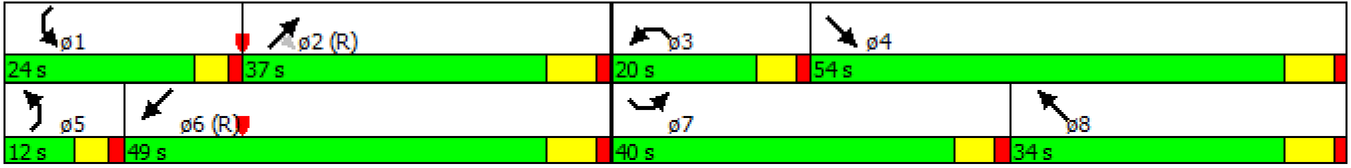
Maximum v/c Ratio: 1.66

Intersection Signal Delay: 263.6 Intersection LOS: F

Intersection Capacity Utilization 135.7% ICU Level of Service H

Analysis Period (min) 15

Splits and Phases: 3: Clear Lake City Blvd. / Clear Lake City Blvd. & Old Galveston Rd. /Old Galveston Rd.



8: Dixie Farm Rd. / Challenger & Old Galveston Rd. /Old Galveston Rd.

Lane Group	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations	↰	↑↱		↰	↑↱		↰	↑↱		↰	↑↱	
Volume (vph)	3	1199	311	183	700	11	138	17	192	93	149	15
Satd. Flow (prot)	1703	3300	0	1703	3399	0	1770	3040	0	1770	3493	0
Flt Permitted	0.950			0.950			0.950			0.950		
Satd. Flow (perm)	1703	3300	0	1703	3399	0	1770	3040	0	1770	3493	0
Satd. Flow (RTOR)		42			1			275			8	
Lane Group Flow (vph)	3	2232	0	271	1047	0	204	302	0	101	178	0
Turn Type	Prot	NA		Prot	NA		Prot	NA		Prot	NA	
Protected Phases	5	2		1	6		7	4		3	8	
Permitted Phases												
Total Split (s)	20.0	50.0		20.0	50.0		15.0	15.0		15.0	15.0	
Total Lost Time (s)	5.5	5.5		5.5	5.5		5.0	5.0		5.0	5.0	
Act Effct Green (s)	5.1	44.5		15.8	63.6		10.0	12.1		8.8	8.7	
Actuated g/C Ratio	0.05	0.44		0.16	0.64		0.10	0.12		0.09	0.09	
v/c Ratio	0.03	1.50		1.01	0.48		1.15	0.50		0.65	0.57	
Control Delay	46.0	252.5		101.3	11.8		156.5	10.5		63.1	49.1	
Queue Delay	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Total Delay	46.0	252.5		101.3	11.8		156.5	10.5		63.1	49.1	
LOS	D	F		F	B		F	B		E	D	
Approach Delay		252.3			30.2			69.3			54.2	
Approach LOS		F			C			E			D	

Intersection Summary

Cycle Length: 100

Actuated Cycle Length: 100

Offset: 40 (40%), Referenced to phase 2:SET and 6:NWT, Start of Green

Control Type: Actuated-Coordinated

Maximum v/c Ratio: 1.50

Intersection Signal Delay: 150.7 Intersection LOS: F

Intersection Capacity Utilization 104.9% ICU Level of Service G

Analysis Period (min) 15

Splits and Phases: 8: Dixie Farm Rd. / Challenger & Old Galveston Rd. /Old Galveston Rd.

11: Old Galveston Rd. / Old Galveston Rd. & Brantly Ave.

Lane Group	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations	↰	↑↱		↰	↑↱			✥			↰↑	↱
Volume (vph)	2	1558	1	1	894	11	2	0	5	90	0	12
Satd. Flow (prot)	1703	3406	0	1703	3402	0	0	1660	0	0	1770	1583
Flt Permitted	0.950			0.950				0.911			0.751	
Satd. Flow (perm)	1703	3406	0	1703	3402	0	0	1536	0	0	1399	1583
Satd. Flow (RTOR)					1			109				109
Lane Group Flow (vph)	2	2304	0	1	1334	0	0	10	0	0	98	13
Turn Type	Prot	NA		Prot	NA		Perm	NA		Perm	NA	Perm
Protected Phases	5	2		1	6			4			8	
Permitted Phases							4			8		8
Total Split (s)	20.0	60.0		20.0	60.0		20.0	20.0		20.0	20.0	20.0
Total Lost Time (s)	6.5	6.5		6.5	6.0			5.0			5.5	5.5
Act Effct Green (s)	5.0	78.4		5.0	78.8			11.1			10.9	10.9
Actuated g/C Ratio	0.05	0.78		0.05	0.79			0.11			0.11	0.11
v/c Ratio	0.02	0.86		0.01	0.50			0.04			0.64	0.05
Control Delay	37.5	19.9		46.0	6.6			0.2			61.3	0.3
Queue Delay	0.0	0.0		0.0	0.0			0.0			0.0	0.0
Total Delay	37.5	19.9		46.0	6.6			0.2			61.3	0.3
LOS	D	B		D	A			A			E	A
Approach Delay		19.9			6.6			0.2			54.2	
Approach LOS		B			A			A			D	

Intersection Summary

Cycle Length: 100

Actuated Cycle Length: 100

Offset: 90 (90%), Referenced to phase 2:SET and 6:NWT, Start of Green

Control Type: Actuated-Coordinated

Maximum v/c Ratio: 0.86

Intersection Signal Delay: 16.1 Intersection LOS: B

Intersection Capacity Utilization 80.3% ICU Level of Service D

Analysis Period (min) 15

Splits and Phases: 11: Old Galveston Rd. / Old Galveston Rd. & Brantly Ave.

Movement	SEL	SET	NWT	NWR	SWL	SWR
Lane Configurations	↰	↑↑	↑↱		↰↱	
Volume (veh/h)	197	653	1005	5	0	11
Sign Control		Free	Free		Stop	
Grade		0%	0%		0%	
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92
Hourly flow rate (vph)	214	823	1267	6	0	13
Pedestrians						
Lane Width (ft)						
Walking Speed (ft/s)						
Percent Blockage						
Right turn flare (veh)						
Median type		None	None			
Median storage veh)						
Upstream signal (ft)			968			
pX, platoon unblocked	0.84				0.84	0.84
vC, conflicting volume	1273				2110	636
vC1, stage 1 conf vol						
vC2, stage 2 conf vol						
vCu, unblocked vol	950				1944	194
tC, single (s)	4.2				6.8	6.9
tC, 2 stage (s)						
tF (s)	2.3				3.5	3.3
p0 queue free %	63				100	98
cM capacity (veh/h)	585				30	686

Direction, Lane #	SE 1	SE 2	SE 3	NW 1	NW 2	SW 1
Volume Total	214	412	412	845	428	13
Volume Left	214	0	0	0	0	0
Volume Right	0	0	0	0	6	13
cSH	585	1700	1700	1700	1700	686
Volume to Capacity	0.37	0.24	0.24	0.50	0.25	0.02
Queue Length 95th (ft)	42	0	0	0	0	1
Control Delay (s)	14.7	0.0	0.0	0.0	0.0	10.3
Lane LOS	B					B
Approach Delay (s)	3.0			0.0		10.3
Approach LOS						B

Intersection Summary			
Average Delay	1.4		
Intersection Capacity Utilization	56.6%	ICU Level of Service	B
Analysis Period (min)	15		

Lane Group	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations	↰	↑↱		↰	↑↱		↰	↑↑	↱	↰	↑↱	
Volume (vph)	173	386	24	216	682	77	144	824	153	114	993	599
Satd. Flow (prot)	1703	3375	0	1703	3348	0	1770	3539	1583	1770	3359	0
Flt Permitted	0.950			0.950			0.950			0.950		
Satd. Flow (perm)	1703	3375	0	1703	3348	0	1770	3539	1583	1770	3359	0
Satd. Flow (RTOR)		4			10				193		93	
Lane Group Flow (vph)	218	517	0	272	838	0	182	1039	193	144	1903	0
Turn Type	Prot	NA		Prot	NA		Prot	NA	Perm	Prot	NA	
Protected Phases	7	4		3	8		5	2		1	6	
Permitted Phases									2			
Total Split (s)	23.0	23.0		25.0	25.0		17.0	52.0	52.0	20.0	55.0	
Total Lost Time (s)	5.5	6.5		5.5	6.5		5.0	6.5	6.5	5.0	6.5	
Act Effct Green (s)	17.1	16.5		19.5	18.9		12.0	47.3	47.3	13.2	48.5	
Actuated g/C Ratio	0.14	0.14		0.16	0.16		0.10	0.39	0.39	0.11	0.40	
v/c Ratio	0.90	1.11		0.99	1.56		1.03	0.75	0.26	0.74	1.35	
Control Delay	88.2	121.3		101.2	296.4		128.3	35.6	4.4	73.9	190.7	
Queue Delay	0.0	0.0		0.0	0.0		0.0	0.0	0.0	0.0	0.0	
Total Delay	88.2	121.3		101.2	296.4		128.3	35.6	4.4	73.9	190.7	
LOS	F	F		F	F		F	D	A	E	F	
Approach Delay		111.4			248.6			43.3			182.5	
Approach LOS		F			F			D			F	

Intersection Summary

Cycle Length: 120

Actuated Cycle Length: 120

Offset: 60 (50%), Referenced to phase 2:NET and 6:SWT, Start of Green

Control Type: Actuated-Coordinated

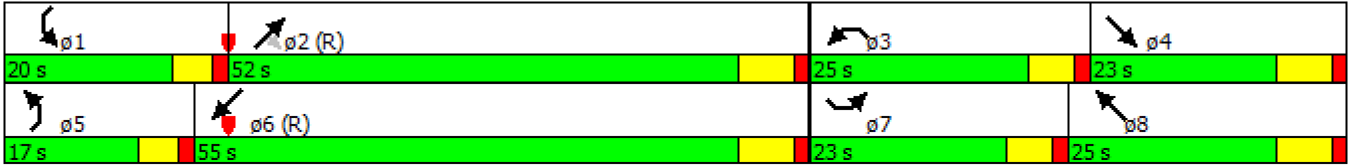
Maximum v/c Ratio: 1.56

Intersection Signal Delay: 149.4 Intersection LOS: F

Intersection Capacity Utilization 112.7% ICU Level of Service H

Analysis Period (min) 15

Splits and Phases: 3: Clear Lake City Blvd. / Clear Lake City Blvd. & Old Galveston Rd. /Old Galveston Rd.



Lane Group	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations	↰	↑↱		↰	↑↱		↰	↑↱		↰	↑↱	
Volume (vph)	10	445	120	134	868	94	183	148	127	10	20	1
Satd. Flow (prot)	1703	3297	0	1703	3361	0	1770	3274	0	1770	3514	0
Flt Permitted	0.950			0.950			0.950			0.950		
Satd. Flow (perm)	1703	3297	0	1703	3361	0	1770	3274	0	1770	3514	0
Satd. Flow (RTOR)		40			12			160			1	
Lane Group Flow (vph)	11	712	0	169	1196	0	231	321	0	11	23	0
Turn Type	Prot	NA		Prot	NA		Prot	NA		Prot	NA	
Protected Phases	5	2		1	6		7	4		3	8	
Permitted Phases												
Total Split (s)	15.0	45.0		15.0	45.0		15.0	25.0		15.0	25.0	
Total Lost Time (s)	5.5	5.5		5.5	5.5		5.0	5.0		5.0	5.0	
Act Effct Green (s)	5.5	51.4		17.4	71.9		10.0	12.9		5.4	6.2	
Actuated g/C Ratio	0.06	0.51		0.17	0.72		0.10	0.13		0.05	0.06	
v/c Ratio	0.12	0.42		0.57	0.49		1.31	0.57		0.11	0.11	
Control Delay	47.4	16.4		42.3	10.7		209.7	24.0		47.3	42.8	
Queue Delay	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Total Delay	47.4	16.4		42.3	10.7		209.7	24.0		47.3	42.8	
LOS	D	B		D	B		F	C		D	D	
Approach Delay		16.9			14.6			101.7			44.2	
Approach LOS		B			B			F			D	

Intersection Summary	
Cycle Length: 100	
Actuated Cycle Length: 100	
Offset: 40 (40%), Referenced to phase 2:SET and 6:NWT, Start of Green	
Control Type: Actuated-Coordinated	
Maximum v/c Ratio: 1.31	
Intersection Signal Delay: 33.6	Intersection LOS: C
Intersection Capacity Utilization 66.8%	ICU Level of Service C
Analysis Period (min) 15	

Splits and Phases: 8: Dixie Farm Rd. / Challenger & Old Galveston Rd. /Old Galveston Rd.

11: Old Galveston Rd. / Old Galveston Rd. & Brantly Ave.

Lane Group	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations	↰	↑↱		↰	↑↱			✥			↰	↱
Volume (vph)	7	602	1	8	1356	88	2	0	1	10	0	3
Satd. Flow (prot)	1703	3406	0	1703	3372	0	0	1735	0	0	1770	1583
Flt Permitted	0.950			0.950								
Satd. Flow (perm)	1703	3406	0	1703	3372	0	0	1799	0	0	1863	1583
Satd. Flow (RTOR)					12			109				109
Lane Group Flow (vph)	8	760	0	10	1574	0	0	4	0	0	11	3
Turn Type	Prot	NA		Prot	NA		Perm	NA		Perm	NA	Perm
Protected Phases	5	2		1	6			4			8	
Permitted Phases							4			8		8
Total Split (s)	18.0	65.0		18.0	65.0		17.0	17.0		17.0	17.0	17.0
Total Lost Time (s)	6.5	6.5		6.5	6.0			5.0			5.5	5.5
Act Effct Green (s)	6.1	89.8		6.2	90.1			5.8			5.6	5.6
Actuated g/C Ratio	0.06	0.90		0.06	0.90			0.06			0.06	0.06
v/c Ratio	0.08	0.25		0.10	0.52			0.02			0.11	0.02
Control Delay	42.9	1.7		45.8	4.1			0.2			46.5	0.0
Queue Delay	0.0	0.0		0.0	0.0			0.0			0.0	0.0
Total Delay	42.9	1.7		45.8	4.1			0.2			46.5	0.0
LOS	D	A		D	A			A			D	A
Approach Delay		2.1			4.3			0.3			36.5	
Approach LOS		A			A			A			D	

Intersection Summary	
Cycle Length: 100	
Actuated Cycle Length: 100	
Offset: 90 (90%), Referenced to phase 2:SET and 6:NWT, Start of Green	
Control Type: Actuated-Coordinated	
Maximum v/c Ratio: 0.52	
Intersection Signal Delay: 3.8	Intersection LOS: A
Intersection Capacity Utilization 62.5%	ICU Level of Service B
Analysis Period (min) 15	

Splits and Phases: 11: Old Galveston Rd. / Old Galveston Rd. & Brantly Ave.

1: Old Galveston Rd. & Hilliard St.

Movement	SEL	SET	NWT	NWR	SWL	SWR
Lane Configurations	↰	↑↑	↑↱		↰↱	
Volume (veh/h)	20	1563	850	1	4	224
Sign Control		Free	Free		Stop	
Grade		0%	0%		0%	
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92
Hourly flow rate (vph)	23	1971	1072	1	5	243
Pedestrians						
Lane Width (ft)						
Walking Speed (ft/s)						
Percent Blockage						
Right turn flare (veh)						
Median type		None	None			
Median storage veh)						
Upstream signal (ft)			968			
pX, platoon unblocked	0.88				0.88	0.88
vC, conflicting volume	1073				2103	536
vC1, stage 1 conf vol						
vC2, stage 2 conf vol						
vCu, unblocked vol	811				1982	202
tC, single (s)	4.2				6.8	6.9
tC, 2 stage (s)						
tF (s)	2.3				3.5	3.3
p0 queue free %	97				90	66
cM capacity (veh/h)	692				46	709

Direction, Lane #	SE 1	SE 2	SE 3	NW 1	NW 2	SW 1
Volume Total	23	985	985	714	358	248
Volume Left	23	0	0	0	0	5
Volume Right	0	0	0	0	1	243
cSH	692	1700	1700	1700	1700	560
Volume to Capacity	0.03	0.58	0.58	0.42	0.21	0.44
Queue Length 95th (ft)	3	0	0	0	0	56
Control Delay (s)	10.4	0.0	0.0	0.0	0.0	16.5
Lane LOS	B					C
Approach Delay (s)	0.1			0.0		16.5
Approach LOS						C

Intersection Summary			
Average Delay	1.3		
Intersection Capacity Utilization	70.9%	ICU Level of Service	C
Analysis Period (min)	15		

3: Clear Lake City Blvd. / Clear Lake City Blvd. & Old Galveston R

Lane Group	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations	↰	↑↱		↰	↑↱		↰	↑↑	↱	↰	↑↱	
Volume (vph)	460	1172	226	204	584	117	40	873	254	118	1043	229
Satd. Flow (prot)	1703	3314	0	1703	3321	0	1770	3539	1583	1770	3444	0
Flt Permitted	0.950			0.950			0.950			0.950		
Satd. Flow (perm)	1703	3314	0	1703	3321	0	1770	3539	1583	1770	3444	0
Satd. Flow (RTOR)		22			16				259		20	
Lane Group Flow (vph)	500	1559	0	257	884	0	50	1101	320	149	1604	0
Turn Type	Prot	NA		Prot	NA		Prot	NA	Perm	Prot	NA	
Protected Phases	7	4		3	8		5	2		1	6	
Permitted Phases									2			
Total Split (s)	40.0	54.0		20.0	34.0		12.0	37.0	37.0	24.0	49.0	
Total Lost Time (s)	5.5	6.5		5.5	6.5		5.0	6.5	6.5	5.0	6.5	
Act Effct Green (s)	34.5	47.5		14.5	27.5		6.7	34.0	34.0	15.5	44.9	
Actuated g/C Ratio	0.26	0.35		0.11	0.20		0.05	0.25	0.25	0.11	0.33	
v/c Ratio	1.15	1.32		1.41	1.28		0.57	1.24	0.54	0.73	1.39	
Control Delay	135.5	186.2		257.2	180.5		88.1	158.0	13.6	78.2	213.7	
Queue Delay	0.0	0.0		0.0	0.0		0.0	0.0	0.0	0.0	0.0	
Total Delay	135.5	186.2		257.2	180.5		88.1	158.0	13.6	78.2	213.7	
LOS	F	F		F	F		F	F	B	E	F	
Approach Delay		173.9			197.7			124.2			202.2	
Approach LOS		F			F			F			F	

Intersection Summary

Cycle Length: 135

Actuated Cycle Length: 135

Offset: 67 (50%), Referenced to phase 2:NET and 6:SWT, Start of Green

Control Type: Actuated-Coordinated

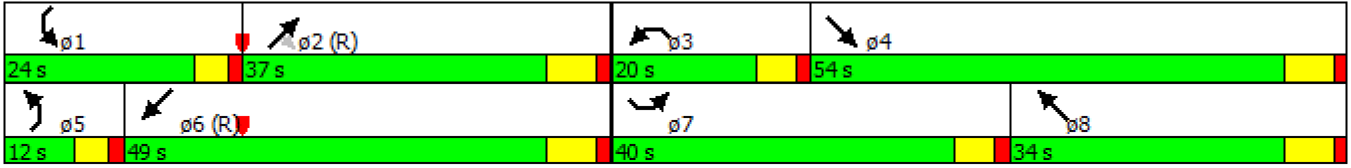
Maximum v/c Ratio: 1.41

Intersection Signal Delay: 174.5 Intersection LOS: F

Intersection Capacity Utilization 119.5% ICU Level of Service H

Analysis Period (min) 15

Splits and Phases: 3: Clear Lake City Blvd. / Clear Lake City Blvd. & Old Galveston Rd. /Old Galveston Rd.



8: Dixie Farm Rd. / Challenger & Old Galveston Rd. /Old Galveston Rd.

Lane Group	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations	↰	↑↱		↰	↑↱		↰	↑↱		↰	↑↱	
Volume (vph)	3	1199	311	183	700	11	138	22	192	103	166	15
Satd. Flow (prot)	1703	3300	0	1703	3399	0	1770	3058	0	1770	3493	0
Flt Permitted	0.950			0.950			0.950			0.950		
Satd. Flow (perm)	1703	3300	0	1703	3399	0	1770	3058	0	1770	3493	0
Satd. Flow (RTOR)		42			2			242			8	
Lane Group Flow (vph)	3	1904	0	231	896	0	174	266	0	112	197	0
Turn Type	Prot	NA		Prot	NA		Prot	NA		Prot	NA	
Protected Phases	5	2		1	6		7	4		3	8	
Permitted Phases												
Total Split (s)	20.0	50.0		20.0	50.0		15.0	15.0		15.0	15.0	
Total Lost Time (s)	5.5	5.5		5.5	5.5		5.0	5.0		5.0	5.0	
Act Effct Green (s)	5.1	45.2		14.8	63.3		10.0	9.9		9.1	9.0	
Actuated g/C Ratio	0.05	0.45		0.15	0.63		0.10	0.10		0.09	0.09	
v/c Ratio	0.03	1.26		0.92	0.42		0.98	0.51		0.70	0.61	
Control Delay	46.0	148.6		83.6	10.4		110.3	11.4		66.6	50.4	
Queue Delay	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Total Delay	46.0	148.6		83.6	10.4		110.3	11.4		66.6	50.4	
LOS	D	F		F	B		F	B		E	D	
Approach Delay		148.4			25.4			50.5			56.3	
Approach LOS		F			C			D			E	

Intersection Summary

Cycle Length: 100

Actuated Cycle Length: 100

Offset: 40 (40%), Referenced to phase 2:SET and 6:NWT, Start of Green

Control Type: Actuated-Coordinated

Maximum v/c Ratio: 1.26

Intersection Signal Delay: 92.9 Intersection LOS: F

Intersection Capacity Utilization 93.2% ICU Level of Service F

Analysis Period (min) 15

Splits and Phases: 8: Dixie Farm Rd. / Challenger & Old Galveston Rd. /Old Galveston Rd.

11: Old Galveston Rd. / Old Galveston Rd. & Brantly Ave.

Lane Group	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations	↰	↑↱		↰	↑↱			✥			↰↑	↱
Volume (vph)	2	1817	1	1	894	11	2	0	5	90	0	12
Satd. Flow (prot)	1703	3406	0	1703	3399	0	0	1668	0	0	1770	1583
Flt Permitted	0.950			0.950				0.902			0.752	
Satd. Flow (perm)	1703	3406	0	1703	3399	0	0	1529	0	0	1401	1583
Satd. Flow (RTOR)					2			109				109
Lane Group Flow (vph)	2	1976	0	1	1140	0	0	9	0	0	103	14
Turn Type	Prot	NA		Prot	NA		Perm	NA		Perm	NA	Perm
Protected Phases	5	2		1	6			4			8	
Permitted Phases							4			8		8
Total Split (s)	20.0	60.0		20.0	60.0		20.0	20.0		20.0	20.0	20.0
Total Lost Time (s)	6.5	6.5		6.5	6.0			5.0			5.5	5.5
Act Effct Green (s)	5.0	78.2		5.0	78.6			11.3			11.1	11.1
Actuated g/C Ratio	0.05	0.78		0.05	0.79			0.11			0.11	0.11
v/c Ratio	0.02	0.74		0.01	0.43			0.03			0.66	0.05
Control Delay	36.0	15.0		46.0	5.9			0.2			62.1	0.4
Queue Delay	0.0	0.0		0.0	0.0			0.0			0.0	0.0
Total Delay	36.0	15.0		46.0	5.9			0.2			62.1	0.4
LOS	D	B		D	A			A			E	A
Approach Delay		15.0			6.0			0.3			54.7	
Approach LOS		B			A			A			D	

Intersection Summary

Cycle Length: 100

Actuated Cycle Length: 100

Offset: 90 (90%), Referenced to phase 2:SET and 6:NWT, Start of Green

Control Type: Actuated-Coordinated

Maximum v/c Ratio: 0.74

Intersection Signal Delay: 13.2 Intersection LOS: B

Intersection Capacity Utilization 72.2% ICU Level of Service C

Analysis Period (min) 15

Splits and Phases: 11: Old Galveston Rd. / Old Galveston Rd. & Brantly Ave.

1: Old Galveston Rd. & Hillard St.

Movement	SEL	SET	NWT	NWR	SWL	SWR
Lane Configurations	↰	↑↑	↑↱		↰↱	
Volume (veh/h)	208	653	1005	5	0	11
Sign Control		Free	Free		Stop	
Grade		0%	0%		0%	
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92
Hourly flow rate (vph)	226	965	1486	6	0	13
Pedestrians						
Lane Width (ft)						
Walking Speed (ft/s)						
Percent Blockage						
Right turn flare (veh)						
Median type		None	None			
Median storage veh)						
Upstream signal (ft)			968			
pX, platoon unblocked	0.77				0.77	0.77
vC, conflicting volume	1492				2423	746
vC1, stage 1 conf vol						
vC2, stage 2 conf vol						
vCu, unblocked vol	1041				2251	73
tC, single (s)	4.2				6.8	6.9
tC, 2 stage (s)						
tF (s)	2.3				3.5	3.3
p0 queue free %	54				100	98
cM capacity (veh/h)	493				15	750

Direction, Lane #	SE 1	SE 2	SE 3	NW 1	NW 2	SW 1
Volume Total	226	483	483	990	501	13
Volume Left	226	0	0	0	0	0
Volume Right	0	0	0	0	6	13
cSH	493	1700	1700	1700	1700	750
Volume to Capacity	0.46	0.28	0.28	0.58	0.29	0.02
Queue Length 95th (ft)	59	0	0	0	0	1
Control Delay (s)	18.3	0.0	0.0	0.0	0.0	9.9
Lane LOS	C					A
Approach Delay (s)	3.5			0.0		9.9
Approach LOS						A

Intersection Summary			
Average Delay	1.6		
Intersection Capacity Utilization	62.8%	ICU Level of Service	B
Analysis Period (min)	15		

Lane Group	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations	↰	↑↱		↰	↑↱		↰	↑↑	↱	↰	↑↱	
Volume (vph)	173	386	24	216	800	77	144	824	153	114	993	710
Satd. Flow (prot)	1703	3375	0	1703	3348	0	1770	3539	1583	1770	3355	0
Flt Permitted	0.950			0.950			0.950			0.950		
Satd. Flow (perm)	1703	3375	0	1703	3348	0	1770	3539	1583	1770	3355	0
Satd. Flow (RTOR)		4			10				226		96	
Lane Group Flow (vph)	256	606	0	319	984	0	213	1218	226	169	2240	0
Turn Type	Prot	NA		Prot	NA		Prot	NA	Perm	Prot	NA	
Protected Phases	7	4		3	8		5	2		1	6	
Permitted Phases									2			
Total Split (s)	23.0	23.0		25.0	25.0		17.0	52.0	52.0	20.0	55.0	
Total Lost Time (s)	5.5	6.5		5.5	6.5		5.0	6.5	6.5	5.0	6.5	
Act Effct Green (s)	17.5	16.5		19.5	18.5		12.0	46.5	46.5	14.0	48.5	
Actuated g/C Ratio	0.15	0.14		0.16	0.15		0.10	0.39	0.39	0.12	0.40	
v/c Ratio	1.03	1.30		1.16	1.88		1.20	0.89	0.30	0.82	1.59	
Control Delay	116.0	190.1		147.8	431.3		178.8	44.0	4.3	80.8	294.0	
Queue Delay	0.0	0.0		0.0	0.0		0.0	0.0	0.0	0.0	0.0	
Total Delay	116.0	190.1		147.8	431.3		178.8	44.0	4.3	80.8	294.0	
LOS	F	F		F	F		F	D	A	F	F	
Approach Delay		168.1			361.9			55.9			279.0	
Approach LOS		F			F			E			F	

Intersection Summary

Cycle Length: 120

Actuated Cycle Length: 120

Offset: 60 (50%), Referenced to phase 2:NET and 6:SWT, Start of Green

Control Type: Actuated-Coordinated

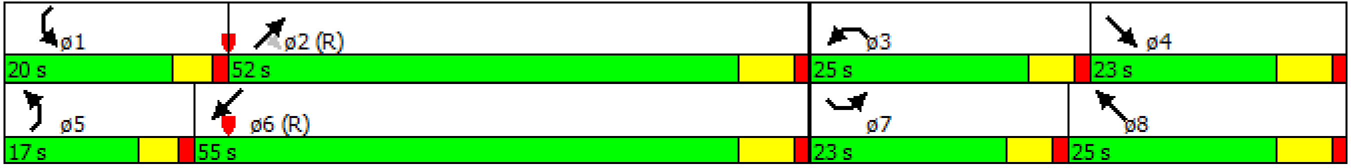
Maximum v/c Ratio: 1.88

Intersection Signal Delay: 221.7 Intersection LOS: F

Intersection Capacity Utilization 129.0% ICU Level of Service H

Analysis Period (min) 15

Splits and Phases: 3: Clear Lake City Blvd. / Clear Lake City Blvd. & Old Galveston Rd. /Old Galveston Rd.



8: Dixie Farm Rd. / Challenger & Old Galveston Rd. /Old Galveston Rd.

Lane Group	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations	↰	↑↱		↰	↑↱		↰	↑↱		↰	↑↱	
Volume (vph)	10	445	120	134	868	99	183	156	127	10	21	1
Satd. Flow (prot)	1703	3297	0	1703	3365	0	1770	3260	0	1770	3518	0
Flt Permitted	0.950			0.950			0.950			0.950		
Satd. Flow (perm)	1703	3297	0	1703	3365	0	1770	3260	0	1770	3518	0
Satd. Flow (RTOR)		40			10			188			1	
Lane Group Flow (vph)	12	835	0	198	1391	0	271	358	0	12	24	0
Turn Type	Prot	NA		Prot	NA		Prot	NA		Prot	NA	
Protected Phases	5	2		1	6		7	4		3	8	
Permitted Phases												
Total Split (s)	15.0	45.0		15.0	45.0		15.0	25.0		15.0	25.0	
Total Lost Time (s)	5.5	5.5		5.5	5.5		5.0	5.0		5.0	5.0	
Act Effct Green (s)	5.5	47.8		20.8	71.7		10.0	13.0		5.5	6.4	
Actuated g/C Ratio	0.06	0.48		0.21	0.72		0.10	0.13		0.06	0.06	
v/c Ratio	0.13	0.52		0.56	0.58		1.53	0.61		0.12	0.11	
Control Delay	47.5	19.6		38.6	12.0		298.3	23.4		47.5	42.5	
Queue Delay	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Total Delay	47.5	19.6		38.6	12.0		298.3	23.4		47.5	42.5	
LOS	D	B		D	B		F	C		D	D	
Approach Delay		20.0			15.3			141.9			44.2	
Approach LOS		B			B			F			D	

Intersection Summary

Cycle Length: 100

Actuated Cycle Length: 100

Offset: 40 (40%), Referenced to phase 2:SET and 6:NWT, Start of Green

Control Type: Actuated-Coordinated

Maximum v/c Ratio: 1.53

Intersection Signal Delay: 42.6 Intersection LOS: D

Intersection Capacity Utilization 73.7% ICU Level of Service D

Analysis Period (min) 15

Splits and Phases: 8: Dixie Farm Rd. / Challenger & Old Galveston Rd. /Old Galveston Rd.

11: Old Galveston Rd. / Old Galveston Rd. & Brantly Ave.

Lane Group	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations	↰	↑↱		↰	↑↱			✣			↰	↱
Volume (vph)	7	602	1	8	1593	88	2	0	1	10	0	3
Satd. Flow (prot)	1703	3406	0	1703	3375	0	0	1735	0	0	1770	1583
Flt Permitted	0.950			0.950								
Satd. Flow (perm)	1703	3406	0	1703	3375	0	0	1799	0	0	1863	1583
Satd. Flow (RTOR)					11			109				109
Lane Group Flow (vph)	8	891	0	12	1838	0	0	4	0	0	12	4
Turn Type	Prot	NA		Prot	NA		Perm	NA		Perm	NA	Perm
Protected Phases	5	2		1	6			4			8	
Permitted Phases							4			8		8
Total Split (s)	18.0	65.0		18.0	65.0		17.0	17.0		17.0	17.0	17.0
Total Lost Time (s)	6.5	6.5		6.5	6.0			5.0			5.5	5.5
Act Effct Green (s)	6.1	89.7		6.3	90.0			5.9			5.7	5.7
Actuated g/C Ratio	0.06	0.90		0.06	0.90			0.06			0.06	0.06
v/c Ratio	0.08	0.29		0.11	0.61			0.02			0.11	0.02
Control Delay	41.3	1.8		45.9	5.1			0.2			46.5	0.2
Queue Delay	0.0	0.0		0.0	0.0			0.0			0.0	0.0
Total Delay	41.3	1.8		45.9	5.1			0.2			46.5	0.2
LOS	D	A		D	A			A			D	A
Approach Delay		2.1			5.4			0.3			34.9	
Approach LOS		A			A			A			C	

Intersection Summary

Cycle Length: 100

Actuated Cycle Length: 100

Offset: 90 (90%), Referenced to phase 2:SET and 6:NWT, Start of Green

Control Type: Actuated-Coordinated

Maximum v/c Ratio: 0.61

Intersection Signal Delay: 4.5 Intersection LOS: A

Intersection Capacity Utilization 69.2% ICU Level of Service C

Analysis Period (min) 15

Splits and Phases: 11: Old Galveston Rd. / Old Galveston Rd. & Brantly Ave.

2030 Build PM Peak Hour

1: Old Galveston Rd. & Hilliard St.

Movement	SEL	SET	NWT	NWR	SWL	SWR
Lane Configurations	↰	↑↑	↑↱		↰↱	
Volume (veh/h)	20	1563	850	1	4	237
Sign Control		Free	Free		Stop	
Grade		0%	0%		0%	
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92
Hourly flow rate (vph)	24	2311	1257	1	5	258
Pedestrians						
Lane Width (ft)						
Walking Speed (ft/s)						
Percent Blockage						
Right turn flare (veh)						
Median type		None	None			
Median storage veh)						
Upstream signal (ft)			968			
pX, platoon unblocked	0.83				0.83	0.83
vC, conflicting volume	1258				2461	629
vC1, stage 1 conf vol						
vC2, stage 2 conf vol						
vCu, unblocked vol	900				2350	142
tC, single (s)	4.2				6.8	6.9
tC, 2 stage (s)						
tF (s)	2.3				3.5	3.3
p0 queue free %	96				80	65
cM capacity (veh/h)	602				24	730

Direction, Lane #	SE 1	SE 2	SE 3	NW 1	NW 2	SW 1
Volume Total	24	1155	1155	838	420	262
Volume Left	24	0	0	0	0	5
Volume Right	0	0	0	0	1	258
cSH	602	1700	1700	1700	1700	473
Volume to Capacity	0.04	0.68	0.68	0.49	0.25	0.55
Queue Length 95th (ft)	3	0	0	0	0	83
Control Delay (s)	11.2	0.0	0.0	0.0	0.0	21.7
Lane LOS	B					C
Approach Delay (s)	0.1			0.0		21.7
Approach LOS						C

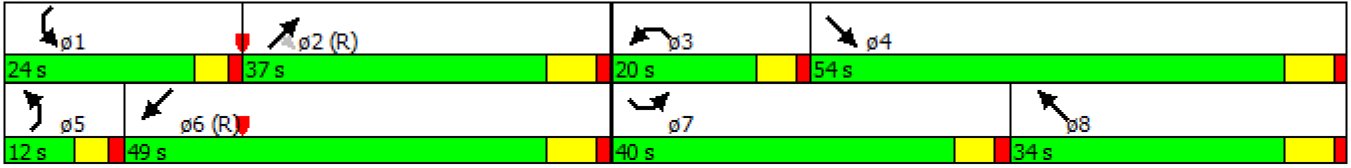
Intersection Summary			
Average Delay	1.5		
Intersection Capacity Utilization	80.3%	ICU Level of Service	D
Analysis Period (min)	15		

Lane Group	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations	↰	↑↱		↰	↑↱		↰	↑↑	↱	↰	↑↱	
Volume (vph)	548	1373	226	204	584	117	40	873	254	118	1043	229
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Storage Length (ft)	300		0	300		0	315		315	125		0
Storage Lanes	1		0	1		0	1		1	1		0
Taper Length (ft)	25			25			25			25		
Satd. Flow (prot)	1703	3314	0	1703	3321	0	1770	3539	1583	1770	3444	0
Flt Permitted	0.950			0.950			0.950			0.950		
Satd. Flow (perm)	1703	3314	0	1703	3321	0	1770	3539	1583	1770	3444	0
Right Turn on Red			Yes			Yes			Yes			Yes
Satd. Flow (RTOR)		22			16				259		20	
Link Speed (mph)		30			30			30			30	
Link Distance (ft)		6101			1008			1045			2119	
Travel Time (s)		138.7			22.9			23.8			48.2	
Lane Group Flow (vph)	596	1826	0	302	1036	0	59	1291	375	174	1881	0
Turn Type	Prot	NA		Prot	NA		Prot	NA	Perm	Prot	NA	
Protected Phases	7	4		3	8		5	2		1	6	
Permitted Phases									2			
Total Split (s)	40.0	54.0		20.0	34.0		12.0	37.0	37.0	24.0	49.0	
Total Lost Time (s)	5.5	6.5		5.5	6.5		5.0	6.5	6.5	5.0	6.5	
Act Effct Green (s)	34.5	47.5		14.5	27.5		6.8	32.8	32.8	16.7	44.9	
Actuated g/C Ratio	0.26	0.35		0.11	0.20		0.05	0.24	0.24	0.12	0.33	
v/c Ratio	1.37	1.55		1.66	1.50		0.67	1.50	0.65	0.80	1.62	
Control Delay	219.2	282.2		356.0	270.8		96.7	267.7	20.1	82.6	315.8	
Queue Delay	0.0	0.0		0.0	0.0		0.0	0.0	0.0	0.0	0.0	
Total Delay	219.2	282.2		356.0	270.8		96.7	267.7	20.1	82.6	315.8	
LOS	F	F		F	F		F	F	C	F	F	
Approach Delay		266.7			290.0			208.0			296.1	
Approach LOS		F			F			F			F	

Intersection Summary

Area Type: Other
Cycle Length: 135
Actuated Cycle Length: 135
Offset: 67 (50%), Referenced to phase 2:NET and 6:SWT, Start of Green
Control Type: Actuated-Coordinated
Maximum v/c Ratio: 1.66
Intersection Signal Delay: 265.4 Intersection LOS: F
Intersection Capacity Utilization 136.0% ICU Level of Service H
Analysis Period (min) 15

Splits and Phases: 3: Clear Lake City Blvd. / Clear Lake City Blvd. & Old Galveston Rd. /Old Galveston Rd.



8: Dixie Farm Rd. / Challenger & Old Galveston Rd. /Old Galveston Rd.

Lane Group	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations	↰	↑↱		↰	↑↱		↰	↑↱		↰	↑↱	
Volume (vph)	3	1199	311	183	700	11	138	23	192	108	175	15
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Storage Length (ft)	200		0	200		0	150		0	200		0
Storage Lanes	1		0	1		0	1		0	1		0
Taper Length (ft)	25			25			25			25		
Satd. Flow (prot)	1703	3300	0	1703	3399	0	1770	3047	0	1770	3493	0
Flt Permitted	0.950			0.950			0.950			0.950		
Satd. Flow (perm)	1703	3300	0	1703	3399	0	1770	3047	0	1770	3493	0
Right Turn on Red			Yes			Yes			Yes			Yes
Satd. Flow (RTOR)		42			2			266			8	
Link Speed (mph)		30			30			30			30	
Link Distance (ft)		968			3524			1823			652	
Travel Time (s)		22.0			80.1			41.4			14.8	
Lane Group Flow (vph)	4	2232	0	271	1048	0	204	307	0	117	208	0
Turn Type	Prot	NA		Prot	NA		Prot	NA		Prot	NA	
Protected Phases	5	2		1	6		7	4		3	8	
Permitted Phases												
Total Split (s)	20.0	50.0		20.0	50.0		15.0	15.0		15.0	15.0	
Total Lost Time (s)	5.5	5.5		5.5	5.5		5.0	5.0		5.0	5.0	
Act Effct Green (s)	5.1	44.5		15.3	63.1		10.0	9.9		9.2	9.2	
Actuated g/C Ratio	0.05	0.44		0.15	0.63		0.10	0.10		0.09	0.09	
v/c Ratio	0.05	1.50		1.04	0.49		1.15	0.57		0.72	0.64	
Control Delay	46.2	252.5		109.1	12.0		156.5	12.9		68.4	51.2	
Queue Delay	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Total Delay	46.2	252.5		109.1	12.0		156.5	12.9		68.4	51.2	
LOS	D	F		F	B		F	B		E	D	
Approach Delay		252.2			31.9			70.2			57.4	
Approach LOS		F			C			E			E	

Intersection Summary

Area Type: Other

Cycle Length: 100

Actuated Cycle Length: 100

Offset: 40 (40%), Referenced to phase 2:SET and 6:NWT, Start of Green

Control Type: Actuated-Coordinated

Maximum v/c Ratio: 1.50

Intersection Signal Delay: 150.4 Intersection LOS: F

Intersection Capacity Utilization 105.6% ICU Level of Service G

Analysis Period (min) 15

Splits and Phases: 8: Dixie Farm Rd. / Challenger & Old Galveston Rd. /Old Galveston Rd.

11: Old Galveston Rd. / Old Galveston Rd. & Brantly Ave.

Lane Group	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations	↰	↑↱		↰	↑↱			✥			↰↑	↱
Volume (vph)	2	2134	1	1	894	11	2	0	5	90	0	12
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Storage Length (ft)	280		0	200		0	0		0	0		0
Storage Lanes	1		0	1		0	0		0	0		1
Taper Length (ft)	25			25			25			25		
Satd. Flow (prot)	1703	3406	0	1703	3402	0	0	1660	0	0	1770	1583
Flt Permitted	0.950			0.950				0.918			0.751	
Satd. Flow (perm)	1703	3406	0	1703	3402	0	0	1548	0	0	1399	1583
Right Turn on Red			Yes			Yes			Yes			Yes
Satd. Flow (RTOR)					1			109				109
Link Speed (mph)		30			30			30			30	
Link Distance (ft)		3524			6101			140			183	
Travel Time (s)		80.1			138.7			3.2			4.2	
Lane Group Flow (vph)	2	2321	0	1	1335	0	0	10	0	0	109	14
Turn Type	Prot	NA		Prot	NA		Perm	NA		Perm	NA	Perm
Protected Phases	5	2		1	6			4			8	
Permitted Phases							4			8		8
Total Split (s)	20.0	60.0		20.0	60.0		20.0	20.0		20.0	20.0	20.0
Total Lost Time (s)	6.5	6.5		6.5	6.0			5.0			5.5	5.5
Act Effct Green (s)	5.0	74.2		5.0	74.7			12.0			11.5	11.5
Actuated g/C Ratio	0.05	0.74		0.05	0.75			0.12			0.12	0.12
v/c Ratio	0.02	0.92		0.01	0.53			0.04			0.68	0.05
Control Delay	36.0	22.1		46.0	7.2			0.2			63.1	0.3
Queue Delay	0.0	0.0		0.0	0.0			0.0			0.0	0.0
Total Delay	36.0	22.1		46.0	7.2			0.2			63.1	0.3
LOS	D	C		D	A			A			E	A
Approach Delay		22.1			7.3			0.2			55.9	
Approach LOS		C			A			A			E	

Intersection Summary

Area Type: Other

Cycle Length: 100

Actuated Cycle Length: 100

Offset: 90 (90%), Referenced to phase 2:SET and 6:NWT, Start of Green

Control Type: Actuated-Coordinated

Maximum v/c Ratio: 0.92

Intersection Signal Delay: 17.9 Intersection LOS: B

Intersection Capacity Utilization 81.2% ICU Level of Service D

Analysis Period (min) 15

Splits and Phases: 11: Old Galveston Rd. / Old Galveston Rd. & Brantly Ave.

1: Old Galveston Rd. & Hillard St.

Movement	SEL	SET	NWT	NWR	SWL	SWR
Lane Configurations	↰	↑↑	↑↱		↰↱	
Volume (veh/h)	197	653	1005	5	0	11
Sign Control		Free	Free		Stop	
Grade		0%	0%		0%	
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92
Hourly flow rate (vph)	214	823	1267	6	0	13
Pedestrians						
Lane Width (ft)						
Walking Speed (ft/s)						
Percent Blockage						
Right turn flare (veh)						
Median type		None	None			
Median storage veh)						
Upstream signal (ft)			968			
pX, platoon unblocked	0.82				0.82	0.82
vC, conflicting volume	1273				2110	636
vC1, stage 1 conf vol						
vC2, stage 2 conf vol						
vCu, unblocked vol	902				1919	129
tC, single (s)	4.2				6.8	6.9
tC, 2 stage (s)						
tF (s)	2.3				3.5	3.3
p0 queue free %	64				100	98
cM capacity (veh/h)	597				31	738

Direction, Lane #	SE 1	SE 2	SE 3	NW 1	NW 2	SW 1
Volume Total	214	412	412	845	428	13
Volume Left	214	0	0	0	0	0
Volume Right	0	0	0	0	6	13
cSH	597	1700	1700	1700	1700	738
Volume to Capacity	0.36	0.24	0.24	0.50	0.25	0.02
Queue Length 95th (ft)	41	0	0	0	0	1
Control Delay (s)	14.4	0.0	0.0	0.0	0.0	10.0
Lane LOS	B					A
Approach Delay (s)	3.0			0.0		10.0
Approach LOS						A

Intersection Summary			
Average Delay	1.4		
Intersection Capacity Utilization	56.6%	ICU Level of Service	B
Analysis Period (min)	15		

Lane Group	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations	↰↰	↑↑	↱	↰↰	↑↑	↱	↰↰	↑↑	↱	↰↰	↑↑	↱
Volume (vph)	173	386	24	216	682	77	144	824	153	114	993	599
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Storage Length (ft)	300		200	300		200	315		315	125		250
Storage Lanes	2		1	2		1	2		1	2		1
Taper Length (ft)	25			25			25			25		
Satd. Flow (prot)	3303	3406	1524	3303	3406	1524	3433	3539	1583	3433	3539	1583
Flt Permitted	0.950			0.950			0.950			0.950		
Satd. Flow (perm)	3303	3406	1524	3303	3406	1524	3433	3539	1583	3433	3539	1583
Right Turn on Red			Yes			Yes			Yes			Yes
Satd. Flow (RTOR)			136			127			193			413
Link Speed (mph)		30			30			30			30	
Link Distance (ft)		6101			1008			1045			2119	
Travel Time (s)		138.7			22.9			23.8			48.2	
Lane Group Flow (vph)	218	487	30	272	741	97	182	1039	193	144	1252	651
Turn Type	Prot	NA	Perm	Prot	NA	Perm	Prot	NA	Perm	Prot	NA	Perm
Protected Phases	7	4		3	8		5	2		1	6	
Permitted Phases			4			8			2			6
Total Split (s)	21.5	32.9	32.9	21.6	33.0	33.0	12.0	53.5	53.5	12.0	53.5	53.5
Total Lost Time (s)	5.5	6.5	6.5	5.5	6.5	6.5	5.0	6.5	6.5	5.0	6.5	6.5
Act Effct Green (s)	13.0	21.5	21.5	20.2	28.8	28.8	7.5	47.7	47.7	7.0	47.3	47.3
Actuated g/C Ratio	0.11	0.18	0.18	0.17	0.24	0.24	0.06	0.40	0.40	0.06	0.39	0.39
v/c Ratio	0.61	0.80	0.08	0.49	0.91	0.21	0.85	0.74	0.26	0.72	0.90	0.75
Control Delay	58.2	57.1	0.4	49.4	60.6	4.0	89.1	34.9	4.2	75.5	44.1	16.8
Queue Delay	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Delay	58.2	57.1	0.4	49.4	60.6	4.0	89.1	34.9	4.2	75.5	44.1	16.8
LOS	E	E	A	D	E	A	F	C	A	E	D	B
Approach Delay		55.1			52.9			37.7			37.6	
Approach LOS		E			D			D			D	

Intersection Summary

Area Type: Other

Cycle Length: 120

Actuated Cycle Length: 120

Offset: 60 (50%), Referenced to phase 2:NET and 6:SWT, Start of Green

Control Type: Actuated-Coordinated

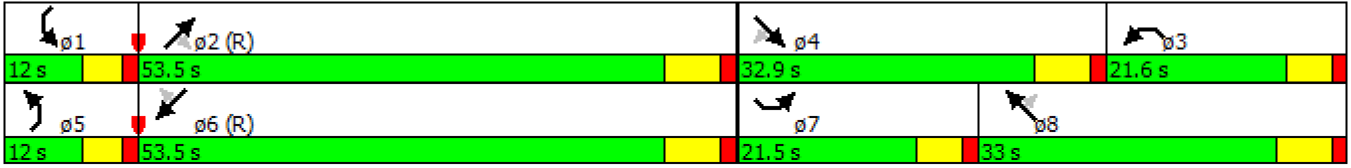
Maximum v/c Ratio: 0.91

Intersection Signal Delay: 43.3 Intersection LOS: D

Intersection Capacity Utilization 80.8% ICU Level of Service D

Analysis Period (min) 15

Splits and Phases: 3: Clear Lake City Blvd. / Clear Lake City Blvd. & Old Galveston Rd. /Old Galveston Rd.



2020 Build - Mitigated AM Peak Hour
8: Dixie Farm Rd. / Challenger & Old Galveston Rd. /Old Galveston Rd.

Lane Group	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations	↰	↑↑	↱	↰	↑↱		↰	↑↱		↰	↑↱	
Volume (vph)	10	445	120	134	868	94	183	148	127	10	20	1
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Storage Length (ft)	200		200	200		0	150		0	200		0
Storage Lanes	1		1	1		0	1		0	1		0
Taper Length (ft)	25			25			25			25		
Satd. Flow (prot)	1703	3406	1524	1703	3361	0	1770	3274	0	1770	3514	0
Flt Permitted	0.950			0.950			0.950			0.950		
Satd. Flow (perm)	1703	3406	1524	1703	3361	0	1770	3274	0	1770	3514	0
Right Turn on Red			Yes			Yes			Yes			Yes
Satd. Flow (RTOR)			251		12			160			1	
Link Speed (mph)		30			30			30			30	
Link Distance (ft)		968			3524			1823			652	
Travel Time (s)		22.0			80.1			41.4			14.8	
Lane Group Flow (vph)	11	561	151	169	1196	0	231	321	0	11	23	0
Turn Type	Prot	NA	Perm	Prot	NA		Prot	NA		Prot	NA	
Protected Phases	5	2		1	6		7	4		3	8	
Permitted Phases			2									
Total Split (s)	10.5	39.6	39.6	16.4	45.5		19.0	34.0		10.0	25.0	
Total Lost Time (s)	5.5	5.5	5.5	5.5	5.5		5.0	5.0		5.0	5.0	
Act Effct Green (s)	5.5	49.9	49.9	15.8	68.8		14.0	16.3		5.0	5.3	
Actuated g/C Ratio	0.06	0.50	0.50	0.16	0.69		0.14	0.16		0.05	0.05	
v/c Ratio	0.12	0.33	0.17	0.63	0.52		0.94	0.48		0.12	0.12	
Control Delay	47.4	17.3	0.4	44.0	12.8		86.9	21.0		48.7	45.0	
Queue Delay	0.0	0.0	0.0	0.0	0.0		0.0	0.0		0.0	0.0	
Total Delay	47.4	17.3	0.4	44.0	12.8		86.9	21.0		48.7	45.0	
LOS	D	B	A	D	B		F	C		D	D	
Approach Delay		14.2			16.7			48.6			46.2	
Approach LOS		B			B			D			D	

Intersection Summary

Area Type: Other
Cycle Length: 100
Actuated Cycle Length: 100
Offset: 40 (40%), Referenced to phase 2:SET and 6:NWT, Start of Green
Control Type: Actuated-Coordinated
Maximum v/c Ratio: 0.94
Intersection Signal Delay: 23.0 Intersection LOS: C
Intersection Capacity Utilization 66.8% ICU Level of Service C
Analysis Period (min) 15

Splits and Phases: 8: Dixie Farm Rd. / Challenger & Old Galveston Rd. /Old Galveston Rd.

2020 Build - Mitigated AM Peak Hour

11: Old Galveston Rd. / Old Galveston Rd. & Brantly Ave.

Lane Group	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations	↰	↑↱		↰	↑↱			✥			↰	↱
Volume (vph)	7	602	1	8	1356	88	2	0	1	10	0	3
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Storage Length (ft)	280		0	200		0	0		0	0		0
Storage Lanes	1		0	1		0	0		0	0		1
Taper Length (ft)	25			25			25			25		
Satd. Flow (prot)	1703	3406	0	1703	3372	0	0	1735	0	0	1770	1583
Flt Permitted	0.950			0.950								
Satd. Flow (perm)	1703	3406	0	1703	3372	0	0	1799	0	0	1863	1583
Right Turn on Red			Yes			Yes			Yes			Yes
Satd. Flow (RTOR)					12			109				109
Link Speed (mph)		30			30			30			30	
Link Distance (ft)		3524			6101			140			183	
Travel Time (s)		80.1			138.7			3.2			4.2	
Lane Group Flow (vph)	8	760	0	10	1574	0	0	4	0	0	11	3
Turn Type	Prot	NA		Prot	NA		Perm	NA		Perm	NA	Perm
Protected Phases	5	2		1	6			4			8	
Permitted Phases							4			8		8
Total Split (s)	18.0	65.0		18.0	65.0		17.0	17.0		17.0	17.0	17.0
Total Lost Time (s)	6.5	6.5		6.5	6.0			5.0			5.5	5.5
Act Effct Green (s)	6.1	89.8		6.2	90.1			5.8			5.6	5.6
Actuated g/C Ratio	0.06	0.90		0.06	0.90			0.06			0.06	0.06
v/c Ratio	0.08	0.25		0.10	0.52			0.02			0.11	0.02
Control Delay	43.3	1.6		45.8	4.1			0.2			46.5	0.0
Queue Delay	0.0	0.0		0.0	0.0			0.0			0.0	0.0
Total Delay	43.3	1.6		45.8	4.1			0.2			46.5	0.0
LOS	D	A		D	A			A			D	A
Approach Delay		2.0			4.3			0.3			36.5	
Approach LOS		A			A			A			D	

Intersection Summary

Area Type: Other

Cycle Length: 100

Actuated Cycle Length: 100

Offset: 90 (90%), Referenced to phase 2:SET and 6:NWT, Start of Green

Control Type: Actuated-Coordinated

Maximum v/c Ratio: 0.52

Intersection Signal Delay: 3.8 Intersection LOS: A

Intersection Capacity Utilization 62.5% ICU Level of Service B

Analysis Period (min) 15

Splits and Phases: 11: Old Galveston Rd. / Old Galveston Rd. & Brantly Ave.

1: Old Galveston Rd. & Hilliard St.

Movement	SEL	SET	NWT	NWR	SWL	SWR
Lane Configurations	↰	↑↑	↑↱		↰↱	
Volume (veh/h)	20	1563	850	1	4	224
Sign Control		Free	Free		Stop	
Grade		0%	0%		0%	
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92
Hourly flow rate (vph)	23	1971	1072	1	5	243
Pedestrians						
Lane Width (ft)						
Walking Speed (ft/s)						
Percent Blockage						
Right turn flare (veh)						
Median type		None	None			
Median storage veh)						
Upstream signal (ft)			968			
pX, platoon unblocked	0.89				0.89	0.89
vC, conflicting volume	1073				2103	536
vC1, stage 1 conf vol						
vC2, stage 2 conf vol						
vCu, unblocked vol	843				1996	242
tC, single (s)	4.2				6.8	6.9
tC, 2 stage (s)						
tF (s)	2.3				3.5	3.3
p0 queue free %	97				90	64
cM capacity (veh/h)	682				45	677

Direction, Lane #	SE 1	SE 2	SE 3	NW 1	NW 2	SW 1
Volume Total	23	985	985	714	358	248
Volume Left	23	0	0	0	0	5
Volume Right	0	0	0	0	1	243
cSH	682	1700	1700	1700	1700	539
Volume to Capacity	0.03	0.58	0.58	0.42	0.21	0.46
Queue Length 95th (ft)	3	0	0	0	0	60
Control Delay (s)	10.5	0.0	0.0	0.0	0.0	17.3
Lane LOS	B					C
Approach Delay (s)	0.1			0.0		17.3
Approach LOS						C

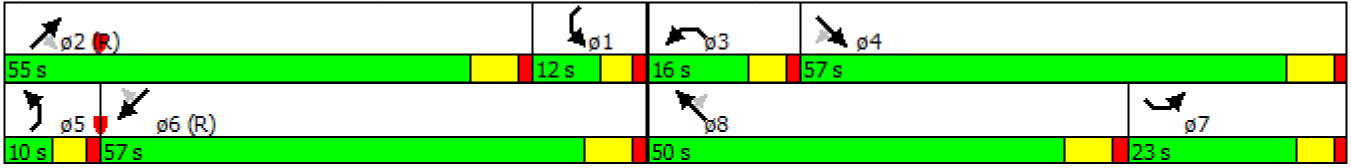
Intersection Summary			
Average Delay	1.4		
Intersection Capacity Utilization	70.9%	ICU Level of Service	C
Analysis Period (min)	15		

3: Clear Lake City Blvd. / Clear Lake City Blvd. & Old Galveston R

Lane Group	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations	↰↰	↑↑	↱	↰↰	↑↑	↱	↰↰	↑↑	↱	↰↰	↑↑	↱
Volume (vph)	460	1172	226	204	584	117	40	873	254	118	1043	229
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Storage Length (ft)	300		300	300		200	315		315	125		250
Storage Lanes	2		1	2		1	2		1	2		1
Taper Length (ft)	25			25			25			25		
Satd. Flow (prot)	3303	3406	1524	3303	3406	1524	3433	3539	1583	3433	3539	1583
Flt Permitted	0.950			0.950			0.950			0.950		
Satd. Flow (perm)	3303	3406	1524	3303	3406	1524	3433	3539	1583	3433	3539	1583
Right Turn on Red			Yes			Yes			Yes			Yes
Satd. Flow (RTOR)			160			168			199			185
Link Speed (mph)		30			30			30			30	
Link Distance (ft)		6101			1008			1045			2119	
Travel Time (s)		138.7			22.9			23.8			48.2	
Lane Group Flow (vph)	500	1274	285	257	736	148	50	1101	320	149	1315	289
Turn Type	Prot	NA	Perm	Prot	NA	Perm	Prot	NA	Perm	Prot	NA	Perm
Protected Phases	7	4		3	8		5	2		1	6	
Permitted Phases			4			8			2			6
Total Split (s)	23.0	57.0	57.0	16.0	50.0	50.0	10.0	55.0	55.0	12.0	57.0	57.0
Total Lost Time (s)	5.5	6.5	6.5	5.5	6.5	6.5	5.0	6.5	6.5	5.0	6.5	6.5
Act Effct Green (s)	24.8	50.5	50.5	10.5	36.2	36.2	5.0	48.5	48.5	7.0	52.5	52.5
Actuated g/C Ratio	0.18	0.36	0.36	0.08	0.26	0.26	0.04	0.35	0.35	0.05	0.38	0.38
v/c Ratio	0.86	1.04	0.44	1.04	0.84	0.29	0.41	0.90	0.47	0.87	0.99	0.41
Control Delay	50.2	58.3	5.9	129.5	57.8	4.7	76.3	54.2	15.3	106.9	66.3	13.5
Queue Delay	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Delay	50.2	58.3	5.9	129.5	57.8	4.7	76.3	54.2	15.3	106.9	66.3	13.5
LOS	D	E	A	F	E	A	E	D	B	F	E	B
Approach Delay		49.1			67.1			46.5			61.0	
Approach LOS		D			E			D			E	

Intersection Summary	
Area Type: Other	
Cycle Length: 140	
Actuated Cycle Length: 140	
Offset: 106 (76%), Referenced to phase 2:NET and 6:SWT, Start of Green	
Control Type: Actuated-Coordinated	
Maximum v/c Ratio: 1.04	
Intersection Signal Delay: 54.9	Intersection LOS: D
Intersection Capacity Utilization 96.3%	ICU Level of Service F
Analysis Period (min) 15	

Splits and Phases: 3: Clear Lake City Blvd. / Clear Lake City Blvd. & Old Galveston Rd. /Old Galveston Rd.



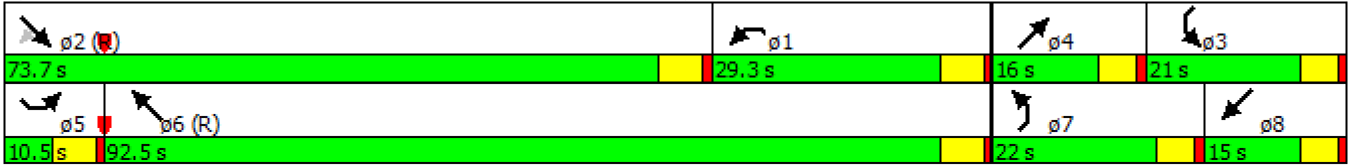
8: Dixie Farm Rd. / Challenger & Old Galveston Rd. /Old Galveston Rd.

Lane Group	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations	↰	↑↑	↱	↰	↑↱		↰	↑↱		↰	↑↱	
Volume (vph)	3	1199	311	183	700	11	138	22	192	103	166	15
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Storage Length (ft)	200		200	200		0	150		0	200		0
Storage Lanes	1		1	1		0	1		0	1		0
Taper Length (ft)	25			25			25			25		
Satd. Flow (prot)	1703	3406	1524	1703	3399	0	1770	3058	0	1770	3493	0
Flt Permitted	0.950			0.950			0.950			0.950		
Satd. Flow (perm)	1703	3406	1524	1703	3399	0	1770	3058	0	1770	3493	0
Right Turn on Red			Yes			Yes			Yes			Yes
Satd. Flow (RTOR)			222		2			242			5	
Link Speed (mph)		30			30			30			30	
Link Distance (ft)		968			3524			1823			652	
Travel Time (s)		22.0			80.1			41.4			14.8	
Lane Group Flow (vph)	3	1512	392	231	896	0	174	266	0	112	197	0
Turn Type	Prot	NA	Perm	Prot	NA		Prot	NA		Prot	NA	
Protected Phases	5	2		1	6		7	4		3	8	
Permitted Phases			2									
Total Split (s)	10.5	73.7	73.7	29.3	92.5		22.0	16.0		21.0	15.0	
Total Lost Time (s)	5.5	5.5	5.5	5.5	5.5		5.0	5.0		5.0	5.0	
Act Effct Green (s)	5.0	69.4	69.4	23.8	96.6		16.0	6.8		19.0	9.9	
Actuated g/C Ratio	0.04	0.50	0.50	0.17	0.69		0.11	0.05		0.14	0.07	
v/c Ratio	0.05	0.90	0.45	0.80	0.38		0.87	0.70		0.47	0.78	
Control Delay	67.0	40.7	11.3	68.1	2.2		96.8	20.9		63.1	83.7	
Queue Delay	0.0	0.0	0.0	0.0	0.0		0.0	0.0		0.0	0.0	
Total Delay	67.0	40.7	11.3	68.1	2.2		96.8	20.9		63.1	83.7	
LOS	E	D	B	E	A		F	C		E	F	
Approach Delay		34.7			15.7			50.9			76.2	
Approach LOS		C			B			D			E	

Intersection Summary

Area Type: Other
Cycle Length: 140
Actuated Cycle Length: 140
Offset: 92 (66%), Referenced to phase 2:SET and 6:NWT, Start of Green
Control Type: Actuated-Coordinated
Maximum v/c Ratio: 0.90
Intersection Signal Delay: 34.3 Intersection LOS: C
Intersection Capacity Utilization 81.7% ICU Level of Service D
Analysis Period (min) 15

Splits and Phases: 8: Dixie Farm Rd. / Challenger & Old Galveston Rd. /Old Galveston Rd.



11: Old Galveston Rd. / Old Galveston Rd. & Brantly Ave.

Lane Group	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations	↰	↑↱		↰	↑↱			✥			↰	↱
Volume (vph)	2	1817	1	1	894	11	2	0	5	90	0	12
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Storage Length (ft)	280		0	200		0	0		0	0		0
Storage Lanes	1		0	1		0	0		0	0		1
Taper Length (ft)	25			25			25			25		
Satd. Flow (prot)	1703	3406	0	1703	3399	0	0	1668	0	0	1770	1583
Flt Permitted	0.950			0.950				0.918			0.752	
Satd. Flow (perm)	1703	3406	0	1703	3399	0	0	1556	0	0	1401	1583
Right Turn on Red			Yes			Yes			Yes			Yes
Satd. Flow (RTOR)					2			78				78
Link Speed (mph)		30			30			30			30	
Link Distance (ft)		3524			6101			140			183	
Travel Time (s)		80.1			138.7			3.2			4.2	
Lane Group Flow (vph)	2	1976	0	1	1140	0	0	9	0	0	103	14
Turn Type	Prot	NA		Prot	NA		Perm	NA		Perm	NA	Perm
Protected Phases	5	2		1	6			4			8	
Permitted Phases							4			8		8
Total Split (s)	11.5	104.5		11.5	104.5		24.0	24.0		24.0	24.0	24.0
Total Lost Time (s)	6.5	6.5		6.5	6.0			5.0			5.5	5.5
Act Effct Green (s)	5.0	111.6		5.0	112.1			14.6			14.1	14.1
Actuated g/C Ratio	0.04	0.80		0.04	0.80			0.10			0.10	0.10
v/c Ratio	0.03	0.73		0.02	0.42			0.04			0.73	0.06
Control Delay	82.5	4.6		91.0	3.9			0.4			88.5	0.5
Queue Delay	0.0	0.0		0.0	0.0			0.0			0.0	0.0
Total Delay	82.5	4.6		91.0	3.9			0.4			88.5	0.5
LOS	F	A		F	A			A			F	A
Approach Delay		4.7			4.0			0.4			78.0	
Approach LOS		A			A			A			E	

Intersection Summary

Area Type: Other

Cycle Length: 140

Actuated Cycle Length: 140

Offset: 7 (5%), Referenced to phase 2:SET and 6:NWT, Start of Green

Control Type: Actuated-Coordinated

Maximum v/c Ratio: 0.73

Intersection Signal Delay: 7.1 Intersection LOS: A

Intersection Capacity Utilization 72.2% ICU Level of Service C

Analysis Period (min) 15

Splits and Phases: 11: Old Galveston Rd. / Old Galveston Rd. & Brantly Ave.

1: Old Galveston Rd. & Hillard St.

Movement	SEL	SET	NWT	NWR	SWL	SWR
Lane Configurations	↰	↑↑	↑↱		Y	
Volume (veh/h)	208	653	1005	5	0	11
Sign Control		Free	Free		Stop	
Grade		0%	0%		0%	
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92
Hourly flow rate (vph)	226	965	1486	6	0	13
Pedestrians						
Lane Width (ft)						
Walking Speed (ft/s)						
Percent Blockage						
Right turn flare (veh)						
Median type		None	None			
Median storage veh)						
Upstream signal (ft)			968			
pX, platoon unblocked	0.75				0.75	0.75
vC, conflicting volume	1492				2423	746
vC1, stage 1 conf vol						
vC2, stage 2 conf vol						
vCu, unblocked vol	983				2229	0
tC, single (s)	4.2				6.8	6.9
tC, 2 stage (s)						
tF (s)	2.3				3.5	3.3
p0 queue free %	55				100	98
cM capacity (veh/h)	504				15	811

Direction, Lane #	SE 1	SE 2	SE 3	NW 1	NW 2	SW 1
Volume Total	226	483	483	990	501	13
Volume Left	226	0	0	0	0	0
Volume Right	0	0	0	0	6	13
cSH	504	1700	1700	1700	1700	811
Volume to Capacity	0.45	0.28	0.28	0.58	0.29	0.02
Queue Length 95th (ft)	57	0	0	0	0	1
Control Delay (s)	17.8	0.0	0.0	0.0	0.0	9.5
Lane LOS	C					A
Approach Delay (s)	3.4			0.0		9.5
Approach LOS						A

Intersection Summary			
Average Delay	1.5		
Intersection Capacity Utilization	62.8%	ICU Level of Service	B
Analysis Period (min)	15		

3: Clear Lake City Blvd. / Clear Lake City Blvd. & Old Galveston

Lane Group	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations	↰↰	↑↑	↱	↰↰	↑↑	↱	↰↰	↑↑	↱	↰↰	↑↑	↱
Volume (vph)	173	386	24	216	800	77	144	824	153	114	993	710
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Storage Length (ft)	300		300	300		200	315		315	125		250
Storage Lanes	2		1	2		1	2		1	2		1
Taper Length (ft)	25			25			25			25		
Satd. Flow (prot)	3303	3406	1524	3303	3406	1524	3433	3539	1583	3433	3539	1583
Flt Permitted	0.950			0.950			0.950			0.950		
Satd. Flow (perm)	3303	3406	1524	3303	3406	1524	3433	3539	1583	3433	3539	1583
Right Turn on Red			Yes			Yes			Yes			Yes
Satd. Flow (RTOR)			156			149			198			318
Link Speed (mph)		30			30			30			30	
Link Distance (ft)		6101			1008			1045			2119	
Travel Time (s)		138.7			22.9			23.8			48.2	
Lane Group Flow (vph)	256	571	35	319	870	114	213	1218	226	169	1468	772
Turn Type	Prot	NA	Perm	Prot	NA	Perm	Prot	NA	Perm	Prot	NA	Perm
Protected Phases	7	4		3	8		5	2		1	6	
Permitted Phases			4			8			2			6
Total Split (s)	21.5	42.2	42.2	23.3	44.0	44.0	14.0	69.5	69.5	15.0	70.5	70.5
Total Lost Time (s)	5.5	6.5	6.5	5.5	6.5	6.5	5.0	6.5	6.5	5.0	6.5	6.5
Act Effct Green (s)	15.1	29.8	29.8	23.7	38.4	38.4	9.0	63.0	63.0	10.0	64.0	64.0
Actuated g/C Ratio	0.10	0.20	0.20	0.16	0.26	0.26	0.06	0.42	0.42	0.07	0.43	0.43
v/c Ratio	0.77	0.85	0.08	0.61	1.00	0.23	1.04	0.82	0.29	0.74	0.97	0.90
Control Delay	81.6	69.9	0.4	65.2	85.2	3.5	139.5	44.1	6.1	88.1	59.5	37.9
Queue Delay	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Delay	81.6	69.9	0.4	65.2	85.2	3.5	139.5	44.1	6.1	88.1	59.5	37.9
LOS	F	E	A	E	F	A	F	D	A	F	E	D
Approach Delay		70.5			73.1			51.2			54.6	
Approach LOS		E			E			D			D	

Intersection Summary

Area Type: Other

Cycle Length: 150

Actuated Cycle Length: 150

Offset: 133 (89%), Referenced to phase 2:NET and 6:SWT, Start of Green

Control Type: Actuated-Coordinated

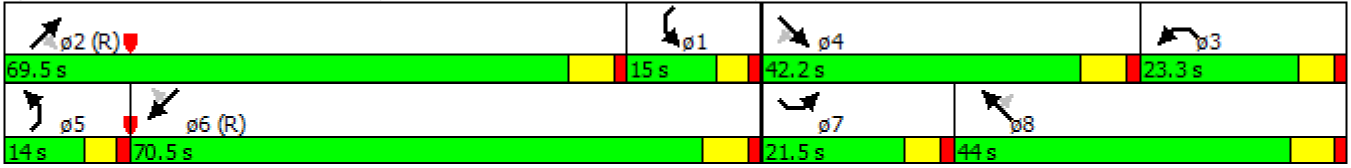
Maximum v/c Ratio: 1.04

Intersection Signal Delay: 59.8 Intersection LOS: E

Intersection Capacity Utilization 91.3% ICU Level of Service F

Analysis Period (min) 15

Splits and Phases: 3: Clear Lake City Blvd. / Clear Lake City Blvd. & Old Galveston Rd. /Old Galveston Rd.



8: Dixie Farm Rd. / Challenger & Old Galveston Rd. /Old Galveston Rd.

Lane Group	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations	↰	↑↑	↱	↰	↑↱		↰	↑↱		↰	↑↱	
Volume (vph)	10	445	120	134	868	99	183	156	127	10	21	1
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Storage Length (ft)	200		200	200		0	150		0	200		0
Storage Lanes	1		1	1		0	1		0	1		0
Taper Length (ft)	25			25			25			25		
Satd. Flow (prot)	1703	3406	1524	1703	3365	0	1770	3260	0	1770	3518	0
Flt Permitted	0.950			0.950			0.950			0.950		
Satd. Flow (perm)	1703	3406	1524	1703	3365	0	1770	3260	0	1770	3518	0
Right Turn on Red			Yes			Yes			Yes			Yes
Satd. Flow (RTOR)			251		10			188			1	
Link Speed (mph)		30			30			30			30	
Link Distance (ft)		968			3524			1823			652	
Travel Time (s)		22.0			80.1			41.4			14.8	
Lane Group Flow (vph)	12	658	177	198	1391	0	271	358	0	12	24	0
Turn Type	Prot	NA	Perm	Prot	NA		Prot	NA		Prot	NA	
Protected Phases	5	2		1	6		7	4		3	8	
Permitted Phases			2									
Total Split (s)	10.5	39.0	39.0	17.0	45.5		19.0	34.0		10.0	25.0	
Total Lost Time (s)	5.5	5.5	5.5	5.5	5.5		5.0	5.0		5.0	5.0	
Act Effct Green (s)	5.5	46.7	46.7	19.0	68.7		14.0	16.3		5.0	5.4	
Actuated g/C Ratio	0.06	0.47	0.47	0.19	0.69		0.14	0.16		0.05	0.05	
v/c Ratio	0.13	0.41	0.21	0.61	0.60		1.10	0.52		0.14	0.13	
Control Delay	47.5	20.0	1.2	39.2	14.0		127.4	20.4		49.1	45.0	
Queue Delay	0.0	0.0	0.0	0.0	0.0		0.0	0.0		0.0	0.0	
Total Delay	47.5	20.0	1.2	39.2	14.0		127.4	20.4		49.1	45.0	
LOS	D	B	A	D	B		F	C		D	D	
Approach Delay		16.5			17.2			66.5			46.4	
Approach LOS		B			B			E			D	

Intersection Summary

Area Type: Other

Cycle Length: 100

Actuated Cycle Length: 100

Offset: 40 (40%), Referenced to phase 2:SET and 6:NWT, Start of Green

Control Type: Actuated-Coordinated

Maximum v/c Ratio: 1.10

Intersection Signal Delay: 27.3 Intersection LOS: C

Intersection Capacity Utilization 73.7% ICU Level of Service D

Analysis Period (min) 15

Splits and Phases: 8: Dixie Farm Rd. / Challenger & Old Galveston Rd. /Old Galveston Rd.

11: Old Galveston Rd. / Old Galveston Rd. & Brantly Ave.

Lane Group	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations	↰	↑↱		↰	↑↱			✣			↰↑	↱
Volume (vph)	7	602	1	8	1593	88	2	0	1	10	0	3
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Storage Length (ft)	280		0	200		0	0		0	0		0
Storage Lanes	1		0	1		0	0		0	0		1
Taper Length (ft)	25			25			25			25		
Satd. Flow (prot)	1703	3406	0	1703	3375	0	0	1735	0	0	1770	1583
Flt Permitted	0.950			0.950								
Satd. Flow (perm)	1703	3406	0	1703	3375	0	0	1799	0	0	1863	1583
Right Turn on Red			Yes			Yes			Yes			Yes
Satd. Flow (RTOR)					11			109				109
Link Speed (mph)		30			30			30			30	
Link Distance (ft)		3524			6101			140			183	
Travel Time (s)		80.1			138.7			3.2			4.2	
Lane Group Flow (vph)	8	891	0	12	1838	0	0	4	0	0	12	4
Turn Type	Prot	NA		Prot	NA		Perm	NA		Perm	NA	Perm
Protected Phases	5	2		1	6			4			8	
Permitted Phases							4			8		8
Total Split (s)	18.0	65.0		18.0	65.0		17.0	17.0		17.0	17.0	17.0
Total Lost Time (s)	6.5	6.5		6.5	6.0			5.0			5.5	5.5
Act Effct Green (s)	6.1	89.7		6.3	90.0			5.9			5.7	5.7
Actuated g/C Ratio	0.06	0.90		0.06	0.90			0.06			0.06	0.06
v/c Ratio	0.08	0.29		0.11	0.61			0.02			0.11	0.02
Control Delay	41.1	1.7		45.9	5.1			0.2			46.5	0.2
Queue Delay	0.0	0.0		0.0	0.0			0.0			0.0	0.0
Total Delay	41.1	1.7		45.9	5.1			0.2			46.5	0.2
LOS	D	A		D	A			A			D	A
Approach Delay		2.1			5.4			0.3			34.9	
Approach LOS		A			A			A			C	

Intersection Summary

Area Type: Other

Cycle Length: 100

Actuated Cycle Length: 100

Offset: 90 (90%), Referenced to phase 2:SET and 6:NWT, Start of Green

Control Type: Actuated-Coordinated

Maximum v/c Ratio: 0.61

Intersection Signal Delay: 4.5 Intersection LOS: A

Intersection Capacity Utilization 69.2% ICU Level of Service C

Analysis Period (min) 15

Splits and Phases: 11: Old Galveston Rd. / Old Galveston Rd. & Brantly Ave.

1: Old Galveston Rd. & Hilliard St.

Movement	SEL	SET	NWT	NWR	SWL	SWR
Lane Configurations	↰	↑↑	↑↱		↰↱	
Volume (veh/h)	20	1563	850	1	4	237
Sign Control		Free	Free		Stop	
Grade		0%	0%		0%	
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92
Hourly flow rate (vph)	24	2311	1257	1	5	258
Pedestrians						
Lane Width (ft)						
Walking Speed (ft/s)						
Percent Blockage						
Right turn flare (veh)						
Median type		None	None			
Median storage veh)						
Upstream signal (ft)			968			
pX, platoon unblocked	0.87				0.87	0.87
vC, conflicting volume	1258				2461	629
vC1, stage 1 conf vol						
vC2, stage 2 conf vol						
vCu, unblocked vol	994				2379	270
tC, single (s)	4.2				6.8	6.9
tC, 2 stage (s)						
tF (s)	2.3				3.5	3.3
p0 queue free %	96				80	59
cM capacity (veh/h)	580				24	632

Direction, Lane #	SE 1	SE 2	SE 3	NW 1	NW 2	SW 1
Volume Total	24	1155	1155	838	420	262
Volume Left	24	0	0	0	0	5
Volume Right	0	0	0	0	1	258
cSH	580	1700	1700	1700	1700	431
Volume to Capacity	0.04	0.68	0.68	0.49	0.25	0.61
Queue Length 95th (ft)	3	0	0	0	0	99
Control Delay (s)	11.5	0.0	0.0	0.0	0.0	25.6
Lane LOS	B					D
Approach Delay (s)	0.1			0.0		25.6
Approach LOS						D

Intersection Summary			
Average Delay	1.8		
Intersection Capacity Utilization	80.3%	ICU Level of Service	D
Analysis Period (min)	15		

Lane Group	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations	↰↰	↑↑	↱	↰↰	↑↑	↱	↰↰	↑↑	↱	↰↰	↑↑	↱
Volume (vph)	548	1373	226	204	584	117	40	873	254	118	1043	229
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Storage Length (ft)	300		300	300		200	315		315	125		250
Storage Lanes	2		1	2		1	2		1	2		1
Taper Length (ft)	25			25			25			25		
Satd. Flow (prot)	3303	3406	1524	3303	3406	1524	3433	3539	1583	3433	3539	1583
Flt Permitted	0.950			0.950			0.950			0.950		
Satd. Flow (perm)	3303	3406	1524	3303	3406	1524	3433	3539	1583	3433	3539	1583
Right Turn on Red			Yes			Yes			Yes			Yes
Satd. Flow (RTOR)			138			132			166			158
Link Speed (mph)		30			30			30			30	
Link Distance (ft)		6101			1008			1045			2119	
Travel Time (s)		138.7			22.9			23.8			48.2	
Lane Group Flow (vph)	596	1492	334	302	863	173	59	1291	375	174	1542	339
Turn Type	Prot	NA	Perm	Prot	NA	Perm	Prot	NA	Perm	Prot	NA	Perm
Protected Phases	7	4		3	8		5	2		1	6	
Permitted Phases			4			8			2			6
Total Split (s)	37.0	70.0	70.0	18.0	51.0	51.0	10.0	69.0	69.0	13.0	72.0	72.0
Total Lost Time (s)	5.5	6.5	6.5	5.5	6.5	6.5	5.0	6.5	6.5	5.0	6.5	6.5
Act Effct Green (s)	31.5	63.5	63.5	12.5	44.5	44.5	5.0	62.5	62.5	8.0	65.5	65.5
Actuated g/C Ratio	0.19	0.37	0.37	0.07	0.26	0.26	0.03	0.37	0.37	0.05	0.39	0.39
v/c Ratio	0.97	1.17	0.51	1.25	0.97	0.35	0.59	0.99	0.55	1.08	1.13	0.48
Control Delay	77.8	117.9	12.7	200.7	84.7	15.8	104.5	75.9	26.0	165.5	115.7	22.5
Queue Delay	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Delay	77.8	117.9	12.7	200.7	84.7	15.8	104.5	75.9	26.0	165.5	115.7	22.5
LOS	E	F	B	F	F	B	F	E	C	F	F	C
Approach Delay		93.5			102.0			66.0			104.5	
Approach LOS		F			F			E			F	

Intersection Summary

Area Type: Other

Cycle Length: 170

Actuated Cycle Length: 170

Offset: 129 (76%), Referenced to phase 2:NET and 6:SWT, Start of Green

Control Type: Actuated-Coordinated

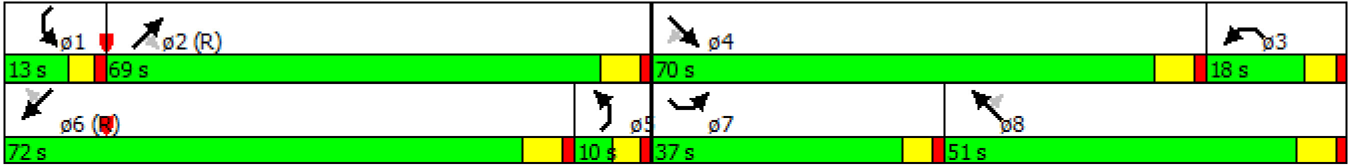
Maximum v/c Ratio: 1.25

Intersection Signal Delay: 91.7 Intersection LOS: F

Intersection Capacity Utilization 108.8% ICU Level of Service G

Analysis Period (min) 15

Splits and Phases: 3: Clear Lake City Blvd. / Clear Lake City Blvd. & Old Galveston Rd. /Old Galveston Rd.



2030 Build - Mitigated PM Peak Hour
8: Dixie Farm Rd. / Challenger & Old Galveston Rd. /Old Galveston Rd.

Lane Group	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations	↰	↑↑	↱	↰	↑↱		↰	↑↱		↰	↑↱	
Volume (vph)	3	1199	311	183	700	11	138	23	192	108	175	15
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Storage Length (ft)	200		200	200		0	150		0	200		0
Storage Lanes	1		1	1		0	1		0	1		0
Taper Length (ft)	25			25			25			25		
Satd. Flow (prot)	1703	3406	1524	1703	3399	0	1770	3047	0	1770	3493	0
Flt Permitted	0.950			0.950			0.950			0.950		
Satd. Flow (perm)	1703	3406	1524	1703	3399	0	1770	3047	0	1770	3493	0
Right Turn on Red			Yes			Yes			Yes			Yes
Satd. Flow (RTOR)			201		2			275			4	
Link Speed (mph)		30			30			30			30	
Link Distance (ft)		968			3524			1823			652	
Travel Time (s)		22.0			80.1			41.4			14.8	
Lane Group Flow (vph)	4	1772	460	271	1048	0	204	307	0	117	208	0
Turn Type	Prot	NA	Perm	Prot	NA		Prot	NA		Prot	NA	
Protected Phases	5	2		1	6		7	4		3	8	
Permitted Phases			2									
Total Split (s)	10.5	96.0	96.0	34.0	119.5		25.0	20.0		20.0	15.0	
Total Lost Time (s)	5.5	5.5	5.5	5.5	5.5		5.0	5.0		5.0	5.0	
Act Effct Green (s)	5.0	90.9	90.9	28.1	122.4		20.0	16.2		13.8	10.0	
Actuated g/C Ratio	0.03	0.53	0.53	0.17	0.72		0.12	0.10		0.08	0.06	
v/c Ratio	0.08	0.97	0.51	0.96	0.43		0.98	0.57		0.82	1.00	
Control Delay	83.8	53.7	15.4	132.3	2.7		130.2	15.8		114.4	136.8	
Queue Delay	0.0	0.0	0.0	0.0	0.0		0.0	0.0		0.0	0.0	
Total Delay	83.8	53.7	15.4	132.3	2.7		130.2	15.8		114.4	136.8	
LOS	F	D	B	F	A		F	B		F	F	
Approach Delay		45.9			29.3			61.5			128.8	
Approach LOS		D			C			E			F	

Intersection Summary

Area Type: Other

Cycle Length: 170

Actuated Cycle Length: 170

Offset: 100 (59%), Referenced to phase 2:SET and 6:NWT, Start of Green

Control Type: Actuated-Coordinated

Maximum v/c Ratio: 1.00

Intersection Signal Delay: 48.9 Intersection LOS: D

Intersection Capacity Utilization 92.1% ICU Level of Service F

Analysis Period (min) 15

Splits and Phases: 8: Dixie Farm Rd. / Challenger & Old Galveston Rd. /Old Galveston Rd.

11: Old Galveston Rd. / Old Galveston Rd. & Brantly Ave.

Lane Group	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations	↰	↑↱		↰	↑↱			✥			↰	↱
Volume (vph)	2	2134	1	1	894	11	2	0	5	90	0	12
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Storage Length (ft)	280		0	200		0	0		0	0		0
Storage Lanes	1		0	1		0	0		0	0		1
Taper Length (ft)	25			25			25			25		
Satd. Flow (prot)	1703	3406	0	1703	3402	0	0	1660	0	0	1770	1583
Flt Permitted	0.950			0.950				0.927			0.751	
Satd. Flow (perm)	1703	3406	0	1703	3402	0	0	1563	0	0	1399	1583
Right Turn on Red			Yes			Yes			Yes			Yes
Satd. Flow (RTOR)					2			64				64
Link Speed (mph)		30			30			30			30	
Link Distance (ft)		3524			6101			140			183	
Travel Time (s)		80.1			138.7			3.2			4.2	
Lane Group Flow (vph)	2	2321	0	1	1335	0	0	10	0	0	109	14
Turn Type	Prot	NA		Prot	NA		Perm	NA		Perm	NA	Perm
Protected Phases	5	2		1	6			4			8	
Permitted Phases							4			8		8
Total Split (s)	11.5	134.5		11.5	134.5		24.0	24.0		24.0	24.0	24.0
Total Lost Time (s)	6.5	6.5		6.5	6.0			5.0			5.5	5.5
Act Effct Green (s)	5.0	139.5		5.0	140.0			16.7			16.2	16.2
Actuated g/C Ratio	0.03	0.82		0.03	0.82			0.10			0.10	0.10
v/c Ratio	0.04	0.83		0.02	0.48			0.05			0.82	0.07
Control Delay	104.0	7.9		113.0	3.3			0.4			115.6	0.6
Queue Delay	0.0	0.0		0.0	0.0			0.0			0.0	0.0
Total Delay	104.0	7.9		113.0	3.3			0.4			115.6	0.6
LOS	F	A		F	A			A			F	A
Approach Delay		8.0			3.4			0.4			102.5	
Approach LOS		A			A			A			F	

Intersection Summary

Area Type: Other

Cycle Length: 170

Actuated Cycle Length: 170

Offset: 1 (1%), Referenced to phase 2:SET and 6:NWT, Start of Green

Control Type: Actuated-Coordinated

Maximum v/c Ratio: 0.83

Intersection Signal Delay: 9.4 Intersection LOS: A

Intersection Capacity Utilization 81.2% ICU Level of Service D

Analysis Period (min) 15

Splits and Phases: 11: Old Galveston Rd. / Old Galveston Rd. & Brantly Ave.

1: Old Galveston Rd. & Hillard St.

Movement	SEL	SET	NWT	NWR	SWL	SWR
Lane Configurations	↰	↑↑	↑↱		Y	
Volume (veh/h)	183	653	1005	5	0	11
Sign Control		Free	Free		Stop	
Grade		0%	0%		0%	
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92
Hourly flow rate (vph)	199	710	1092	5	0	12
Pedestrians						
Lane Width (ft)						
Walking Speed (ft/s)						
Percent Blockage						
Right turn flare (veh)						
Median type		None	None			
Median storage veh)						
Upstream signal (ft)			968			
pX, platoon unblocked	0.90				0.90	0.90
vC, conflicting volume	1098				1848	549
vC1, stage 1 conf vol						
vC2, stage 2 conf vol						
vCu, unblocked vol	876				1714	263
tC, single (s)	4.2				6.8	6.9
tC, 2 stage (s)						
tF (s)	2.3				3.5	3.3
p0 queue free %	70				100	98
cM capacity (veh/h)	664				51	658

Direction, Lane #	SE 1	SE 2	SE 3	NW 1	NW 2	SW 1
Volume Total	199	355	355	728	370	12
Volume Left	199	0	0	0	0	0
Volume Right	0	0	0	0	5	12
cSH	664	1700	1700	1700	1700	658
Volume to Capacity	0.30	0.21	0.21	0.43	0.22	0.02
Queue Length 95th (ft)	31	0	0	0	0	1
Control Delay (s)	12.7	0.0	0.0	0.0	0.0	10.6
Lane LOS	B					B
Approach Delay (s)	2.8			0.0		10.6
Approach LOS						B

Intersection Summary			
Average Delay	1.3		
Intersection Capacity Utilization	51.4%	ICU Level of Service	A
Analysis Period (min)	15		

3: Clear Lake City Blvd. / Clear Lake City Blvd. & Old Galveston R

Lane Group	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations	↰	↑↑↱		↰	↑↑↱		↰	↑↑	↱	↰	↑↑↱	
Volume (vph)	173	386	24	216	577	77	144	824	153	114	993	512
Satd. Flow (prot)	1703	3375	0	1703	3344	0	1770	3539	1583	1770	3359	0
Flt Permitted	0.950			0.950			0.950			0.950		
Satd. Flow (perm)	1703	3375	0	1703	3344	0	1770	3539	1583	1770	3359	0
Satd. Flow (RTOR)		4			10				166		92	
Lane Group Flow (vph)	188	446	0	235	711	0	157	896	166	124	1636	0
Turn Type	Prot	NA		Prot	NA		Prot	NA	Perm	Prot	NA	
Protected Phases	7	4		3	8		5	2		1	6	
Permitted Phases									2			
Total Split (s)	23.0	23.0		25.0	25.0		17.0	52.0	52.0	20.0	55.0	
Total Lost Time (s)	5.5	6.5		5.5	6.5		5.0	6.5	6.5	5.0	6.5	
Act Effct Green (s)	16.2	17.3		18.7	19.8		11.9	48.0	48.0	12.5	48.6	
Actuated g/C Ratio	0.14	0.14		0.16	0.16		0.10	0.40	0.40	0.10	0.40	
v/c Ratio	0.82	0.91		0.89	1.27		0.89	0.63	0.23	0.68	1.16	
Control Delay	77.1	74.2		82.8	177.2		98.2	31.8	4.5	69.7	111.1	
Queue Delay	0.0	0.0		0.0	0.0		0.0	0.0	0.0	0.0	0.0	
Total Delay	77.1	74.2		82.8	177.2		98.2	31.8	4.5	69.7	111.1	
LOS	E	E		F	F		F	C	A	E	F	
Approach Delay		75.1			153.7			36.7			108.2	
Approach LOS		E			F			D			F	

Intersection Summary

Cycle Length: 120

Actuated Cycle Length: 120

Offset: 60 (50%), Referenced to phase 2:NET and 6:SWT, Start of Green

Control Type: Actuated-Coordinated

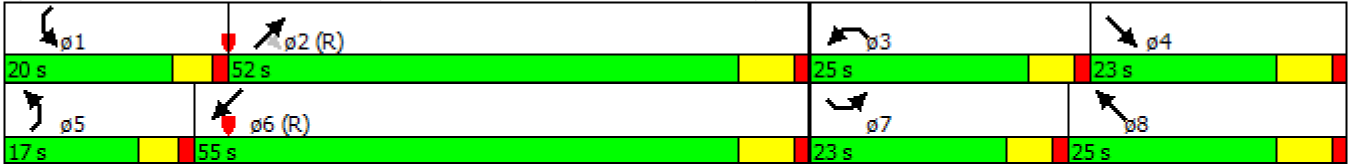
Maximum v/c Ratio: 1.27

Intersection Signal Delay: 93.9 Intersection LOS: F

Intersection Capacity Utilization 99.4% ICU Level of Service F

Analysis Period (min) 15

Splits and Phases: 3: Clear Lake City Blvd. / Clear Lake City Blvd. & Old Galveston Rd. /Old Galveston Rd.



8: Dixie Farm Rd. / Challenger & Old Galveston Rd. /Old Galveston Rd.

Lane Group	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations	↰	↑↱		↰	↑↱		↰	↑↱		↰	↑↱	
Volume (vph)	10	445	120	134	868	80	183	127	127	10	14	1
Satd. Flow (prot)	1703	3297	0	1703	3361	0	1770	3274	0	1770	3507	0
Flt Permitted	0.950			0.950			0.950			0.950		
Satd. Flow (perm)	1703	3297	0	1703	3361	0	1770	3274	0	1770	3507	0
Satd. Flow (RTOR)		40			11			138			1	
Lane Group Flow (vph)	11	614	0	146	1030	0	199	276	0	11	16	0
Turn Type	Prot	NA		Prot	NA		Prot	NA		Prot	NA	
Protected Phases	5	2		1	6		7	4		3	8	
Permitted Phases												
Total Split (s)	15.0	45.0		15.0	45.0		15.0	25.0		15.0	25.0	
Total Lost Time (s)	5.5	5.5		5.5	5.5		5.0	5.0		5.0	5.0	
Act Effct Green (s)	5.5	54.7		14.4	72.2		10.0	12.6		5.4	5.9	
Actuated g/C Ratio	0.06	0.55		0.14	0.72		0.10	0.13		0.05	0.06	
v/c Ratio	0.12	0.34		0.60	0.42		1.12	0.52		0.11	0.08	
Control Delay	47.4	13.9		46.1	9.3		147.6	23.4		47.3	42.3	
Queue Delay	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Total Delay	47.4	13.9		46.1	9.3		147.6	23.4		47.3	42.3	
LOS	D	B		D	A		F	C		D	D	
Approach Delay		14.5			13.9			75.4			44.4	
Approach LOS		B			B			E			D	

Intersection Summary

Cycle Length: 100

Actuated Cycle Length: 100

Offset: 40 (40%), Referenced to phase 2:SET and 6:NWT, Start of Green

Control Type: Actuated-Coordinated

Maximum v/c Ratio: 1.12

Intersection Signal Delay: 27.1 Intersection LOS: C

Intersection Capacity Utilization 60.8% ICU Level of Service B

Analysis Period (min) 15

Splits and Phases: 8: Dixie Farm Rd. / Challenger & Old Galveston Rd. /Old Galveston Rd.

Existing AM Peak Hour
11: Old Galveston Rd. / Old Galveston Rd. & Brantly Ave.

Lane Group	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations												
Volume (vph)	7	602	1	8	1157	88	2	0	1	10	0	3
Satd. Flow (prot)	1703	3406	0	1703	3368	0	0	1722	0	0	1770	1583
Flt Permitted	0.950			0.950								
Satd. Flow (perm)	1703	3406	0	1703	3368	0	0	1779	0	0	1863	1583
Satd. Flow (RTOR)					14			109				109
Lane Group Flow (vph)	8	655	0	9	1354	0	0	3	0	0	11	3
Turn Type	Prot	NA		Prot	NA		Perm	NA		Perm	NA	Perm
Protected Phases	5	2		1	6			4			8	
Permitted Phases							4			8		8
Total Split (s)	18.0	65.0		18.0	65.0		17.0	17.0		17.0	17.0	17.0
Total Lost Time (s)	6.5	6.5		6.5	6.0			5.0			5.5	5.5
Act Effct Green (s)	6.1	89.9		6.2	90.1			5.8			5.6	5.6
Actuated g/C Ratio	0.06	0.90		0.06	0.90			0.06			0.06	0.06
v/c Ratio	0.08	0.21		0.09	0.45			0.01			0.11	0.02
Control Delay	44.7	1.6		45.6	3.5			0.0			46.5	0.0
Queue Delay	0.0	0.0		0.0	0.0			0.0			0.0	0.0
Total Delay	44.7	1.6		45.6	3.5			0.0			46.5	0.0
LOS	D	A		D	A			A			D	A
Approach Delay		2.2			3.7			0.0			36.5	
Approach LOS		A			A			A			D	

Intersection Summary

Cycle Length: 100
Actuated Cycle Length: 100
Offset: 90 (90%), Referenced to phase 2:SET and 6:NWT, Start of Green
Control Type: Actuated-Coordinated
Maximum v/c Ratio: 0.45
Intersection Signal Delay: 3.4 Intersection LOS: A
Intersection Capacity Utilization 56.9% ICU Level of Service B
Analysis Period (min) 15

Splits and Phases: 11: Old Galveston Rd. / Old Galveston Rd. & Brantly Ave.

1: Old Galveston Rd. & Hilliard St.

Movement	SEL	SET	NWT	NWR	SWL	SWR
Lane Configurations	↰	↑↑	↑↱		Y	
Volume (veh/h)	20	1563	850	1	4	209
Sign Control		Free	Free		Stop	
Grade		0%	0%		0%	
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92
Hourly flow rate (vph)	22	1699	924	1	4	227
Pedestrians						
Lane Width (ft)						
Walking Speed (ft/s)						
Percent Blockage						
Right turn flare (veh)						
Median type		None	None			
Median storage veh)						
Upstream signal (ft)			968			
pX, platoon unblocked	0.92				0.92	0.92
vC, conflicting volume	925				1817	462
vC1, stage 1 conf vol						
vC2, stage 2 conf vol						
vCu, unblocked vol	735				1709	230
tC, single (s)	4.2				6.8	6.9
tC, 2 stage (s)						
tF (s)	2.3				3.5	3.3
p0 queue free %	97				94	68
cM capacity (veh/h)	770				73	708

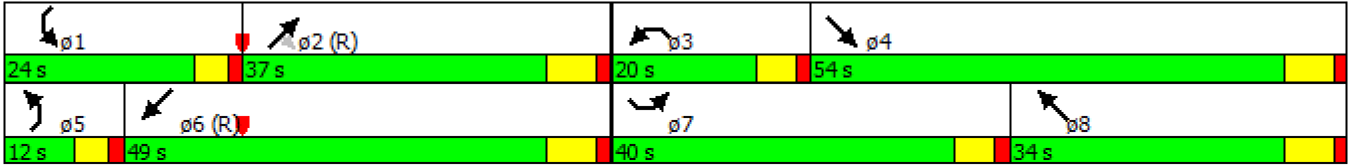
Direction, Lane #	SE 1	SE 2	SE 3	NW 1	NW 2	SW 1
Volume Total	22	849	849	616	309	232
Volume Left	22	0	0	0	0	4
Volume Right	0	0	0	0	1	227
cSH	770	1700	1700	1700	1700	608
Volume to Capacity	0.03	0.50	0.50	0.36	0.18	0.38
Queue Length 95th (ft)	2	0	0	0	0	44
Control Delay (s)	9.8	0.0	0.0	0.0	0.0	14.5
Lane LOS	A					B
Approach Delay (s)	0.1			0.0		14.5
Approach LOS						B

Intersection Summary			
Average Delay	1.2		
Intersection Capacity Utilization	63.0%	ICU Level of Service	B
Analysis Period (min)	15		

Lane Group	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations	↰	↑↱		↰	↑↱		↰	↑↑	↱	↰	↑↱	
Volume (vph)	392	1002	226	204	584	117	40	873	254	118	1043	229
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Storage Length (ft)	300		0	300		0	315		315	125		0
Storage Lanes	1		0	1		0	1		1	1		0
Taper Length (ft)	25			25			25			25		
Satd. Flow (prot)	1703	3310	0	1703	3321	0	1770	3539	1583	1770	3444	0
Flt Permitted	0.950			0.950			0.950			0.950		
Satd. Flow (perm)	1703	3310	0	1703	3321	0	1770	3539	1583	1770	3444	0
Right Turn on Red			Yes			Yes			Yes			Yes
Satd. Flow (RTOR)		22			16				259		20	
Link Speed (mph)		30			30			30			30	
Link Distance (ft)		6101			1008			1045			2119	
Travel Time (s)		138.7			22.9			23.8			48.2	
Lane Group Flow (vph)	426	1335	0	222	762	0	43	949	276	128	1383	0
Turn Type	Prot	NA		Prot	NA		Prot	NA	Perm	Prot	NA	
Protected Phases	7	4		3	8		5	2		1	6	
Permitted Phases									2			
Total Split (s)	40.0	54.0		20.0	34.0		12.0	37.0	37.0	24.0	49.0	
Total Lost Time (s)	5.5	6.5		5.5	6.5		5.0	6.5	6.5	5.0	6.5	
Act Effct Green (s)	34.5	47.5		14.5	27.5		6.6	35.2	35.2	14.3	44.9	
Actuated g/C Ratio	0.26	0.35		0.11	0.20		0.05	0.26	0.26	0.11	0.33	
v/c Ratio	0.98	1.13		1.22	1.11		0.51	1.03	0.46	0.68	1.19	
Control Delay	88.1	110.5		187.3	115.0		82.6	86.0	8.9	75.9	134.7	
Queue Delay	0.0	0.0		0.0	0.0		0.0	0.0	0.0	0.0	0.0	
Total Delay	88.1	110.5		187.3	115.0		82.6	86.0	8.9	75.9	134.7	
LOS	F	F		F	F		F	F	A	E	F	
Approach Delay		105.1			131.3			69.1			129.7	
Approach LOS		F			F			E			F	

Intersection Summary	
Area Type: Other	
Cycle Length: 135	
Actuated Cycle Length: 135	
Offset: 67 (50%), Referenced to phase 2:NET and 6:SWT, Start of Green	
Control Type: Actuated-Coordinated	
Maximum v/c Ratio: 1.22	
Intersection Signal Delay: 108.2	Intersection LOS: F
Intersection Capacity Utilization 106.1%	ICU Level of Service G
Analysis Period (min) 15	

Splits and Phases: 3: Clear Lake City Blvd. / Clear Lake City Blvd. & Old Galveston Rd. /Old Galveston Rd.



8: Dixie Farm Rd. / Challenger & Old Galveston Rd. /Old Galveston Rd.

Lane Group	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations	↰	↑↱		↰	↑↱		↰	↑↱		↰	↑↱	
Volume (vph)	3	1199	311	183	700	11	138	17	192	93	149	15
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Storage Length (ft)	200		0	200		0	150		0	200		0
Storage Lanes	1		0	1		0	1		0	1		0
Taper Length (ft)	25			25			25			25		
Satd. Flow (prot)	1703	3300	0	1703	3399	0	1770	3051	0	1770	3493	0
Flt Permitted	0.950			0.950			0.950			0.950		
Satd. Flow (perm)	1703	3300	0	1703	3399	0	1770	3051	0	1770	3493	0
Right Turn on Red			Yes			Yes			Yes			Yes
Satd. Flow (RTOR)		42			2			209			8	
Link Speed (mph)		30			30			30			30	
Link Distance (ft)		968			3524			1823			652	
Travel Time (s)		22.0			80.1			41.4			14.8	
Lane Group Flow (vph)	3	1641	0	199	773	0	150	227	0	101	178	0
Turn Type	Prot	NA		Prot	NA		Prot	NA		Prot	NA	
Protected Phases	5	2		1	6		7	4		3	8	
Permitted Phases												
Total Split (s)	20.0	50.0		20.0	50.0		15.0	15.0		15.0	15.0	
Total Lost Time (s)	5.5	5.5		5.5	5.5		5.0	5.0		5.0	5.0	
Act Effct Green (s)	5.1	46.6		13.9	63.8		9.8	11.9		8.8	8.7	
Actuated g/C Ratio	0.05	0.47		0.14	0.64		0.10	0.12		0.09	0.09	
v/c Ratio	0.03	1.05		0.84	0.36		0.87	0.42		0.65	0.57	
Control Delay	46.0	65.5		74.1	9.1		86.1	10.4		63.1	49.1	
Queue Delay	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Total Delay	46.0	65.5		74.1	9.1		86.1	10.4		63.1	49.1	
LOS	D	E		E	A		F	B		E	D	
Approach Delay		65.5			22.4			40.5			54.2	
Approach LOS		E			C			D			D	

Intersection Summary

Area Type: Other
Cycle Length: 100
Actuated Cycle Length: 100
Offset: 40 (40%), Referenced to phase 2:SET and 6:NWT, Start of Green
Control Type: Actuated-Coordinated
Maximum v/c Ratio: 1.05
Intersection Signal Delay: 48.9 Intersection LOS: D
Intersection Capacity Utilization 83.0% ICU Level of Service E
Analysis Period (min) 15

Splits and Phases: 8: Dixie Farm Rd. / Challenger & Old Galveston Rd. /Old Galveston Rd.

11: Old Galveston Rd. / Old Galveston Rd. & Brantly Ave.

Lane Group	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations	↰	↑↑↱		↰	↑↑↱			↰↑↱			↰↑	↱
Volume (vph)	2	1558	1	1	894	11	2	0	5	90	0	12
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Storage Length (ft)	280		0	200		0	0		0	0		0
Storage Lanes	1		0	1		0	0		0	0		1
Taper Length (ft)	25			25			25			25		
Satd. Flow (prot)	1703	3406	0	1703	3399	0	0	1660	0	0	1770	1583
Flt Permitted	0.950			0.950				0.919			0.753	
Satd. Flow (perm)	1703	3406	0	1703	3399	0	0	1548	0	0	1403	1583
Right Turn on Red			Yes			Yes			Yes			Yes
Satd. Flow (RTOR)					2			109				109
Link Speed (mph)		30			30			30			30	
Link Distance (ft)		3524			6101			140			183	
Travel Time (s)		80.1			138.7			3.2			4.2	
Lane Group Flow (vph)	2	1694	0	1	984	0	0	7	0	0	98	13
Turn Type	Prot	NA		Prot	NA		Perm	NA		Perm	NA	Perm
Protected Phases	5	2		1	6			4			8	
Permitted Phases							4			8		8
Total Split (s)	20.0	60.0		20.0	60.0		20.0	20.0		20.0	20.0	20.0
Total Lost Time (s)	6.5	6.5		6.5	6.0			5.0			5.5	5.5
Act Effct Green (s)	5.0	78.4		5.0	78.8			11.1			10.9	10.9
Actuated g/C Ratio	0.05	0.78		0.05	0.79			0.11			0.11	0.11
v/c Ratio	0.02	0.63		0.01	0.37			0.03			0.64	0.05
Control Delay	36.5	11.9		46.0	5.4			0.2			61.2	0.3
Queue Delay	0.0	0.0		0.0	0.0			0.0			0.0	0.0
Total Delay	36.5	11.9		46.0	5.4			0.2			61.2	0.3
LOS	D	B		D	A			A			E	A
Approach Delay		12.0			5.4			0.2			54.0	
Approach LOS		B			A			A			D	

Intersection Summary

Area Type: Other

Cycle Length: 100

Actuated Cycle Length: 100

Offset: 90 (90%), Referenced to phase 2:SET and 6:NWT, Start of Green

Control Type: Actuated-Coordinated

Maximum v/c Ratio: 0.64

Intersection Signal Delay: 11.3 Intersection LOS: B

Intersection Capacity Utilization 64.8% ICU Level of Service C

Analysis Period (min) 15

Splits and Phases: 11: Old Galveston Rd. / Old Galveston Rd. & Brantly Ave.

Appendix I

General Aviation Facility Concept

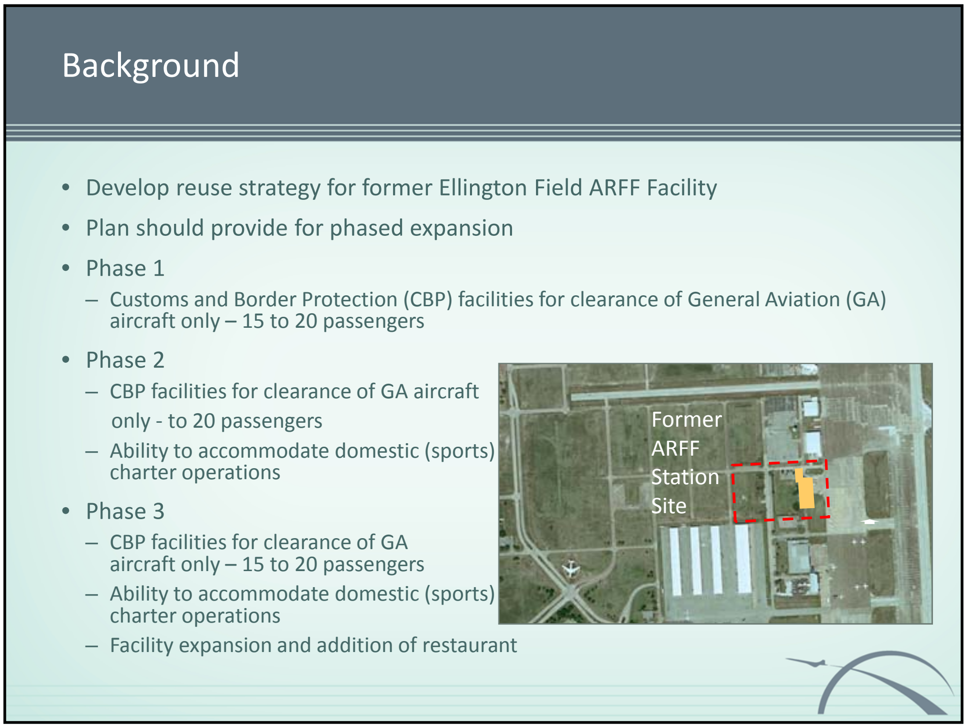
RdIR ARCHITECTS
ARCHITECTURE | PLANNING | INTERIORS

RICONDO® & ASSOCIATES

ELLINGTON AIRPORT GENERAL AVIATION FACILITY

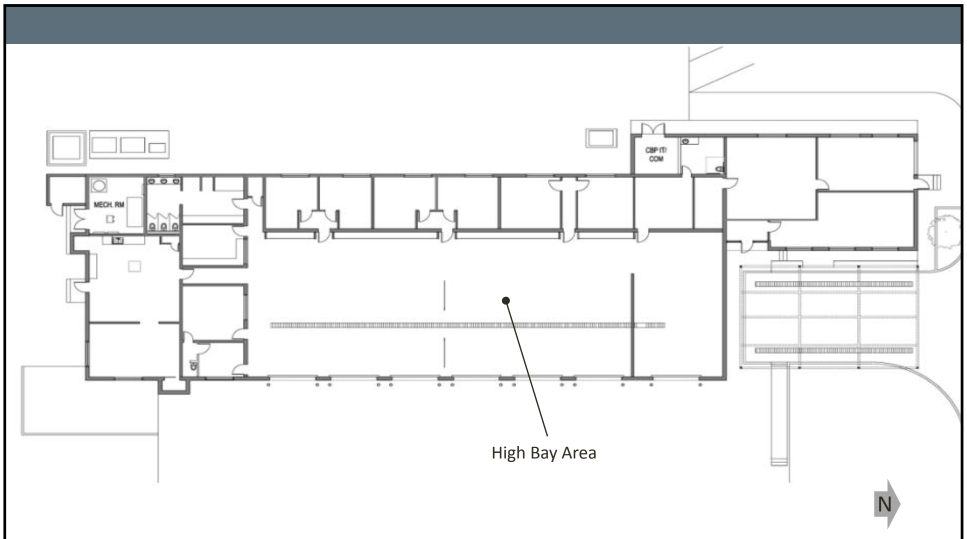
Conceptual Design | June 2012

PHOTOS COURTESY OF HOUSTON AIRPORT SYSTEM

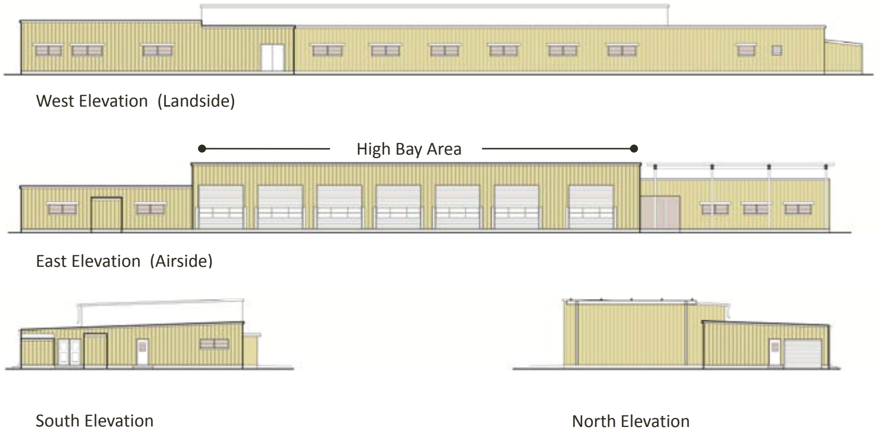


Background

- Develop reuse strategy for former Ellington Field ARFF Facility
- Plan should provide for phased expansion
- Phase 1
  - Customs and Border Protection (CBP) facilities for clearance of General Aviation (GA) aircraft only – 15 to 20 passengers
- Phase 2
  - CBP facilities for clearance of GA aircraft only - to 20 passengers
  - Ability to accommodate domestic (sports) charter operations
- Phase 3
  - CBP facilities for clearance of GA aircraft only – 15 to 20 passengers
  - Ability to accommodate domestic (sports) charter operations
  - Facility expansion and addition of restaurant



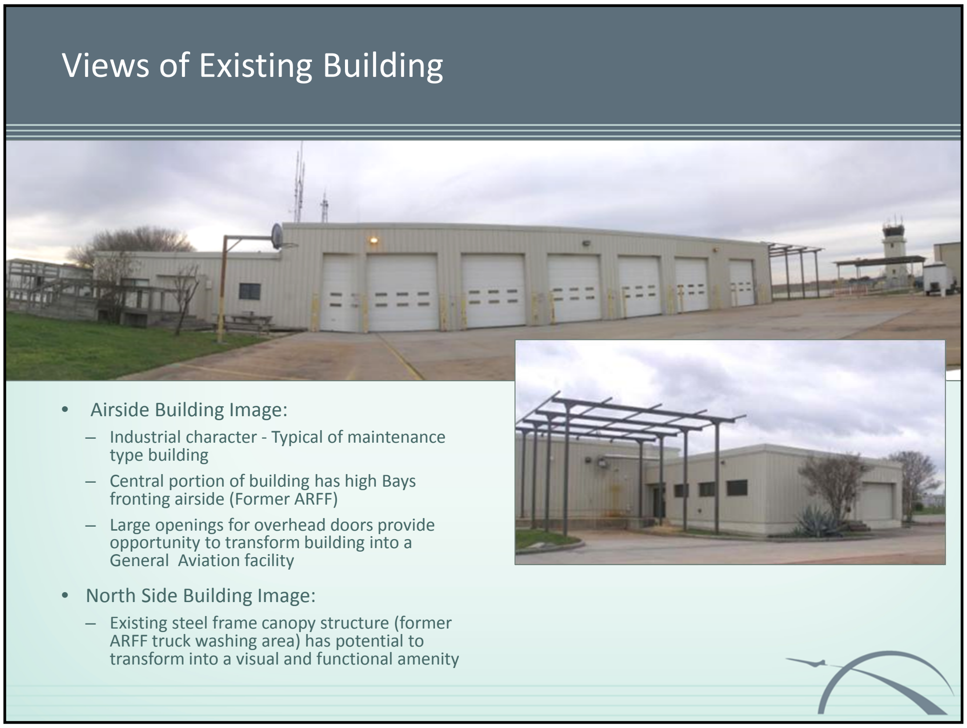
Existing Floor Plan (Former ARFF)



Existing Building Elevations

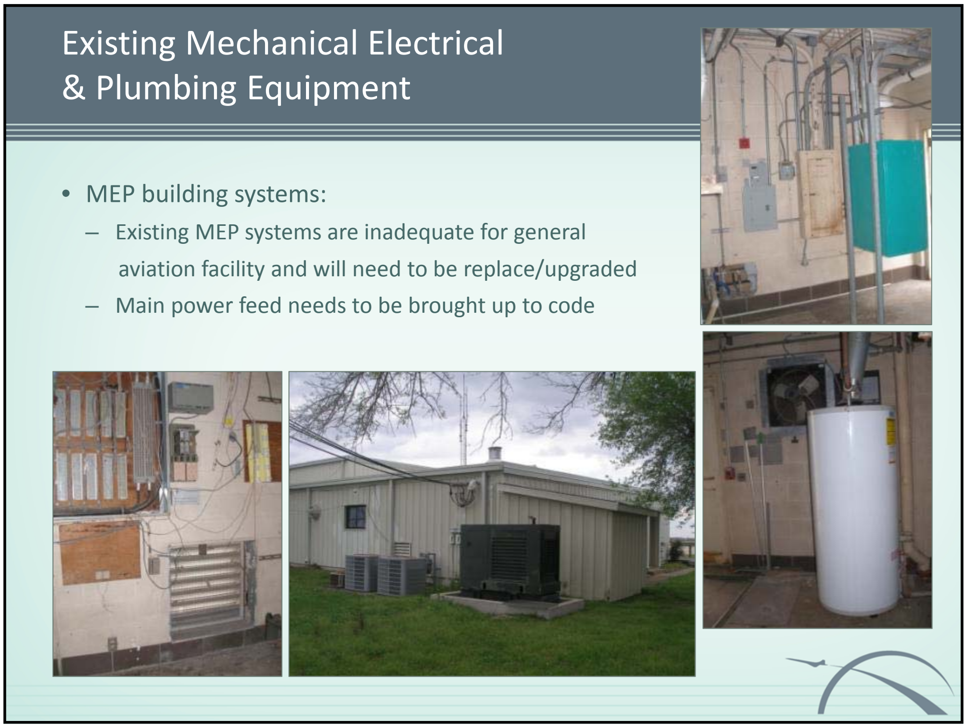
West View of Existing Building

- Landside building image:
  - Industrial character
  - Very low height at front bays of building
  - Industrial metal siding with small operable windows
  - Requires a transformative intervention to create appropriate building entry
  - Foreground and parking needs modification to adequately support General Aviation facility



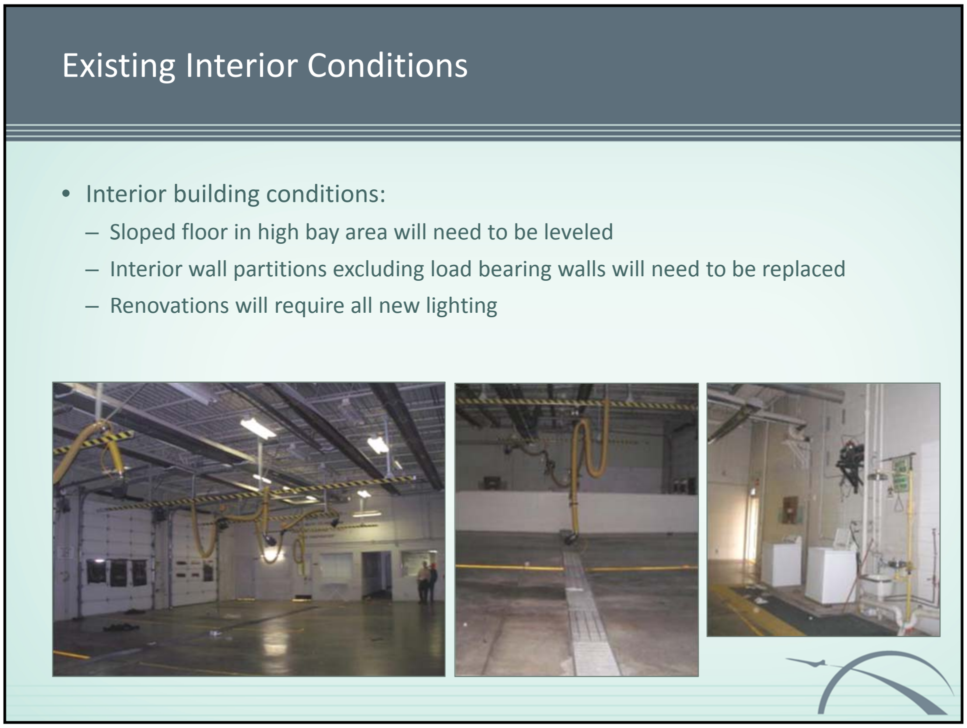
Views of Existing Building

- Airside Building Image:
  - Industrial character - Typical of maintenance type building
  - Central portion of building has high Bays fronting airside (Former ARFF)
  - Large openings for overhead doors provide opportunity to transform building into a General Aviation facility
- North Side Building Image:
  - Existing steel frame canopy structure (former ARFF truck washing area) has potential to transform into a visual and functional amenity



Existing Mechanical Electrical & Plumbing Equipment

- MEP building systems:
  - Existing MEP systems are inadequate for general aviation facility and will need to be replace/upgraded
  - Main power feed needs to be brought up to code



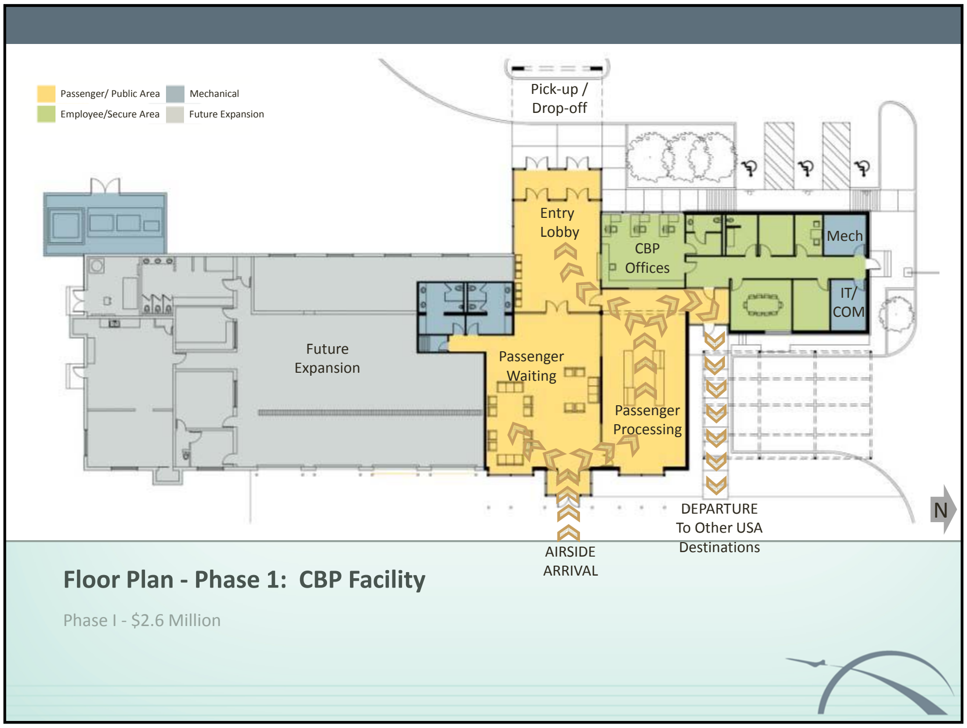
Existing Interior Conditions

- Interior building conditions:
  - Sloped floor in high bay area will need to be leveled
  - Interior wall partitions excluding load bearing walls will need to be replaced
  - Renovations will require all new lighting

ELLINGTON AIRPORT GENERAL AVIATION FACILITY

PHASE I – GENERAL AVIATION CUSTOMS FACILITY

Site Plan - Phase 1: CBP Facility



🟨 Passenger/ Public Area
🟩 Employee/Secure Area
▨ Mechanical
▨ Future Expansion

Pick-up / Drop-off

Entry Lobby

CBP Offices

Mech

IT/ COM

Future Expansion

Passenger Waiting

Passenger Processing

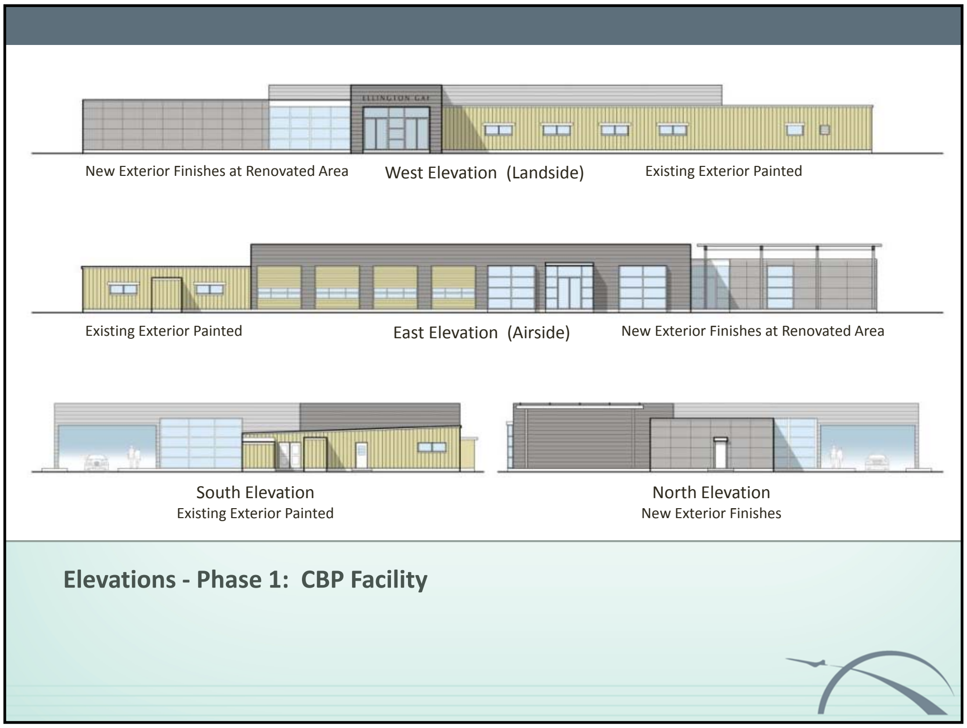
DEPARTURE
To Other USA Destinations

AIRSIDE
ARRIVAL

N

Floor Plan - Phase 1: CBP Facility

Phase I - $2.6 Million



New Exterior Finishes at Renovated Area

West Elevation (Landside)

Existing Exterior Painted

Existing Exterior Painted

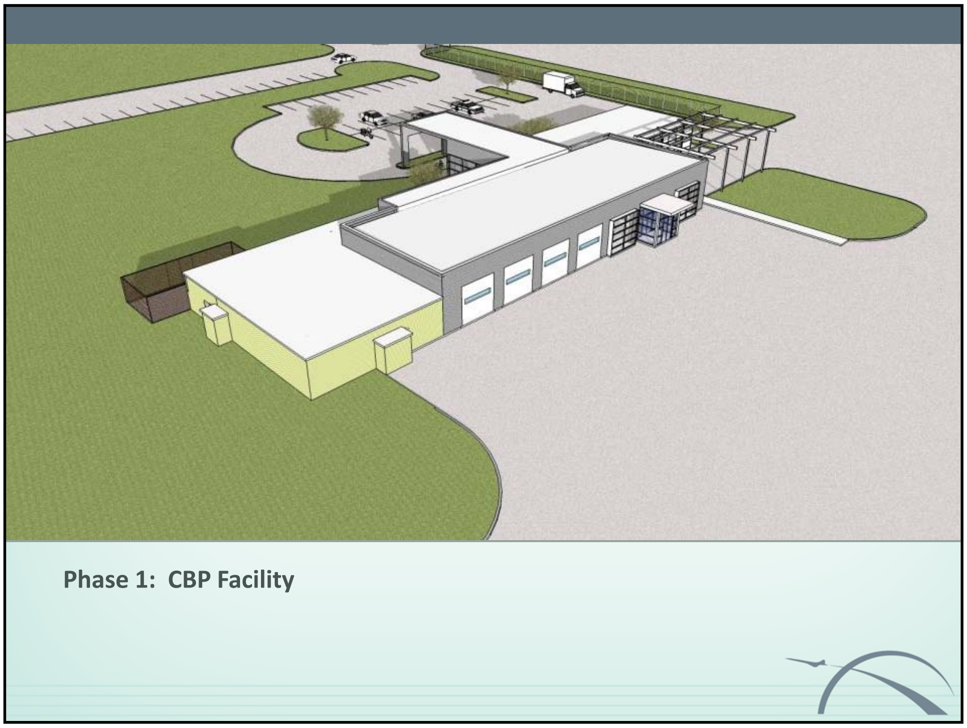
East Elevation (Airside)

New Exterior Finishes at Renovated Area

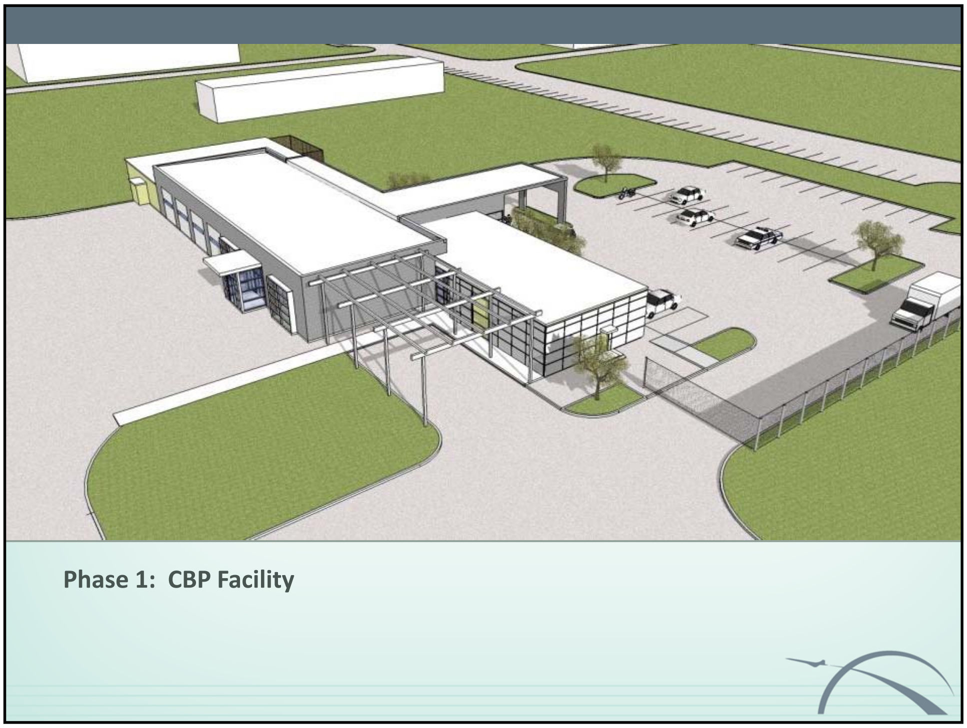
South Elevation
Existing Exterior Painted

North Elevation
New Exterior Finishes

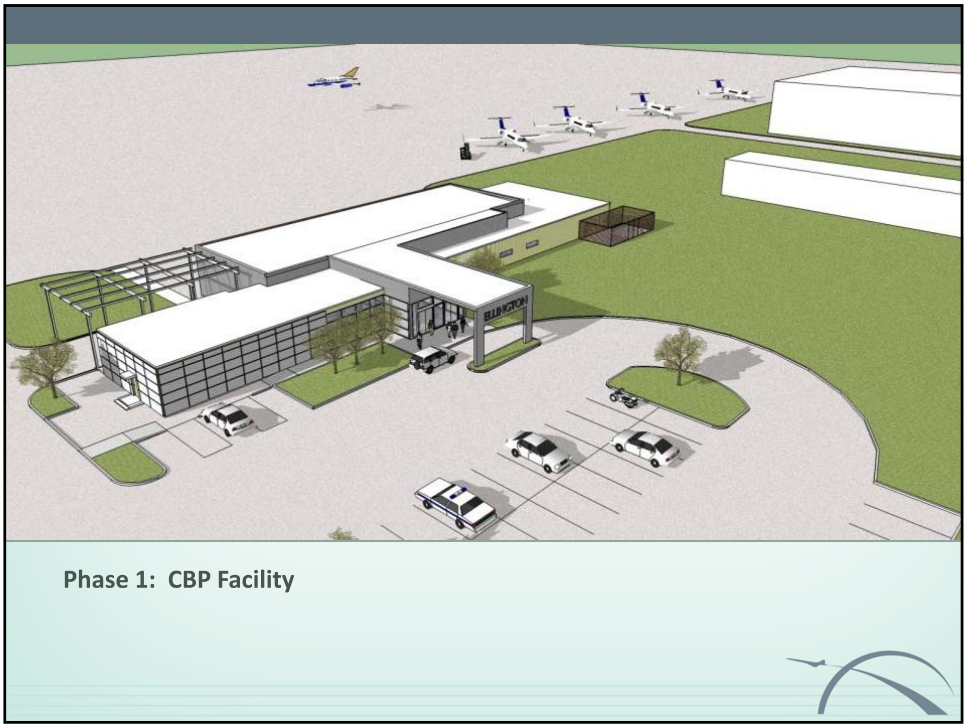
Elevations - Phase 1: CBP Facility



Phase 1: CBP Facility



Phase 1: CBP Facility



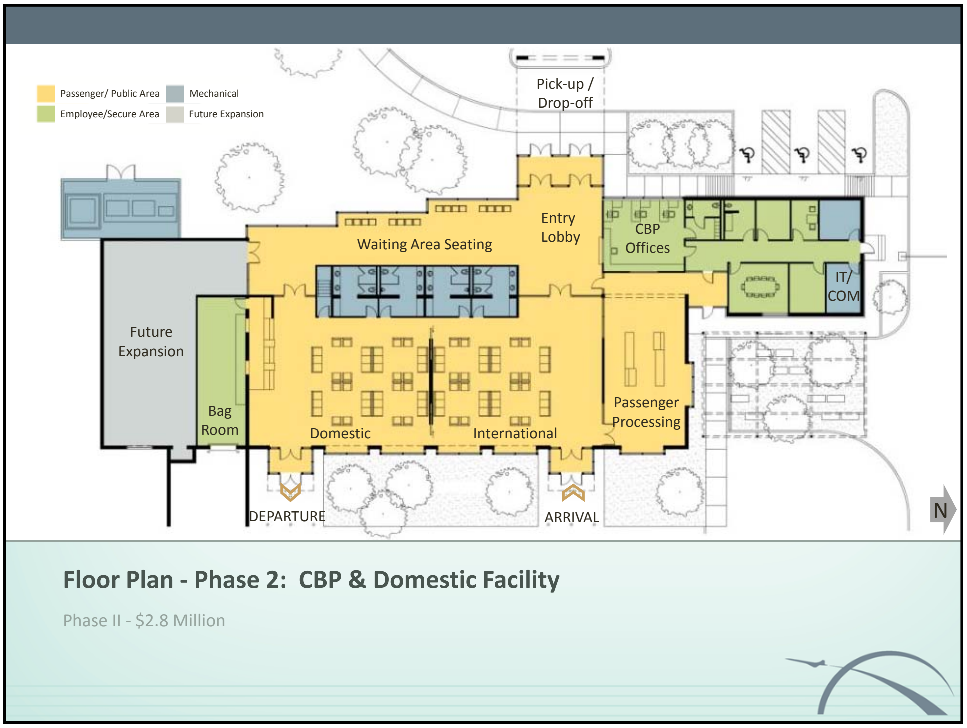
Phase 1: CBP Facility

Phase 1: CBP Facility

ELLINGTON AIRPORT GENERAL AVIATION FACILITY

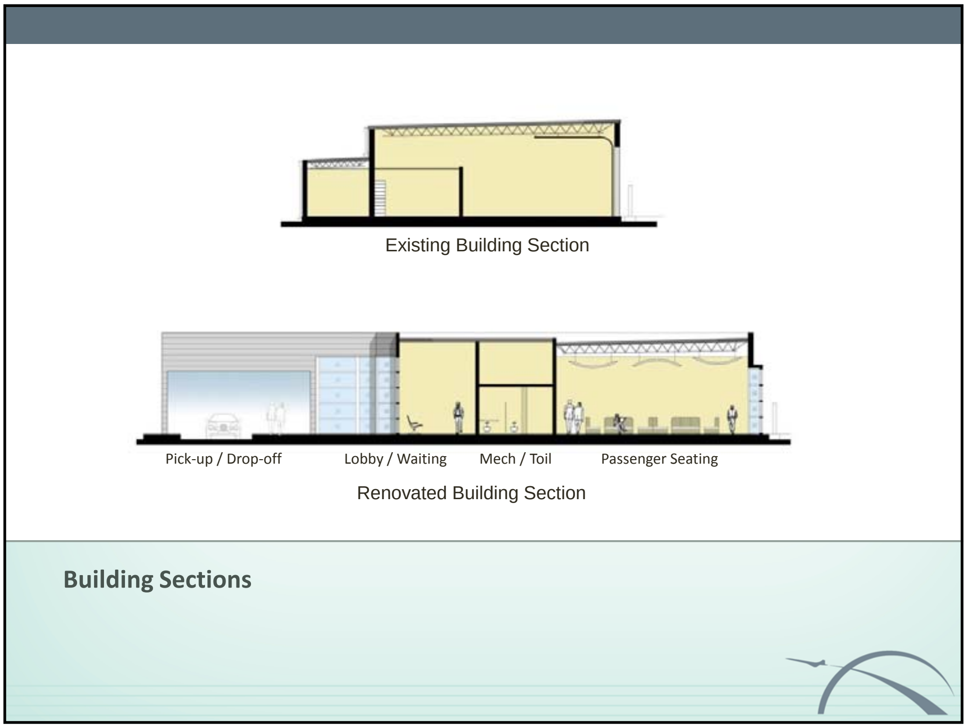
PHASE II – GENERAL AVIATION CUSTOMS FACILITY /DOMESTIC CHARTER FACILITY

Site Plan - Phase 2: CBP & Domestic Facility

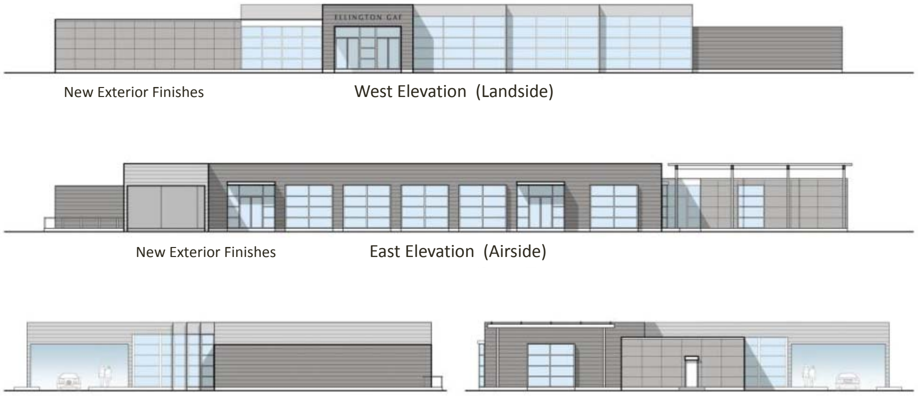


Floor Plan - Phase 2: CBP & Domestic Facility

Phase II - $2.8 Million



Building Sections



New Exterior Finishes West Elevation (Landside)

New Exterior Finishes East Elevation (Airside)

New Exterior Finishes South Elevation

New Exterior Finishes North Elevation

Elevations - Phase 2: CBP & Domestic Facility

Phase 2: CBP & Domestic Facility

Phase 2: CBP & Domestic Facility

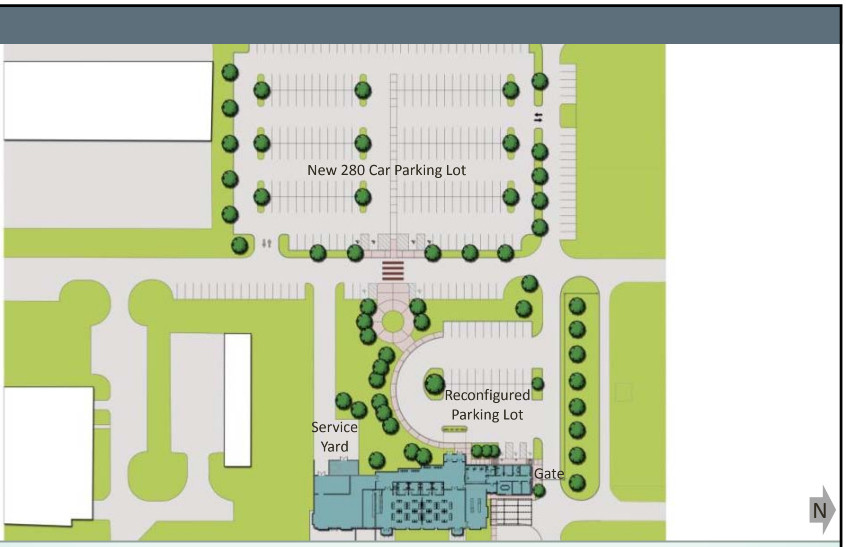
Phase 2: CBP & Domestic Facility

Phase 2: CBP & Domestic Facility

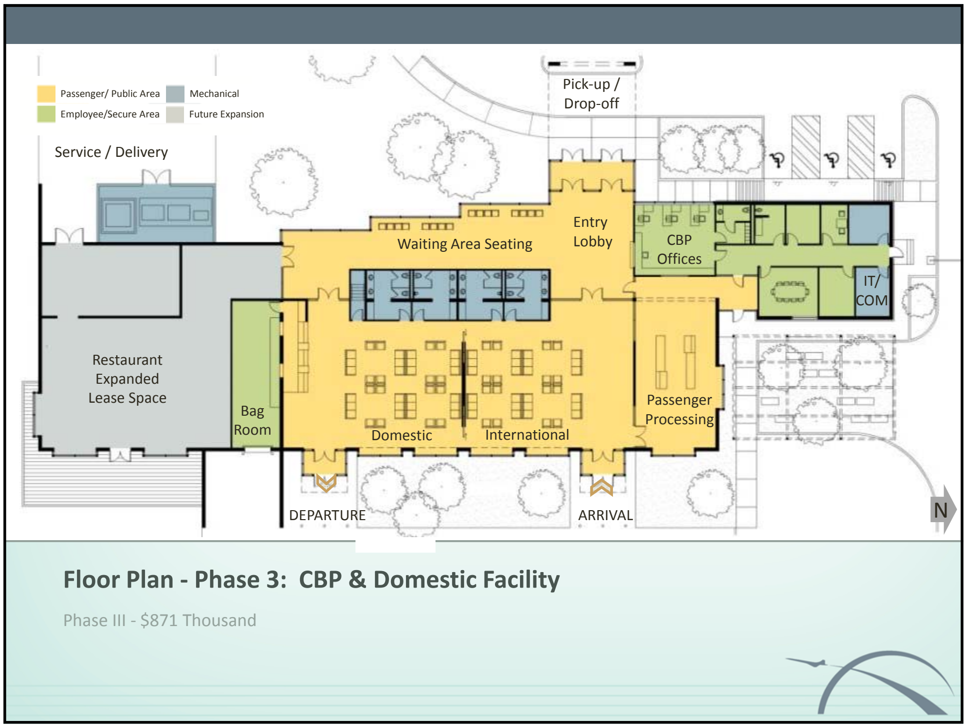
Phase 2: CBP & Domestic Facility

ELLINGTON AIRPORT GENERAL AVIATION FACILITY

PHASE III – GENERAL AVIATION CUSTOMS FACILITY /DOMESTIC CHARTER FACILITY/RESTAURANT

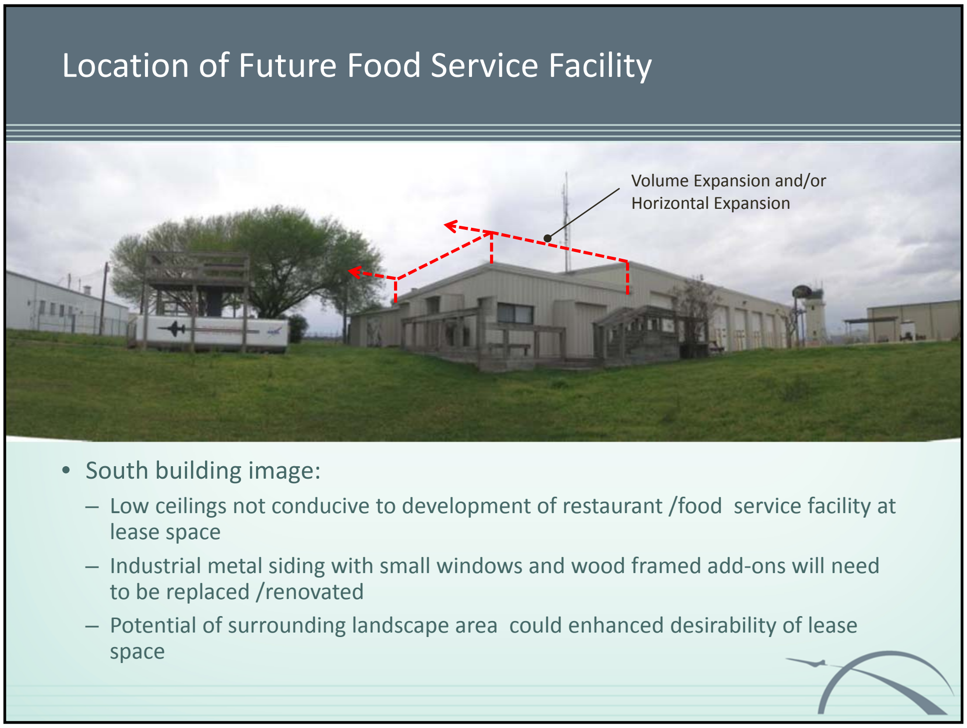


Site Plan - Phase 3: CBP & Domestic Facility



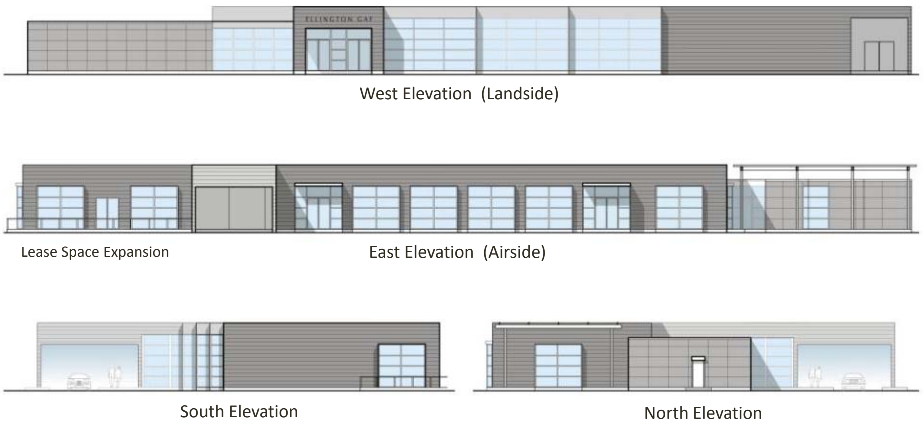
Floor Plan - Phase 3: CBP & Domestic Facility

Phase III - $871 Thousand



Location of Future Food Service Facility

- South building image:
  - Low ceilings not conducive to development of restaurant /food service facility at lease space
  - Industrial metal siding with small windows and wood framed add-ons will need to be replaced /renovated
  - Potential of surrounding landscape area could enhanced desirability of lease space



West Elevation (Landside)

Lease Space Expansion

East Elevation (Airside)

South Elevation

North Elevation

Elevations - Phase 3: CBP & Domestic Facility

Phase 2: CBP & Domestic Facility

Phase 3: CBP & Domestic Facility

Phase 3: CBP & Domestic Facility

Phase 3: CBP & Domestic Facility

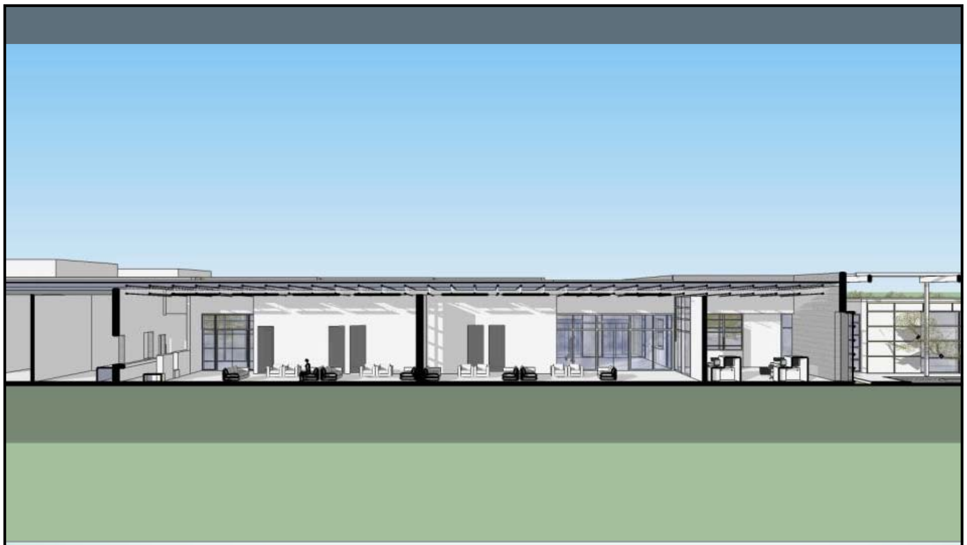
Phase 3: CBP & Domestic Facility

Cost Estimate Summary and Assumptions

Phase 1	$2.6 Million*
Phase 2	$2.8 Million*
Phase 3	$0.9 Million*
Total	**$6.3 Million***

General Contractor Markups Included	
Project Phasing & Temporary Construction	1.0%
General Conditions	10.0%
General Contractors Overhead and Profit	5.0%
Estimating Design Evolution	10.0%
Payment &Performance Bonds	1.5%
Insurance	1.0%
Construction Contingency	10.0%
LEED Requirements	0.0%
Escalation	0.0%

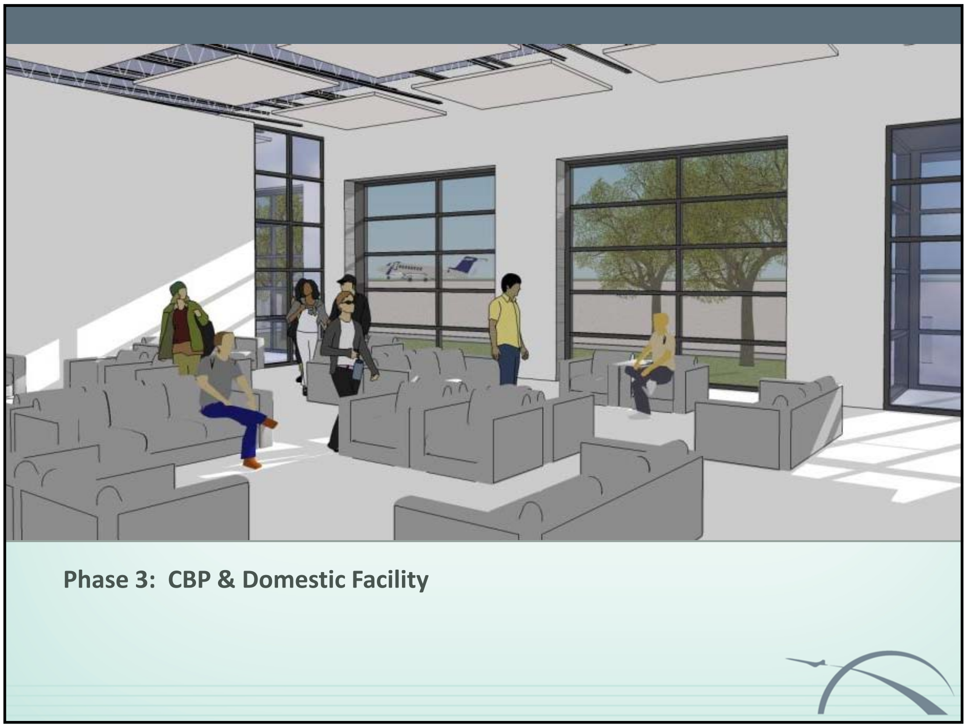
* Does not include cost to improvements to airside pavement



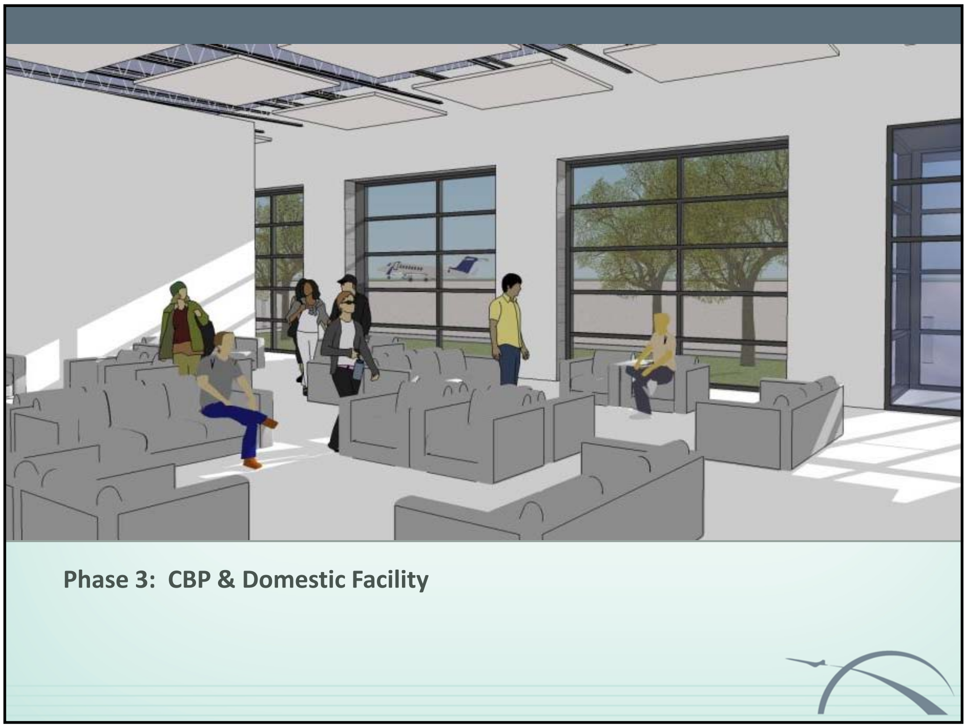
Phase 3: CBP & Domestic Facility

Phase 3: CBP & Domestic Facility

Phase 3: CBP & Domestic Facility



Phase 3: CBP & Domestic Facility



Phase 3: CBP & Domestic Facility

Appendix J

HAS CIP

HAS CIP FY 2015 - 2030 (HOU-EFD-HAS)

Updated as of 9/16/14

CIP #	Loc	PN	Phase	Description	Council Date	Sponsor	FY15	FY16	FY17	FY18	FY19	FY14-19 Total Amount X $1000	FY20	FY21	FY22	FY23	FY24	FY25	FY26	FY27	FY28	FY29	FY30	FY 2019 - 2030 Total Amount X $1000
				Critical Infrastructure																				
A-0513.11	EFD	460B	C	PAVEMENT REPLACEMENT AT EFD (R&R)	9/1/2014	Brian Rinehart	350			0		350												
A-0441.01	EFD	628	D	EXTEND CHALLENGER TO BRANTLEY	N/A	Brian Rinehart				0		0												
	EFD	**629**	**D**	**DESIGN IN HOUSE**						0		0												
A-0564.01	EFD	629	C	REPLACE THE AIR TRAFFIC TOWER - $2 million from FAA	**8/1/2016**	Brian Rinehart			6,400	0		**6,400**												
A-0422.82	EFD	629	C	ART - AIR TRAFFIC CONTROL TOWER	**8/1/2016**	Brian Rinehart			101	0		**101**												
A-0564.04	EFD	629A	O	FAA Engineering Agreement	8/1/2016	PDC			105	0		105												
A-0555.01	**EFD**	**632**	**D**	**DESIGN IN HOUSE**						0														
A-0555.02	EFD	632	C	REHAB SCHOLL ST. BETWEEN AEROSPACE & BRANTLEY AVE.	**10/1/2015**	Brian Rinehart		2,700		0		**2,700**												
A-0564.07	EFD	633	D	DESIGN UNDER ON CALL - 715B (EFD DUCTBANK)						0														
				Project Total			3,800	68,800	6,606	0	7,500	86,706	0	0	0	0	0	0	0	0	0	0	0	0
				Accumulative Total			**23,800**	**68,800**	**6,606**	**0**	**7,500**	**106,706**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
				Revenue Generator																				
A-0530.01	EFD	708	D	FIS & GENERAL AVIATION CENTER - Planning	9/1/2014	Brian Rinehart	900					900												
A-0629.01	EFD	743	O	EFO SELF-FUELING SYSTEM (equipment purchase)	9/1/2014	Chuck Farina	295					295												
				Project Total			1,195	3,000	0	0	0	4,195												
				Accumulative Total			**52,670**	**82,550**	**18,356**	**11,750**	**18,650**	**183,976**												
				Infrastructure																				
A-0513.14	EFD	460C	C	PAVEMENT REPLACEMENT AT EFD (R&R)	7/1/2017	Samar Mukhopadhyay				250		250												
A-0513.08	EFD	460D	C	PAVEMENT REPLACEMENT AT EFD (R&R)	7/1/2018	Samar Mukhopadhyay					250	250												
A-0577.01	EFD	654	D	NEW ELECTRICAL VAULT AT AOA	7/1/2017	Brian Rinehart				275		275												
A-0577.02	EFD	654	C	NEW ELECTRICAL VAULT AT AOA	7/1/2017	Brian Rinehart				2,475		2,475												
A-0597.04	HAS	684	C	ROADWAY SIGNAGE AT HOBBY & EFD	9/1/2014	HAPMT	6,133					6,133												
A-0422.04	HAS	684	C	ROADWAY SIGNAGE AT HOBBY & EFD	9/1/2014	HAPMT	98					98												
A-0523.03	EFD	707	D	NEW TAXIWAY ON SOUTHEAST SIDE OF R/W 4-22	7/1/2021	Brian Rinehart						0			660									660
A-0523.04	EFD	707	C	NEW TAXIWAY ON SOUTHEAST SIDE OF R/W 4-22	7/1/2021	Brian Rinehart						0			5,940									5,940
A-0615.01	EFD	728	D	CARGO LANE TO CARGO RAMP	9/1/2014	Chuck Farina	300					**300**												
A-0615.02	EFD	728	C	CARGO LANE TO CARGO RAMP	9/1/2015	Chuck Farina		2,700				**2,700**												
A-0616.01	EFD	729	D	INSTALL CATEGORY IIIA ILS	9/1/2015	Brian Rinehart		645				645												
A-0616.02	EFD	729	C	INSTALL CATEGORY IIIA ILS	9/1/2016	Brian Rinehart			5,805			5,805												
A-0617.01	EFD	730	D	EXTEND RUNWAY 17R-35L	9/1/2018	Brian Rinehart					545	545												
A-0617.02	EFD	730	C	EXTEND RUNWAY 17R-35L FY21	9/1/2020	Brian Rinehart						0		4,905										4,905
A-0618.01	EFD	731	D	RUNWAY 17R-35L IMPROVEMENT- ASPHALT SHOULDERS FY21	9/1/2018	Brian Rinehart					1,745	1,745												
A-0618.02	EFD	731	C	RUNWAY 17R-35L IMPROVEMENT - ASPHALT SHOULDERS	9/1/2020	Brian Rinehart						0		15,700										15,700
A-0619.01	EFD	732	D	DESIGN IN HOUSE								0												
A-0619.01	EFD	732	C	REHABILITATION OF AIRFIELD SERVICE ROAD	9/1/2015	Brian Rinehart		547				547												
A-0620.01	EFD	733	D	**DESIGN IN HOUSE**		Brian Rinehart						0												
A-0620.02	EFD	733	C	T-HANGER RAMP AND TAXIWAY D PAVEMENT REHAB	9/1/2015	Brian Rinehart		1,287				1,287												
				Project Total			15,535	10,484	10,710	15,650	3,090	55,469												
				Accumulative Total			**68,205**	**93,034**	**29,066**	**27,400**	**21,740**	**239,445**												
				OTHER/PRODUCT																				
A-0532.01	EFD	529	D	Construction of Ellington Field Bypass	7/1/2018						900	900												
A-0532.02	EFD	529	C	Construction of Ellington Field Bypass	7/1/2019							0	5,100											5,100
A-0579.01	EFD	656	D	GRASS ISLAND PAVING - NORTH SIDE 2 (~~BUSINESS DEAL~~)	7/1/2015	Brian Rinehart		150				150												
A-0579.02	EFD	656	C	GRASS ISLAND PAVING - NORTH SIDE 2 (~~BUSINESS DEAL~~)	7/1/2022	Brian Rinehart						0				1,350								1,350
A-0593.02	EFD	671	C	HORSEPEN BAYOU DRAINAGE IMPROVEMENT	7/1/2020	Brian Rinehart						0		6,300										6,300
A-0523.01	EFD	706	D	REHAB OUTER PANELS ON RUNWAY 4-22	7/1/2020	Brian Rinehart						0		420										420
A-0523.02	EFD	706	C	REHAB OUTER PANELS ON RUNWAY 4-22	7/1/2020	Brian Rinehart						0		3,780										3,780
A-0533.01	EFD	709	D	RAMP PAVEMENT RECONSTRUCTION ADJACENT TO SW AIRPOI	7/1/2017	Brian Rinehart				200		200												
A-0533.02	EFD	709	C	RAMP PAVEMENT RECONSTRUCTION ADJACENT TO SW AIRPOI	7/1/2020	Brian Rinehart						0		1,800										1,800
							11,006	150	50	3,150	8,400	22,756												
						Proposed CIP	**79,211**	**93,184**	**29,116**	**30,550**	**30,140**	**262,201**												
													19,100	122,305	90,537	61,750								293,692

Appendix K

Cost Estimates

PRELIMINARY ROUGH ORDER OF MAGNITUDE COST ESTIMATE

Report Date:
March 26, 2015

REVISED: March 26, 2015

Ellington Airport
Houston, Texas

Master Plan Update – Airport Development Plan

Prepared for:

Ricondo & Associates
909 Lake Carolyn Parkway
Suite 850
Irving, TX 75039

Prepared by:

Connico Incorporated
2594 N. Mount Juliet Road
Mount Juliet, TN 37122-3007

CONNICO
INCORPORATED

March 26, 2015

Dr. Max Kiesling
Ricondo & Associates
909 Lake Carolyn Parkway
Suite 850
Irving, TX 75039

RE: **Master Plan Update – Airport Layout Plan**
Ellington Airport
Houston, Texas
Preliminary Rough Order of Magnitude Cost Estimate

Dear Dr. Kiesling:

We are pleased to present the Rough Order of Magnitude Estimate for the referenced project. This has been drawn from information noted in Exhibit A.

Included within the report are our Estimate Notes, which outline the criteria and allowances that were used to produce the estimate.

We appreciate the opportunity of working with you on this project. Should you have any questions or need additional information, please contact us at your convenience.

Sincerely,
CONNICO INCORPORATED

Derek L. Brown, CCP, CPE, LEED AP BD+C
Vice President, Senior Cost Estimator
dlbrown@connico.com

File No. 3692.14 EFD – Ellington Airport Master Plan Update 2015.03.26

2594 N. Mount Juliet Road • Mount Juliet, TN 37122
(615) 758-7474 • Fax (615) 758-7477
www.connico.com

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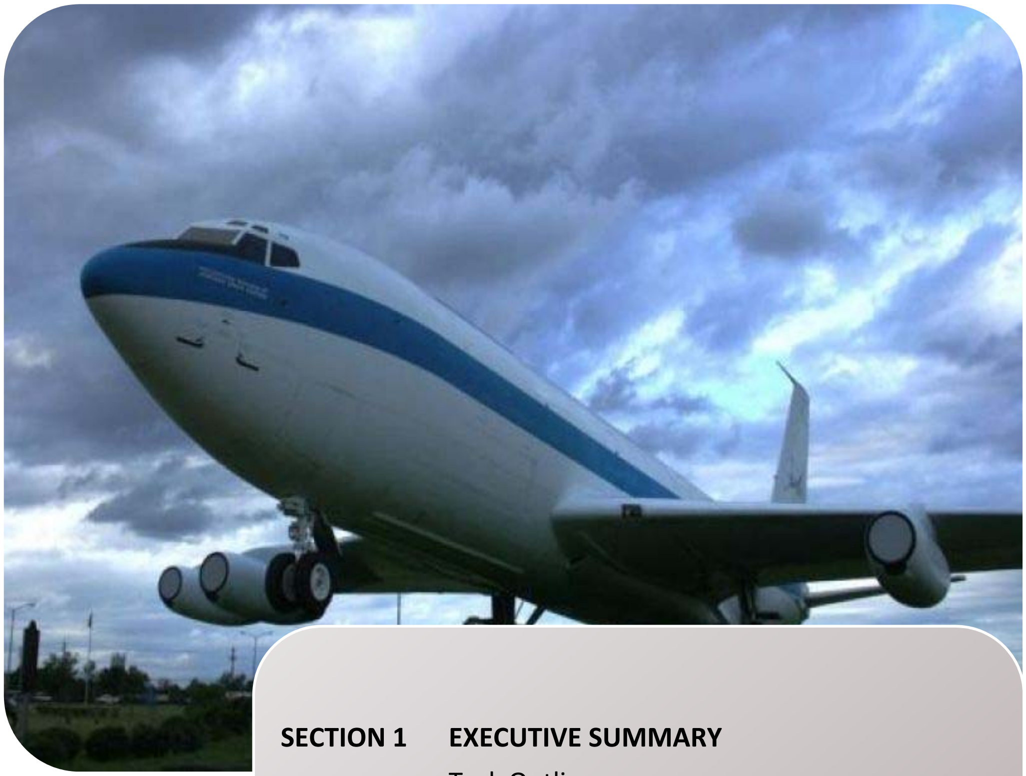

EXECUTIVE SUMMARY

TASK OUTLINE

- ✈ Ricondo & Associates retained Connico Incorporated as cost consultants to provide an opinion of probable cost for Master Plan Update at Ellington Airport for the Houston Airport System. The estimate was based on plans and other information as noted in Exhibit A of this report.

- ✈ In providing opinions of probable construction cost (cost estimates), the Client understands that the Consultant has no control over the cost or availability of labor, equipment or materials, or over market conditions or the Contractor's method of pricing, and that the Consultant's opinions of probable construction costs are made on the basis of the Consultant's professional judgment and experience. The Consultant makes no warranty, express or implied, that the bids or the negotiated cost of the Work will not vary from the Consultant's opinion of probable construction cost.

- ✈ The Opinion of Probable Cost has been prepared based on information prepared/provided by others. Connico has not verified the accuracy and/or completeness of this information and shall not be responsible for any errors or omissions that may be incorporated as a result of erroneous information provided by others.

PROJECT DESCRIPTION

The preliminary rough order of magnitude planning estimates include the following project components:

PHASE 1 (2016-2020)

- Taxiway Connection between First Spaceport Hangar and RWY 4-22
- Construction of Runway and Taxiway Shoulders
  - TWYs A, H, F and C
  - RWYs 17R-35L & 4-22

PHASE 2 (2021-2025)

- Full Length Parallel Taxiway to RWY 4-22
- Realignment of TWY G and Tie-in to TWY C
- Closure of TWY G and a portion of TWY B
- Realignment of TWY E
- Closure of TWY E
- Roadway Connection to Beltway 8
- Realignment of Perimeter Road and Fence around RWY 17R End
- RWY 17R End Extension and TWY H Extension
- Decommissioning of RWY 17L-35R

PHASE 3 (2026-2030)

- Rail Spur into SE Quadrant
- Road into SE Quadrant
- Roadway Flyover at Train Tracks
- Relocation of Oxidizer Loading Area (OLA) and OLA Taxiway Access
- RWY 17R-35L Parallel Taxiway on East and Northernmost Side
- Realignment of TWY B and D and closure of old pavement

ESTIMATE NOTES

GENERAL

- ✈ Connico did not perform a limited site observation in preparing this estimate.
- ✈ The Rough Order of Magnitude/Conceptual/Schematic cost estimates have been developed using "cost per square foot" models based on other similar projects.
- ✈ The Rough Order of Magnitude Estimated Costs represent raw construction costs only. It is understood that markups and soft costs will be applied to these raw construction values by Ricondo & Associates.

MARKUPS AND SOFT COSTS

General Contractor Markups - EXCLUDED
Owners Soft Costs - EXCLUDED

- ✈ The estimate is costed on the understanding that there will be free and open competition at all levels of contracting, that there will not be a restricted bidders list either for general or trade contractors, that there will be at minimum three general contract bidders and at minimum three sub bids will be available for each trade involved. The Owner can facilitate these conditions by ensuring that the project is publicly advertised for bids in general circulation as well as trade publications where advertisements for bid are regularly posted, that prequalification requirements, if prequalification of either general or sub bidders is contemplated, are not unduly restrictive, and by maintaining good industry relations.
- ✈ The Opinion of Probable Cost is based on first quarter 2015 dollars with **no** adjustment for escalation.
- ✈ The Opinion of Probable Cost does not include any allowance for fees normally attributed to the Owner such as Real Estate fees, Impact fees, Tap fees, etc.
- ✈ Temporary site storage and parking for contractor is assumed to be within the vicinity of the site.

ESTIMATE SUMMARY

	DESCRIPTION	CONSTRUCTION YEAR	RAW CONSTRUCTION COST (2015 DOLLARS)
Phase 1 (2016-2020)	**Taxiway Connection Between First Spaceport Hangar and Rwy 4-22**	2017	$ 4,300,000
	Construction of Runway & Taxiway Shoulders	2019	$ 18,225,000
	PHASE 1 TOTAL - CONSTRUCTION COST		***$ 22,525,000***
Phase 2 (2021-2025)	**Full-length Parallel Taxiway to Rwy 4-22 + Rwy 4-22 Exits + Rwy 35 Tie-in**	2021	$ 29,000,000
	Realignment of Twy G & Tie-in to Twy C	2021	$ 13,400,000
	Closure of Twy G and a Portion of Twy B	2021	$ 400,000
	Realignment of Twy E	2021	$ 1,100,000
	Closure of Twy E	2021	$ 100,000
	Roadway Connection to Beltway 8	2021	$ 5,200,000
	Realignment of Perimeter Road and Fence around Rwy 17R End	2022	$ 1,000,000
	Rwy 17R End Extension + Taxiway H Extension	2023	$ 10,500,000
	Decommissioning of Rwy 17L-35R	2024	$ 600,000
	PHASE 2 TOTAL - CONSTRUCTION COST		***$ 61,300,000***
Phase 3 (2026-2030)	**Rail Spur into SE Quadrant**	2026	$ 5,000,000
	Road into SE quadrant	2026	$ 4,000,000
	Roadway Flyover over Railroad Tracks	2026	$ 13,800,000
	Relocation of Oxidizer Loading Area (OLA) + OLA taxiway access	2027	$ 5,600,000
	Rwy 17R-35L Parallel Twy on East Side	2029	$ 12,900,000
	Realignment of Twys B & D and Closure of Old Pavement	2029	$ 5,300,000
	PHASE 3 TOTAL - CONSTRUCTION COST		***$ 46,600,000***

ESTIMATE DETAIL – PHASE 1

Project Title	Master Plan Update - Airport Development Plan		
Location	Ellington Airport		
Submittal Stage	Concept		
Project No.		**Revision**	1
Original Date	17-Sep-14	**Revision Date**	25-Feb-15
Assumed Bid Opening Date	TBD	**CI Project No.**	3692.14
Project Manager	DLB	**Checked by**	CSG

Taxiway Connection Between First Spaceport Hangar and Rwy 4-22

	DESCRIPTION			QUANTITY	UNIT COST	TOTAL COST
		Taxiway Pavement			16,500 sy	
		Taxiway Shoulders			6,000 sy	
A	*SUBSTRUCTURE*					
B	*SHELL*					
C	*INTERIORS*					
C	*SERVICES*					
E	*EQUIPMENT & FURNISHINGS*					
F	*SPECIAL*					
G	*SITEWORK*					
		G20	Site Improvements			
			G2010 Taxiway Pavement Construction, including painting, lights, etc.	16,500 sy	$ 210.00	$ 3,465,000
			G2011 Taxiway shoulders	6,000 sy	$ 135.00	$ 810,000
	Subtotal Sitework					*$ 4,275,000*
			TOTAL OPINION OF PROBABLE RAW CONSTRUCTION COST			***$ 4,300,000***

Project Title	Master Plan Update - Airport Development Plan		
Location	Ellington Airport		
Submittal Stage	Concept		
Project No.		**Revision**	1
Original Date	17-Sep-14	**Revision Date**	25-Feb-15
Assumed Bid Opening Date	TBD	**CI Project No.**	3692.14
Project Manager	DLB	**Checked by**	CSG

Construction of Runway & Taxiway Shoulders

	DESCRIPTION	QUANTITY	UNIT COST	TOTAL COST
	Taxiway Shoulders		55,000 sy	
	Runway Shoulders		80,000 sy	
A	*SUBSTRUCTURE*			
B	*SHELL*			
C	*INTERIORS*			
C	*SERVICES*			
E	*EQUIPMENT & FURNISHINGS*			
F	*SPECIAL*			
G	*SITEWORK*			
	G20 Site Improvements			
	G2011 Taxiway shoulders	135,000 sy	$ 135.00	$ 18,225,000
	Subtotal Sitework			***$ 18,225,000***
	TOTAL OPINION OF PROBABLE RAW CONSTRUCTION COST			***$ 18,200,000***

ESTIMATE DETAIL – PHASE 2

Project Title	Master Plan Update - Airport Development Plan		
Location	Ellington Airport		
Submittal Stage	Concept		
Project No.		**Revision**	1
Original Date	17-Sep-14	**Revision Date**	25-Feb-15
Assumed Bid Opening Date	TBD	**CI Project No.**	3692.14
Project Manager	DLB	**Checked by**	CSG

Full-length Parallel Taxiway to Rwy 4-22 + Rwy 4-22 Exits + Rwy 35 Tie-in

	DESCRIPTION			QUANTITY		UNIT COST	TOTAL COST
		Taxiway Pavement				1,250,000 sf	
A	***SUBSTRUCTURE***						
B	***SHELL***						
C	***INTERIORS***						
C	***SERVICES***						
E	***EQUIPMENT &***						
F	***SPECIAL***						
G	***SITEWORK***						
		G20	Site Improvements				
			G2010	Taxiway Pavement Construction, including painting, lights, etc.	138,889 sy	$ 210.00	$ 29,166,667
	Subtotal Sitework						***$ 29,166,667***

TOTAL OPINION OF PROBABLE RAW CONSTRUCTION COST $ 29,000,000

Project Title	Master Plan Update - Airport Development Plan		
Location	Ellington Airport		
Submittal Stage	Concept		
Project No.		**Revision**	1
Original Date	17-Sep-14	**Revision Date**	25-Feb-15
Assumed Bid Opening Date	TBD	**CI Project No.**	3692.14
Project Manager	DLB	**Checked by**	CSG

Realignment of Twy G & Tie-in to Twy C

	DESCRIPTION		QUANTITY		UNIT COST	TOTAL COST
	Taxiway Pavement				575,000	sf
A	*SUBSTRUCTURE*					
B	*SHELL*					
C	*INTERIORS*					
C	*SERVICES*					
E	*EQUIPMENT &*					
F	*SPECIAL*					
G	*SITEWORK*					
	G20	Site Improvements				
	G2010	Taxiway Pavement Construction, including painting, lights, etc.	63,889	sy	$ 210.00	$ 13,416,667
	Subtotal Sitework					***$ 13,416,667***

TOTAL OPINION OF PROBABLE RAW CONSTRUCTION COST $ 13,400,000

Project Title	Master Plan Update - Airport Development Plan		
Location	Ellington Airport		
Submittal Stage	Concept		
Project No.		**Revision**	1
Original Date	17-Sep-14	**Revision Date**	25-Feb-15
Assumed Bid Opening Date	TBD	**CI Project No.**	3692.14
Project Manager	DLB	**Checked by**	CSG

Closure of Twy G and a Portion of Twy B

	DESCRIPTION	QUANTITY	UNIT COST	TOTAL COST
	Taxiway Demolition		650,000 sf	
A	***SUBSTRUCTURE***			
B	***SHELL***			
C	***INTERIORS***			
C	***SERVICES***			
E	***EQUIPMENT & FURNISHINGS***			
F	***SPECIAL***			
G	***SITEWORK***			
	G20 Site Improvements			
	G2010 Taxiway closure (pavement to remain)	72,222 sy	$ 5.00	$ 361,111
	Subtotal Sitework			***$ 361,111***
	TOTAL OPINION OF PROBABLE RAW CONSTRUCTION COST			***$ 400,000***

Project Title	Master Plan Update - Airport Development Plan		
Location	Ellington Airport		
Submittal Stage	Concept		
Project No.		**Revision**	1
Original Date	17-Sep-14	**Revision Date**	25-Feb-15
Assumed Bid Opening Date	TBD	**CI Project No.**	3692.14
Project Manager	DLB	**Checked by**	CSG

Realignment of Twy E

	DESCRIPTION				QUANTITY	UNIT COST	TOTAL COST
		Taxiway Pavement				45,000 sf	
A	*SUBSTRUCTURE*						
B	*SHELL*						
C	*INTERIORS*						
C	*SERVICES*						
E	*EQUIPMENT &*						
F	*SPECIAL*						
G	*SITEWORK*						
		G20	Site Improvements				
			G2010	Taxiway Pavement Construction, including painting, lights, etc.	5,000 sy	$ 210.00	$ 1,050,000
	Subtotal Sitework						***$ 1,050,000***
				TOTAL OPINION OF PROBABLE RAW CONSTRUCTION COST			***$ 1,100,000***

Project Title	Master Plan Update - Airport Development Plan		
Location	Ellington Airport		
Submittal Stage	Concept		
Project No.		**Revision**	1
Original Date	17-Sep-14	**Revision Date**	25-Feb-15
Assumed Bid Opening Date		**CI Project No.**	3692.14
Project Manager	DLB	**Checked by**	CSG

Closure of Twy E

	DESCRIPTION	QUANTITY	UNIT COST	TOTAL COST
	Taxiway Pavement		60,000 sf	
A	*SUBSTRUCTURE*			
B	*SHELL*			
C	*INTERIORS*			
C	*SERVICES*			
E	*EQUIPMENT &*			
F	*SPECIAL*			
G	*SITEWORK*			
G20	Site Improvements			
G2010	Taxiway closure (pavement to remain)	6,667 sy	$ 7.50	$ 50,000
	Subtotal Sitework			*$ 50,000*
	TOTAL OPINION OF PROBABLE RAW CONSTRUCTION COST			***$ 100,000***

Project Title	Master Plan Update - Airport Development Plan		
Location	Ellington Airport		
Submittal Stage	Concept		
Project No.		**Revision**	1
Original Date	17-Sep-14	**Revision Date**	25-Feb-15
Assumed Bid Opening Date		**CI Project No.**	3537.13
Project Manager	DLB	**Checked by**	CSG

Roadway Connection to Beltway 8

		DESCRIPTION	QUANTITY		UNIT COST	TOTAL COST
A		*SUBSTRUCTURE*				
B		*SHELL*				
C		*INTERIORS*				
C		*SERVICES*				
E		*EQUIPMENT & FURNISHINGS*				
G		*SITEWORK*				
	G20	*Site Improvements*				
	G2020	Roadways	65,000	sy	$ 75.00	$ 4,875,000
	G2040	Landscaping & Signage	1	ea	$ 250,000	$ 250,000
	G2040	Signalization	1	ea	$ 100,000	$ 100,000
		Subtotal Sitework				*$ 5,225,000*
		TOTAL OPINION OF PROBABLE RAW CONSTRUCTION COST				***$ 5,200,000***

CONNICO INCORPORATED

Project Title	Master Plan Update - Airport Development Plan		
Location	Ellington Airport		
Submittal Stage	Concept		
Project No.		**Revision**	1
Original Date	17-Sep-14	**Revision Date**	25-Feb-15
Assumed Bid Opening Date		**CI Project No.**	3537.13
Project Manager	DLB	**Checked by**	CSG

Realignment of Perimeter Road and Fence around Rwy 17R End

		DESCRIPTION	QUANTITY	UNIT COST	TOTAL COST
A		*SUBSTRUCTURE*			
B		*SHELL*			
C		*INTERIORS*			
C		*SERVICES*			
E		*EQUIPMENT & FURNISHINGS*			
G		*SITEWORK*			
	G20	*Site Improvements*			
	G2020	Roadways	17,500 sy	$ 50.00	$ 875,000
	G2040	Landscaping & Signage	1 ea	$ 150,000	$ 150,000
		Subtotal Sitework			*$ 1,025,000*
		TOTAL OPINION OF PROBABLE RAW CONSTRUCTION COST			*$ 1,000,000*

Project Title	Master Plan Update - Airport Development Plan		
Location	Ellington Airport		
Submittal Stage	Concept		
Project No.		**Revision**	1
Original Date	17-Sep-14	**Revision Date**	25-Feb-15
Assumed Bid Opening Date	TBD	**CI Project No.**	3692.14
Project Manager	DLB	**Checked by**	CSG

Rwy 17R End Extension + Taxiway H Extension

	DESCRIPTION		**QUANTITY**	**UNIT COST**	**TOTAL COST**
	Taxiway Pavement			140,000 sf	
	Taxiway Shoulders			100,000 sf	
	Runway Pavement			165,000 sf	
	Runway Shoulders			45,000 sf	
A	*SUBSTRUCTURE*				
B	*SHELL*				
C	*INTERIORS*				
C	*SERVICES*				
E	*EQUIPMENT &*				
F	*SPECIAL*				
G	*SITEWORK*				
	G20	Site Improvements			
	G2010	Taxiway Pavement Construction, including painting, lights, etc.	15,556 sy	$ 210.00	$ 3,266,667
	G2011	Taxiway Shoulders	11,111 sy	$ 135.00	$ 1,500,000
	G2012	Runway Pavement Construction, including painting, lights, etc.	18,333 sy	$ 275.00	$ 5,041,667
	G2013	Runway Shoulders	5,000 sy	$ 135.00	$ 675,000
	Subtotal Sitework				*$ 10,483,333*
				TOTAL OPINION OF PROBABLE RAW CONSTRUCTION COST	*$ 10,500,000*

Project Title	Master Plan Update - Airport Development Plan		
Location	Ellington Airport		
Submittal Stage	Concept		
Project No.		**Revision**	1
Original Date	17-Sep-14	**Revision Date**	25-Feb-15
Assumed Bid **Opening Date**		**CI Project No.**	3692.14
Project Manager	DLB	**Checked by**	CSG

Decommissioning of Rwy 17L-35R

	DESCRIPTION			QUANTITY	UNIT COST	TOTAL COST
		Taxiway Pavement			720,000 sf	
A	***SUBSTRUCTURE***					
B	***SHELL***					
C	***INTERIORS***					
C	***SERVICES***					
E	***EQUIPMENT &***					
F	***SPECIAL***					
G	***SITEWORK***					
		G20	Site Improvements			
			G2010 Runway Demolition	80,000 sy	$ 7.50	$ 600,000
	Subtotal Sitework					***$ 600,000***

TOTAL OPINION OF PROBABLE RAW CONSTRUCTION COST $ 600,000

CONNICO INCORPORATED

ESTIMATE DETAIL – PHASE 3

Project Title	Master Plan Update - Airport Development Plan		
Location	Ellington Airport		
Submittal Stage	Concept		
Project No.		**Revision**	1
Original Date	17-Sep-14	**Revision Date**	25-Feb-15
Assumed Bid Opening Date		**CI Project No.**	3692.14
Project Manager	DLB	**Checked by**	CSG

Rail Spur into SE Quadrant

		DESCRIPTION	QUANTITY		UNIT COST	TOTAL COST
		New Rail Spur Line	9,000.00	lf		
A	*SUBSTRUCTURE*					
B	*SHELL*					
C	*INTERIORS*					
C	*SERVICES*					
E	*EQUIPMENT & FURNISHINGS*					
G	*SITEWORK*					
G20		*Site Improvements*				
	G2010	Railway	1.70	mile	$ 2,750,000	$ 4,687,500
	G2020	Crossing at Road into Southeast Quadrant	1	ea	$ 200,000	$ 200,000
	G2040	Signalization	1	ea	$ 150,000	$ 150,000

Subtotal Sitework ***$ 5,037,500***

TOTAL OPINION OF PROBABLE RAW CONSTRUCTION COST $ 5,000,000

Project Title	Master Plan Update - Airport Development Plan		
Location	Ellington Airport		
Submittal Stage	Concept		
Project No.		**Revision**	1
Original Date	17-Sep	**Revision Date**	25-Feb-15
Assumed Bid Opening Date	TBD	**CI Project No.**	3692.14
Project Manager	DLB	**Checked by**	CSG

Road into SE quadrant

	DESCRIPTION		QUANTITY	UNIT COST	TOTAL COST
A	***SUBSTRUCTURE***				
B	***SHELL***				
C	***INTERIORS***				
C	***SERVICES***				
E	***EQUIPMENT & FURNISHINGS***				
G	***SITEWORK***				
G20	***Site Improvements***				
G2020	Roadways		65,000 sy	$ 55.00	$ 3,575,000
G2040	Landscaping & Signage		1 ea	$ 200,000	$ 200,000
G2040	Signalization		1 ea	$ 250,000	$ 250,000
	Subtotal Sitework				***$ 4,025,000***
	TOTAL OPINION OF PROBABLE RAW CONSTRUCTION COST				***$ 4,000,000***

Project Title	Master Plan Update - Airport Development Plan		
Location	Ellington Airport		
Submittal Stage	Concept		
Project No.		**Revision**	1
Original Date	17-Sep-14	**Revision Date**	25-Feb-15
Assumed Bid Opening Date		**CI Project No.**	3692.14
Project Manager	DLB	**Checked by**	CSG

Roadway Flyover over Railroad Tracks

DESCRIPTION	QUANTITY	UNIT COST	TOTAL COST
Elevated roadway		152,000	sf
A SUBSTRUCTURE			
B SHELL			
C INTERIORS			
C SERVICES			
E EQUIPMENT & FURNISHINGS			
G SITEWORK			
G20 Site Improvements			
G2010 Temporary Construction Measures	1 ls	$ 250,000	$ 250,000
G2020 At-grade roadway	50,000 sy	$ 55.00	$ 2,750,000
G2020 Elevated Roadway	100,000 sf	$ 95.00	$ 9,500,000
G2040 Landscaping & Signage	1 ea	$ 750,000	$ 750,000
G2040 Signalization	1 ea	$ 500,000	$ 500,000
Subtotal Sitework			***$ 13,750,000***
TOTAL OPINION OF PROBABLE RAW CONSTRUCTION COST			***$ 13,800,000***

Project Title	Master Plan Update - Airport Development Plan		
Location	Ellington Airport		
Submittal Stage	Concept		
Project No.		**Revision**	1
Original Date	17-Sep-14	**Revision Date**	25-Feb-15
Assumed Bid Opening Date		**CI Project No.**	3692.14
Project Manager	DLB	**Checked by**	CSG

Relocation of Oxidizer Loading Area (OLA) + OLA taxiway access

			DESCRIPTION	QUANTITY		UNIT COST	TOTAL COST
			Taxiway Pavement	150,000	sf		
			Taxiway Shoulders	100,000	sf		
			Oxidizer loading pad	25,000	sf		
A	***SUBSTRUCTURE***						
B	***SHELL***						
C	***INTERIORS***						
C	***SERVICES***						
E	***EQUIPMENT & FURNISHINGS***						
G	***SITEWORK***						
	G20		***Site Improvements***				
		G2010	Taxiway Pavement Construction, including painting, lights, etc.	16,667	sy	$ 210.00	$ 3,500,000
		G2011	Taxiway shoulders	11,111	sy	$ 135.00	$ 1,500,000
		G2012	Oxidizer loading pad	2,778	sy	$ 225.00	$ 625,000
	Subtotal Sitework						***$ 5,625,000***
			TOTAL OPINION OF PROBABLE RAW CONSTRUCTION COST				***$ 5,600,000***

Project Title	Master Plan Update - Airport Development Plan		
Location	Ellington Airport		
Submittal Stage	Concept		
Project No.		**Revision**	1
Original Date	17-Sep-14	**Revision Date**	25-Feb-15
Assumed Bid Opening Date		**CI Project No.**	3692.14
Project Manager	DLB	**Checked by**	CSG

Rwy 17R-35L Parallel Twy on East Side

			DESCRIPTION	QUANTITY		UNIT COST	TOTAL COST
			Taxiway Pavement			410,000 sf	
			Taxiway Shoulder Pavement			225,000 sf	
A	***SUBSTRUCTURE***						
B	***SHELL***						
C	***INTERIORS***						
C	***SERVICES***						
E	***EQUIPMENT & FURNISHINGS***						
G	***SITEWORK***						
		G20	Site Improvements				
		G2010	Taxiway Pavement Construction, including painting, lights, etc.	45,556	sy	$ 210.00	$ 9,566,667
		G2011	Taxiway shoulders	25,000	sy	$ 135.00	$ 3,375,000

Subtotal Sitework ***$ 12,941,667***

TOTAL OPINION OF PROBABLE RAW CONSTRUCTION COST $ 12,900,000

Project Title	Master Plan Update - Airport Development Plan		
Location	Ellington Airport		
Submittal Stage	Concept		
Project No.		**Revision**	1
Original Date	17-Sep-14	**Revision Date**	25-Feb-15
Assumed Bid Opening Date		**CI Project No.**	3692.14
Project Manager	DLB	**Checked by**	CSG

Realignment of Twys B & D and Closure of Old Pavement

	DESCRIPTION		QUANTITY	UNIT COST	TOTAL COST
		Taxiway B Pavement		80,000 sf	
		Taxiway B Shoulder Pavement		51,300 sf	
		Taxiway D Pavement		80,000 sf	
		Taxiway D Shoulder Pavement		54,000 sf	
A	*SUBSTRUCTURE*				
B	*SHELL*				
C	*INTERIORS*				
C	*SERVICES*				
E	*EQUIPMENT & FURNISHINGS*				
G	*SITEWORK*				
		G20 Site Improvements			
		Taxiway B			
		G2010 Taxiway Pavement Construction, including painting, lights, etc.	8,889 sy	$ 210.00	$ 1,866,667
		G2011 Taxiway shoulders	5,700 sy	$ 135.00	$ 769,500
		Taxiway D			
		G2010 Taxiway Pavement Construction, including painting, lights, etc.	8,889 sy	$ 210.00	$ 1,866,667
		G2011 Taxiway shoulders	6,000 sy	$ 135.00	$ 810,000
	Subtotal Sitework				*$ 5,312,833*

TOTAL OPINION OF PROBABLE RAW CONSTRUCTION COST $ 5,300,000

EXHIBITS

Exhibit A
Document List

EXHIBIT A – DOCUMENT LIST

- ✈ The estimate reflects the documents listed herein (attached for reference)

Description	Date
Airport Development Plan - 2016-2030	March 2015
Future Airport Layout Plan	March 2015

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