Colorado Air and Space Port

Spaceport Master Plan

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COLORADO AIR AND SPACE PORT
SPACEPORT MASTER PLAN

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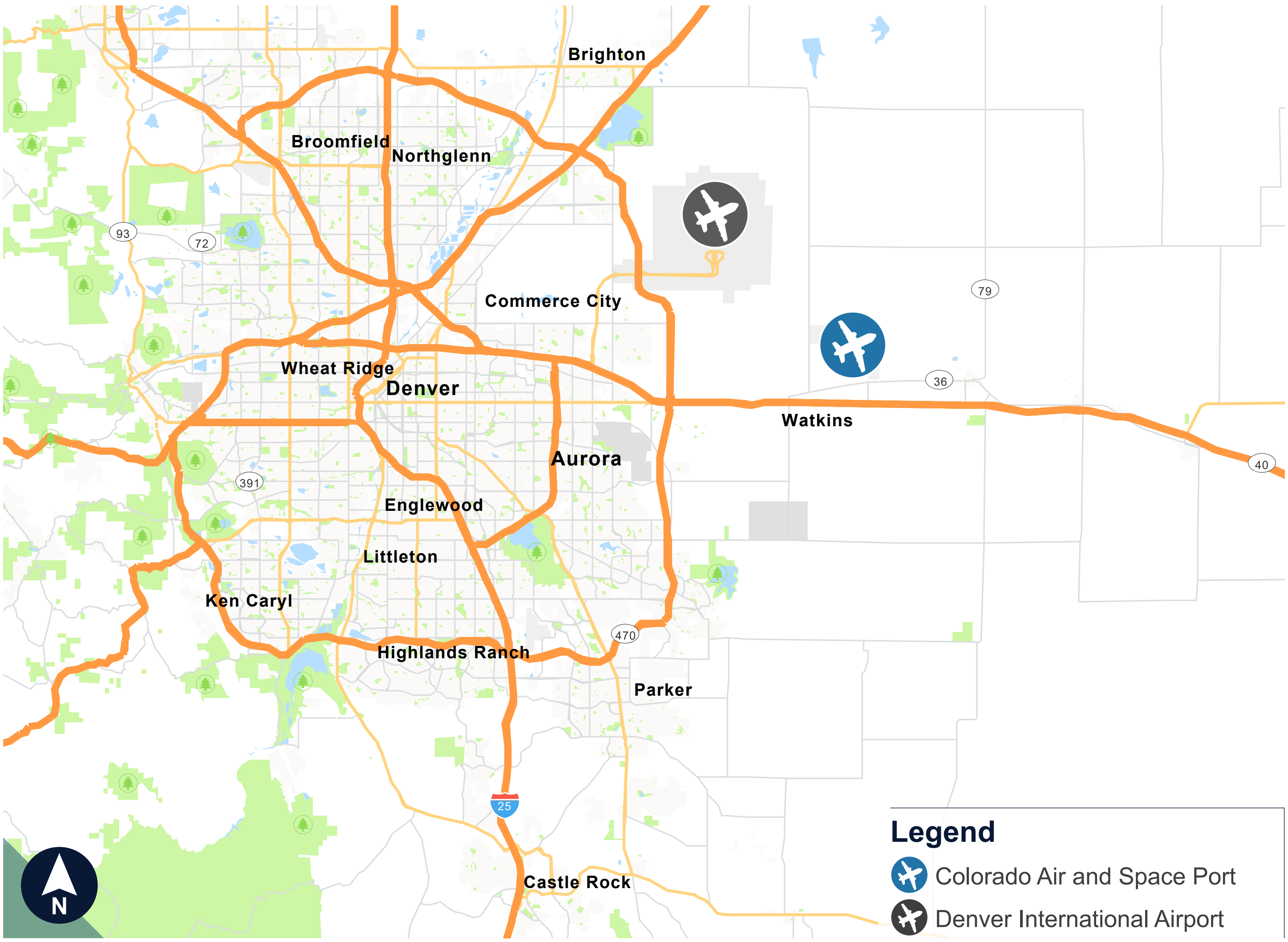
Chapter 1

Introduction

INTRODUCTION

The Colorado Air and Space Port (CASP or CFO) is one of 12 Federal Aviation Administration (FAA) licensed commercial launch sites in the United States and one of nine that can support horizontal launch and landing activities. The facility, formerly named Front Range Airport (FTG), consists of 3,349-acres and is located in Adams County, Colorado in the northeast quadrant of the Denver metropolitan area (see **Figure 1**). Approximately 85-acres of the entire facility have been developed. Non-developed areas consist of relatively flat, agricultural, land covered with prairie grass and a sparse collection of trees. Landside development at the CASP includes a terminal building, fixed base operator (FBO) facilities, an aerospace test facility, and aircraft hangar facilities. The CASP is approximately 7 miles southeast of the Denver International Airport (DEN) and is designated as a General Aviation (GA) – Reliever Airport in the FAA's National Plan of Integrated Airport Systems (NPIAS).

Figure 1-1. Vicinity Map



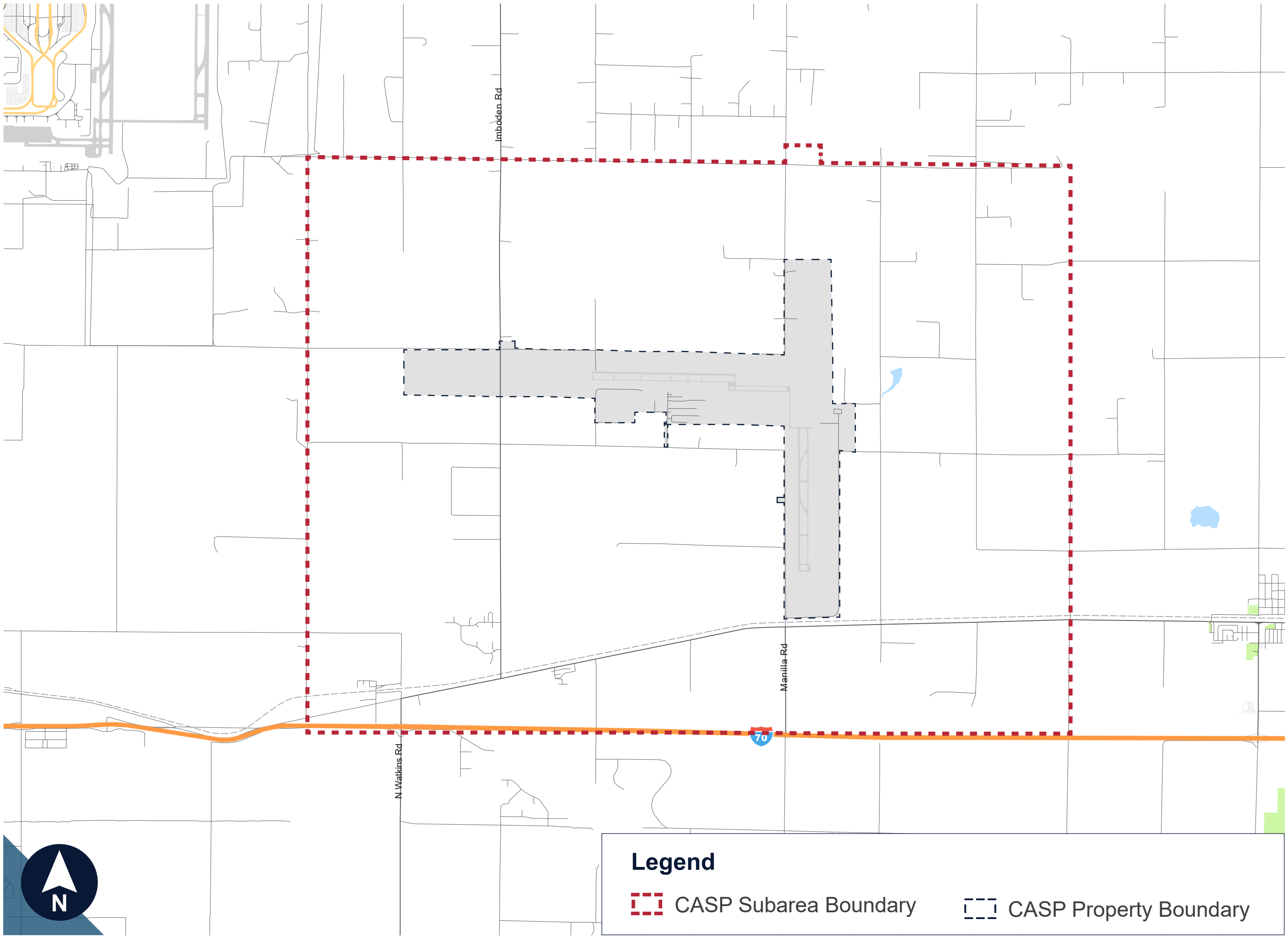
Source: Kimley-Horn

Purpose of the Spaceport Master Plan

The purpose of a Spaceport Master Plan is to supplement existing airport master planning documents with spaceport specific elements. The goal of an traditional Airport Master Plan is to provide the framework needed to guide future airport development that will cost-effectively satisfy aviation demand, while considering potential environmental and socioeconomic impacts. While CASP updates its Airport Master Plan on regular intervals, the focus of that plan is primarily on aviation infrastructure and aviation forecasts. The Airport Master Planning guidance documents from the FAA do not currently recognize commercial space transportation infrastructure needs and forecasts in the planning process.

The goal of the Spaceport Master Plan process is to bridge the gaps between the Airport Master Planning process and the unique needs of a commercial spaceport. The Spaceport Master Plan will evaluate the existing inventory conditions of the spaceport infrastructure with a space transportation market forecast to identify near-term and long- term infrastructure needs. The result of the Spaceport Master Plan will be an implementation plan for different planning horizons.

Figure 1-2. Colorado Air and Space Port Area



Source: Adams County

Background

In 1974, The Denver Regional Airport System Plan (RASP) identified aviation facilities needed to meet both existing and future aviation needs in the Denver region. The study forecasted growth in aviation beyond the capabilities of the current available airport facilities. The RASP study determined that even if the existing airports in the region were expanded to their maximum development potential, by the year 2000 four new general aviation airports would be required in the region.

The 1980 National Airport System Plan recommended construction of two general aviation reliever airports in the Denver Metropolitan Region. One of these airports was Adams County Airport, which later became known as Front Range Airport and is now known as the Colorado Air and Space Port.

In 1982, the first Airport Master Plan was completed and accepted for Front Range Airport, which including planned development through 2003. Initial construction of the Airport was undertaken in 1983 beginning with Runway 8-26 and followed by Runway 17-35 in 1985.

Following the initial construction of the Airport, three additional master plans were completed in 1988, 2004, and 2019. In 2004, the master plan focused on increased opportunity for air cargo operations, enhancement of general aviation activities, and to encourage local economic growth and development. The 2004 master plan became known as an aggressive approach with much of the planned development never reaching fruition.

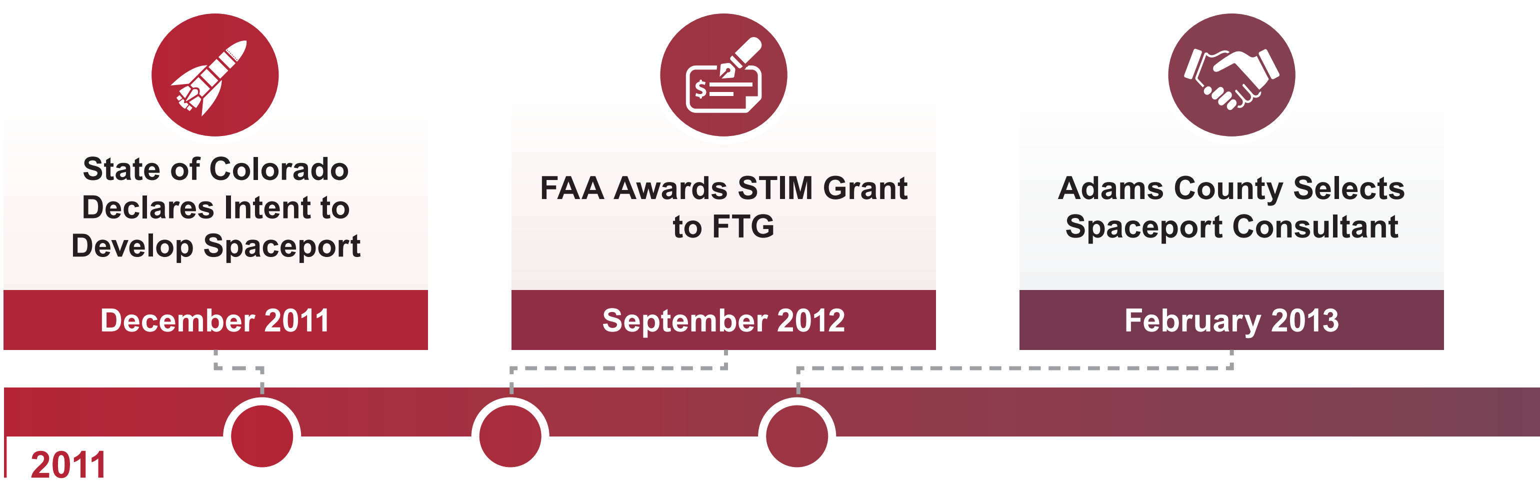
Front Range Airport was identified as a candidate for development as a spaceport in 2011 and FAA licensing began shortly after. In 2014, The Front Range Airport Authority was dissolved by Adams County and the County assumed direct management of the facility. The decision was made in an effort to stabilize the economics and future of the Airport. The FAA licensing activities continued through 2018, when the FAA granted a Launch Site Operator License (LSOL) to Adams County for the operation of a commercial spaceport at Front Range Airport. Shortly after the license was issued the Airport was renamed to the Colorado Air and Space Port.

The most recent master planning effort was completed in 2019 following the current FAA planning process for airports. The document looked at Front Range Airport in the following roles as a public-use reliever service level airport, a regional airport, and as a Colorado major general aviation airport. The master plan was completed in parallel with the Launch Site Operator License process, described below. Therefore, the master plan states that it considered only, "the airport land area needed to meet the potential facility requirements" for the spaceport. The master plan also ensured that "prospective spaceport development areas do not adversely impact traditional airport operation activities."

The Airport Layout Plan (ALP) was updated during the 2019 Airport Master Plan Update. While Sheet 18 of the updated ALP contains the Launch Site Boundary Plan for the CASP, additional spaceport infrastructure needs and future aerospace development are not included as part of the ALP set.

As noted in the 2019 ALP, "FAA's conditional approval of FTG's ALP and commercial spaceport boundary plan does not include any development shown on this drawing that is associated with commercial space launch operators. At time of printing, the FAA Airports had not established airport safety standards and federal grant assurances for evaluating commercial space operations, including the determination if such operations are an aeronautical use. When these standards are established, FAA Airports will evaluate proposed commercial space facilities shown on this drawing."

Figure 1-3. Colorado Air and Space Port Development Timeline



Becoming an FAA Licensed Launch Site

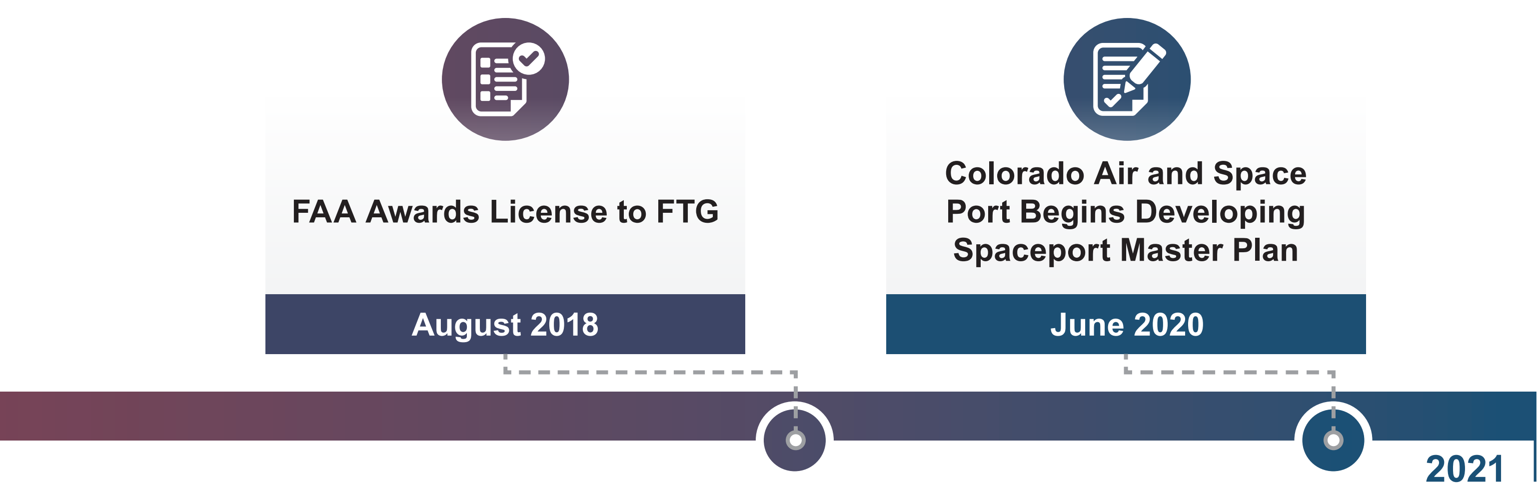
As an FAA licensed launch site, Colorado Air and Space Port can offer its facility for use by licensed launch operators. The path to receiving the LSOL took almost 7 years and required the support of many stakeholders and partners that included the State of Colorado, Adams County, Colorado Department of Transportation (CDOT) Aeronautics, Denver International Airport, the Citiy of Aurora and the Town of Bennet.

On December 7, 2011, Colorado Governor John Hickenlooper announced that the state would seek FAA approval for a dedicated commercial spaceport. In a letter sent to the FAA, Front Range Airport was identified as the likely candidate location for the spaceport.

After an initial exploratory effort by Adams County, Airport Director Dennis Heap submitted an application for an FAA Space Transportation Infrastructure Matching (STIM) grant. On September 26, 2012 the FAA announced that Front Range Airport was the recipient of a $200,000 grant to support the development of an Environmental Assessment (EA) needed for an LSOL.

On February 13, 2013, Adams County selected HDR, Inc. to conduct the spaceport feasibility studies and prepare the license application. In 2016, Adams County added Kimley-Horn to the spaceport consulting team to provide additional support in updating and finalizing the LSOL application. The final application was accepted by the FAA as "complete enough" for review on February 20, 2018. On August 17, 2018 Adams County was issued a license to operate a launch site at Front Range Airport. It was the eleventh commercial LSOL issued and seventh at an Airport. Adams County renamed the Airport Colorado Air and Space Port and changed the FAA identifier from FTG to CFO. The development of this Spaceport Master Plan builds on the desire of Adams County to continue to invest in the future development and opportunities associated with the commercial space and aerospace sector.

To obtain an LSOL, Adams County had to submit an application to the FAA the complied with the Code of Federal Regulations (CFR) Title 14, Parts 413 and 420. The application included a description of the proposed launch site, a launch site location review, flight safety analysis, a scheduling and notification plan, an accident investigation plan, an access control plan, an explosive site plan, a lightning protection plan, and an agreement with Air Traffic Control (ATC) to issue a Notice to Airmen (NOTAM) prior to a launch.



Support for Commercial Launch Vehicles

In addition to normal aviation operations, the current site operator license and Programmatic Environmental Assessment (PEA) provide the framework for CASP to support the proposed operations of licensed horizontal takeoff and horizontal landing (HTHL) suborbital reusable launch vehicles (RLVs). At present there are a broad range of HTHL RLVs in various stages of development. While a more detailed market assessment will be provided in **Chapter 3**, this section will focus on the vehicle type included in the site operator license.

CASP is currently licensed to support Concept X RLVs. A Concept X RLV is a manned winged aircraft that utilizes both jet engines and rocket engines. A Concept X RLV departs from a runway under jet power, similar to other jet powered aircraft. Under jet power the Concept X RLV travels to its designated launch operating area and prepares for rocket ignition. Once in the operating area, the Concept X RLV can ignite its rocket engine(s) and begins a steep climb for the suborbital portion of flight. Once the engine burn is complete, the vehicle coasts in a parabolic trajectory, reaching its apogee before returning to Earth. While in parabolic flight, pilots and participant can experience approximately 4 minutes of microgravity. During the return to Earth, the Concept X RLV falls in a ballistic trajectory until aerodynamic control is regained and the jet engines can be restarted. The Concept X RLV returns to CASP to completes its mission with runway landing.

While other launch and reentry vehicles types may also be compatible with CASP, currently only the Concept X RLV is included in the site operate license. In the future additional vehicles such as the Concept Y RLV, Concept Z RLV, reentry vehicles, and high-altitude balloons could be evaluated to determine if they can safely operate from CASP.

Figure 1-4. Concept Vehicle Category included in LSOL

Concept X

Figure 1-5. Concept Vehicles Categories in Development

Concept Y

Concept Z

Reentry Vehicle

Stratospheric Balloon

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Chapter 2

Inventory of Existing Conditions

INVENTORY OF EXISTING CONDITIONS

The existing aviation infrastructure that has been designated for proposed spaceport operations can provide limited capabilities in the near-term, however special use dedicated facilities will eventually be needed for expanded operations. The inventory of existing conditions for aviation infrastructure at the Air and Space Port has been extensively documented in the 2019 Airport Master Plan [1]. This Spaceport Master Plan focuses exclusively on spaceport related existing conditions, which include spaceport infrastructure, launch operating areas, aviation/aerospace activities, environmental conditions, and land use and socioeconomic conditions.

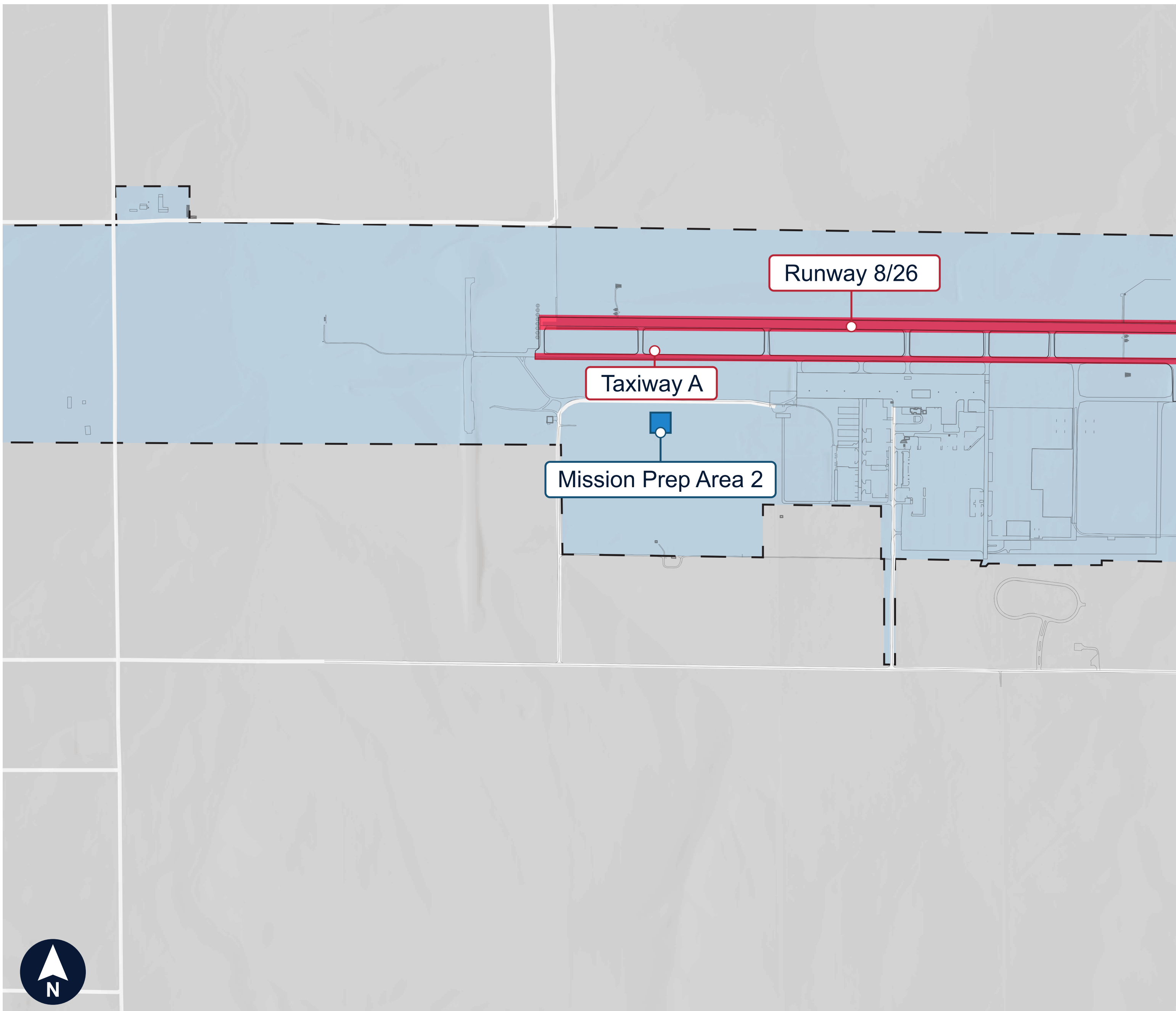
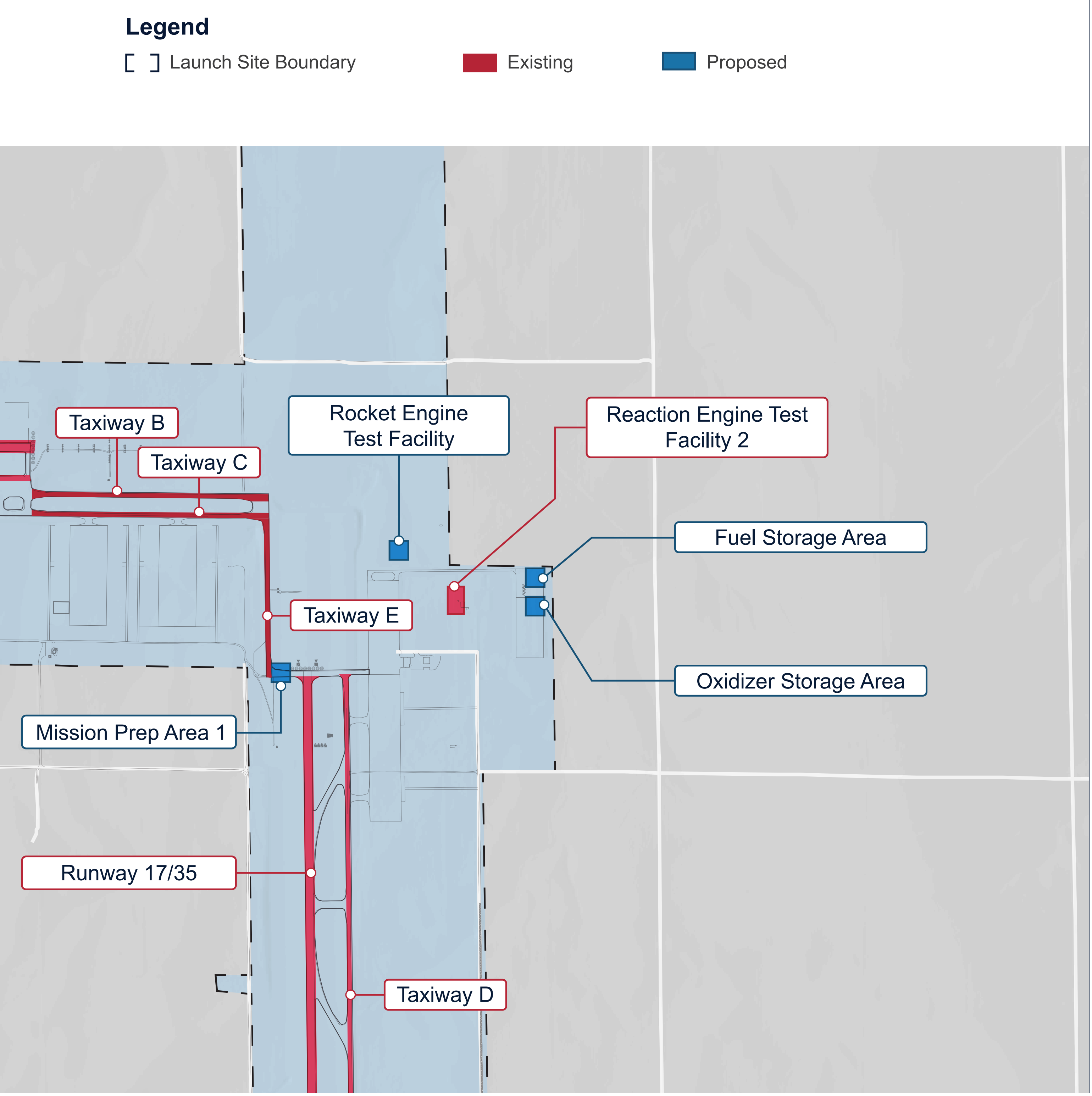


Figure 2-1. Existing and Proposed Spaceport Infrastructure



Source: Kimley-Horn

Spaceport Infrastructure

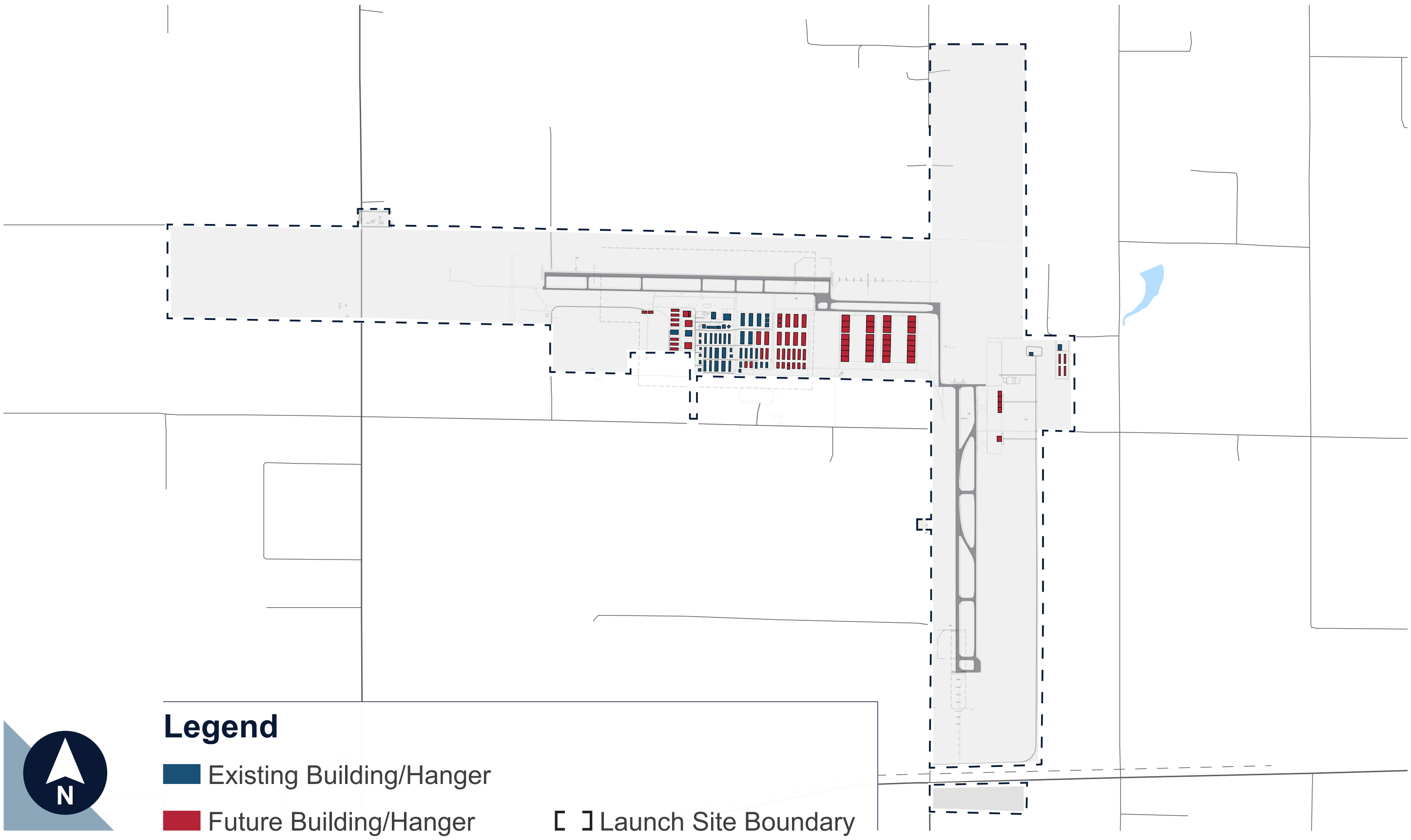
This section identifies existing and proposed spaceport infrastructure resulting from the Federal Aviation Administration (FAA) licensing process and recent developments at CASP. The spaceport infrastructure listed below and shown in **Figure 2-1** includes existing airport infrastructure as well as proposed new spaceport support areas that will need to be developed. Each item is described in more detail in the subsequent subsections.

1. Launch Site Boundary (Existing)
2. Runways (Existing)
3. Explosive Hazard Facilities (Proposed)
   a. Fuel Storage Area
   b. Oxidizer Storage Area
   c. Mission Preparation Area #1
   d. Mission Preparation Area #2
4. Rocket Engine Test Site (Proposed)
5. Reaction Engines Test Facility 2 (Existing)

Launch Site Boundary

The launch site boundary is the same as the existing CASP property boundary and encompasses approximately 3,349 acres [1]. The launch site boundary includes both airside and landside facilities at CASP. While the launch site boundary encompasses the entirety of CASP, only licensed activities that fall within the jurisdiction of the FAA Office of Commercial Space Transportation (AST) are subject to FAA-AST review. All other aeronautical and non-aeronautical activities are managed the same as at other airports.

Figure 2-2. CASP Launch Site Boundary



Source: Colorado Air and Space Port

Runways

The most crucial piece of infrastructure at a spaceport that supports horizontal takeoff horizontal landing (HTHL) operations is the runway. While runway requirements vary by launch vehicle manufacturer and altitude, runways 10,000 ft and longer are commonly preferred. Generally, the minimum runway length recommended for supporting HTHL operations is 8,000 feet. **Figure 2-3** presents a high-level correlation between the percent of HTHL space planes potentially supported by a facility relative to a facility's runway length. The maximum existing runway length at CASP is 8,000 feet, which is capable of supporting about a third of HTHL vehicles currently in development.

CASP has two existing runways: Runway 8/26 and Runway 17/35. Both Runway 8/26 and Runway 17/35 are 8,000 feet long by 100 feet wide asphalt runways and each is equipped with a full-length parallel taxiway.

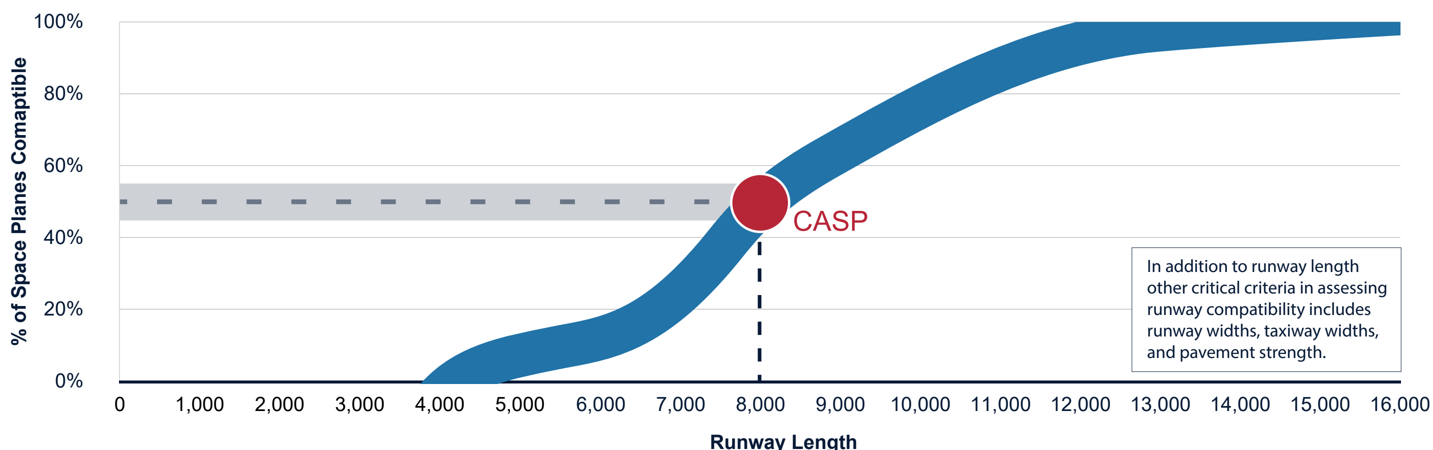
As identified in the 2019 Airport Master Plan, CASP has allocated land to extend and widen both runways. Runway 8/26 is planned to be extended 2,000 feet to the west for an ultimate length of 10,000 feet and widened symmetrically for an ultimate width of 150 feet. Runway 17/35 is planned to be extended 4,000 feet to the north for an ultimate length of 12,000 feet and widened symmetrically for an ultimate width of 150 feet. Additional characteristics for Runway 8/26 and Runway 17/35 are presented in **Table 1-1.** Existing Runway Characteristics [1]. In support of launch operations, departures on either Runway 8 or Runway 17 are preferred. For additional information on the runways at CASP, reference the 2019 Airport Master Plan [1].

**According to a 2009 pavement evaluation study, actual pavement strengths for Runways 8/26 and 17/35 are nearly twice the published values.*

Table 2-1. Existing Runway Characteristics [1]

Element	Runway Data
Runway 8/26	
Dimensions	8,000' x 100'
Runway Markings	Precision-Instrument
Runway Surface Type	Asphalt
Runway End Elevations	5,453.4' / 5,488.1'
Visual Slope Indicator	PAPI-2L / PAPI-2L
Effective Gradient	0.4%
Published Pavement Strength*	28,000 lbs. Single Wheel (SW) 40,000 lbs. Dual Wheel (DW)
Pavement Condition	Excellent (PCI = 86-100)
Runway Design Code	C-II
Critical Aircraft	Bombardier Challenger CL604
Runway 17/35	
Dimensions	8,000' x 100'
Runway Markings	Precision-Instrument
Runway Surface Type	Asphalt
Runway End Elevations	5,476.5' / 5,515.2'
Visual Slope Indicator	PAPI-4L / PAPI-4L
Effective Gradient	0.04%
Published Pavement Strength*	34,000 lbs. SW 75,000 lbs. DW
Pavement Condition	Fair (PCI = 56-70)
Runway Design Code	C-II
Critical Aircraft	Bombardier Challenger CL604

Figure 2-3. Space Plane Compatibility Based on Runway Length



Source: Kimley-Horn

Explosive Hazard Facilities

An explosive site plan was prepared as part of the Launch Site Operator License (LSOL) [2]. The explosive site plan identified potential explosive hazard facilities to support spaceport operations. The following five facilities were included (see **Figure 2-4**) and are summarized below:

1 Mission Prep Area 1

2 Mission Prep Area 2

3 Fuel Storage Area

4 Oxidizer Storage Area

5 Rocket Engine Test Site

It should be noted that all of the explosive hazard facilities identified in the explosive site plan have been proposed but not constructed.

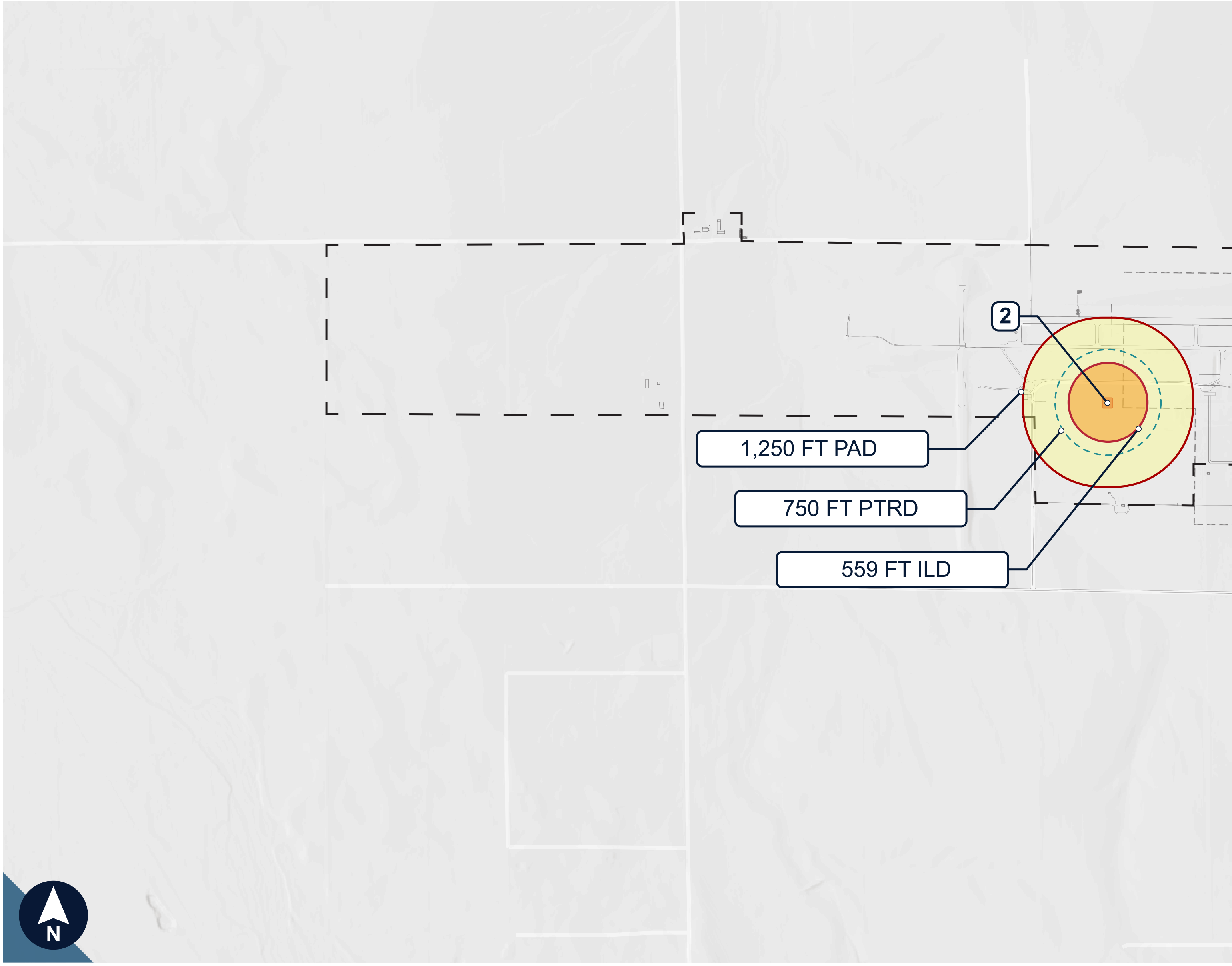
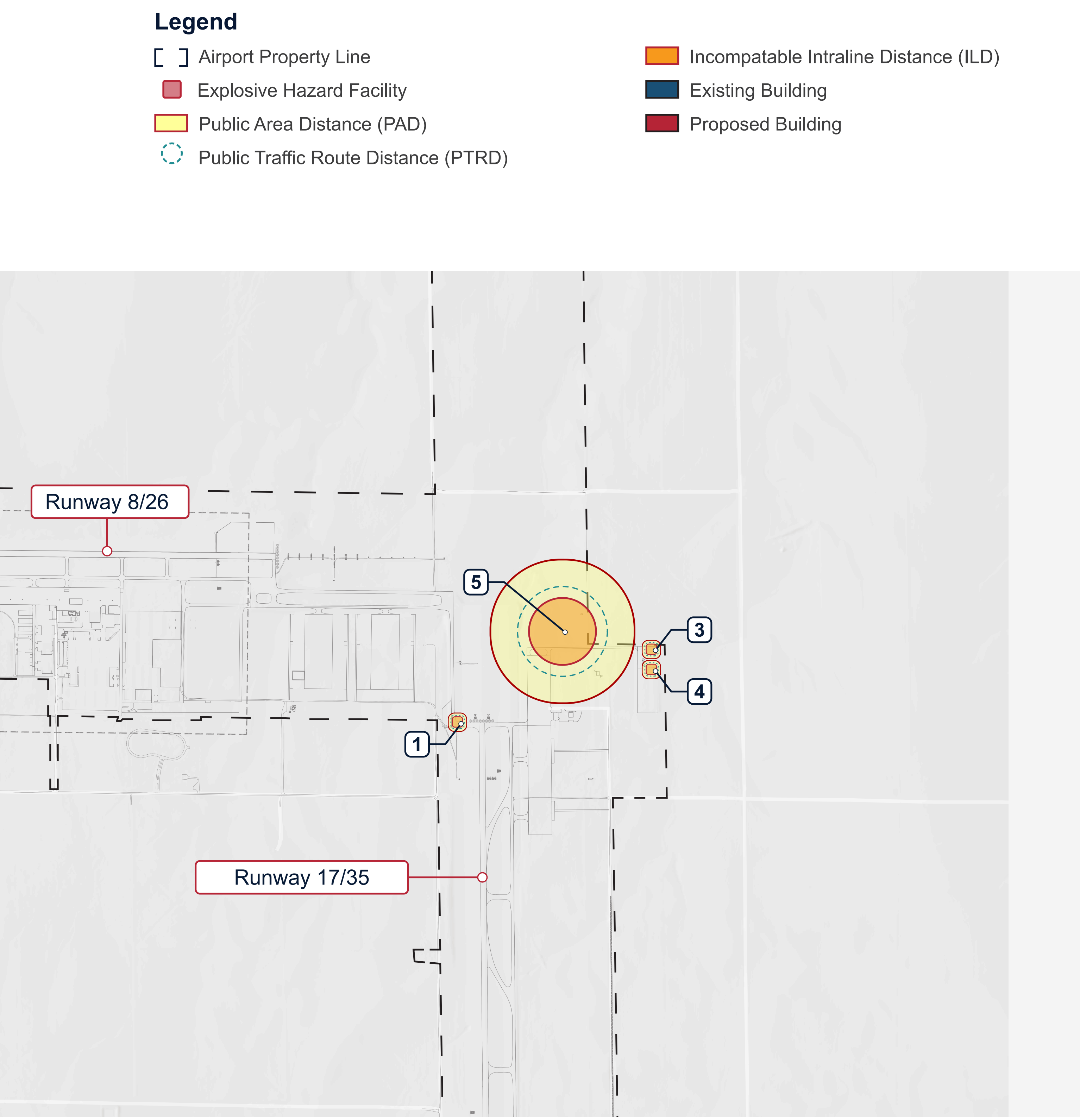


Figure 2-4. Explosive Site Plan from Launch Site Operator License



Source: [2]

Mission Preparation Area #1

Mission Preparation Area #1 is anticipated to be utilized for rocket fuel loading (without oxidizer) and is proposed to be located on the south end of Taxiway E, west of the northern end of Runway 17/35 (see **Figure 2-1**). Jet fuel is anticipated to be loaded onto the aircraft utilizing an existing aviation apron prior to the launch vehicle moving to Mission Preparation Area #1 for rocket fuel loading. Once the liquid fuel is loaded, the final oxidizer loading will occur at Mission Preparation Area #2.

Mission Preparation Area #2

Mission Preparation Area #2 is anticipated to be utilized for rocket oxidizer loading operations and is proposed to be located south of Taxiway A on the western side of the airfield (see **Figure 2-1**). Final mission preparation will occur at this site and propellants will be topped off as needed. If the launch vehicle will be carrying space flight participants, participant loading will occur at this site prior to departure. If a mission is scrubbed, Mission Preparation Area #2 can be used to unload participants and propellants.

Fuel Storage Area (FSA)

Liquid fuels, such as RP-1 (Refined Kerosene), are common propellants used for launch vehicle propulsion. Currently no permanent liquid rocket fuel storage infrastructure exists at CASP.

An FSA is proposed and sited to be located on the eastern end of the airfield near the existing aircraft T-hangars, as identified in **Figure 2-1**. The near-term plan is to utilize the north end of the existing pavement east of the T-hangars for the temporary storage of rocket fuel tanker trucks. Rocket fuel tanker truck delivery will be coordinated with the launch operator and will remain on-site in accordance with operational plans. The long-term plan for the FSA is to construct permanent bulk storage tanks that will be sized to satisfy the storage requirements of the future launch operators.

Oxidizer Storage Area (OSA)

Liquid oxidizers, such as Liquid Oxygen (LOX), are common propellants used for launch vehicle propulsion. Currently no liquid oxidizer storage infrastructure exists at CASP.

An OSA is proposed and sited to be located on the eastern end of the airfield near the existing aircraft T-hangars, as identified in **Figure 2-1**. Near-term plans are to construct a concrete pad on the southern end of the existing pavement east of the T-hangars to support temporary storage of oxidizer tanker trucks. Oxidizer tanker truck delivery will be coordinated with the launch operator and will remain on-site in accordance with operational plans.

Rocket Engine Test Site

A dedicated Rocket Engine Test Site is proposed to be located northeast of Runway 17/35 (see **Figure 2-1**). The location of this site was selected to minimize potential impacts to existing aviation operations and the onsite Aircraft Rescue and Firefighting (ARFF) station.

In the future, this site will enable on-site testing of rocket engines. Safety separation distances have been applied to ensure compatibility with the proposed spaceport and existing and forecasted airport operations and development. Testing events will be coordinated with other Airport tenants to minimize potential impacts. If a new building is constructed within the 1,250 foot public area distance (PAD) of the test stand then the affected building will be vacated during testing operations, unless it can be demonstrated that the test will not adversely affect the safety of the uninvolved public. The Reaction Engines, Inc. Test Facility 2 (TF2) currently sits within the PAD of the proposed Rocket Engine Test Site. This facility would need to be vacated during rocket engine testing.

In February 2021 a Categorical Exclusion (CATEX) was issued by the FAA for small rocket engine testing at CASP and included the area for the proposed Rocket Engine Test Site.

Reaction Engines Test Facility 2 (TF2)

In addition to proposed launch site infrastructure and explosive hazard facilities, Reaction Engines TF2 is an important element of the Spaceport Master Plan because it enables the testing of components that may make their way into future commercial launch systems and advanced aircraft.

Reaction Engines, Inc. developed TF2 to provide long duration high-mass flow at high temperatures to test the company's innovative precooler technology. The facility contains a 3,500 square foot indoor test facility, a 500 square foot control room, and an 11,000 square foot test equipment pad.

In 2019, Reaction Engines, Inc. completed a test on their precooler heat exchanger that replicated supersonic flight conditions, and the company plans to conduct future tests at higher temperatures. The TF2 facility is currently available to support the testing needs of other users in addition to Reaction Engines, Inc.

Figure 2-5. Reaction Engines Test Facility 2

Source: Reaction Engines, Inc.

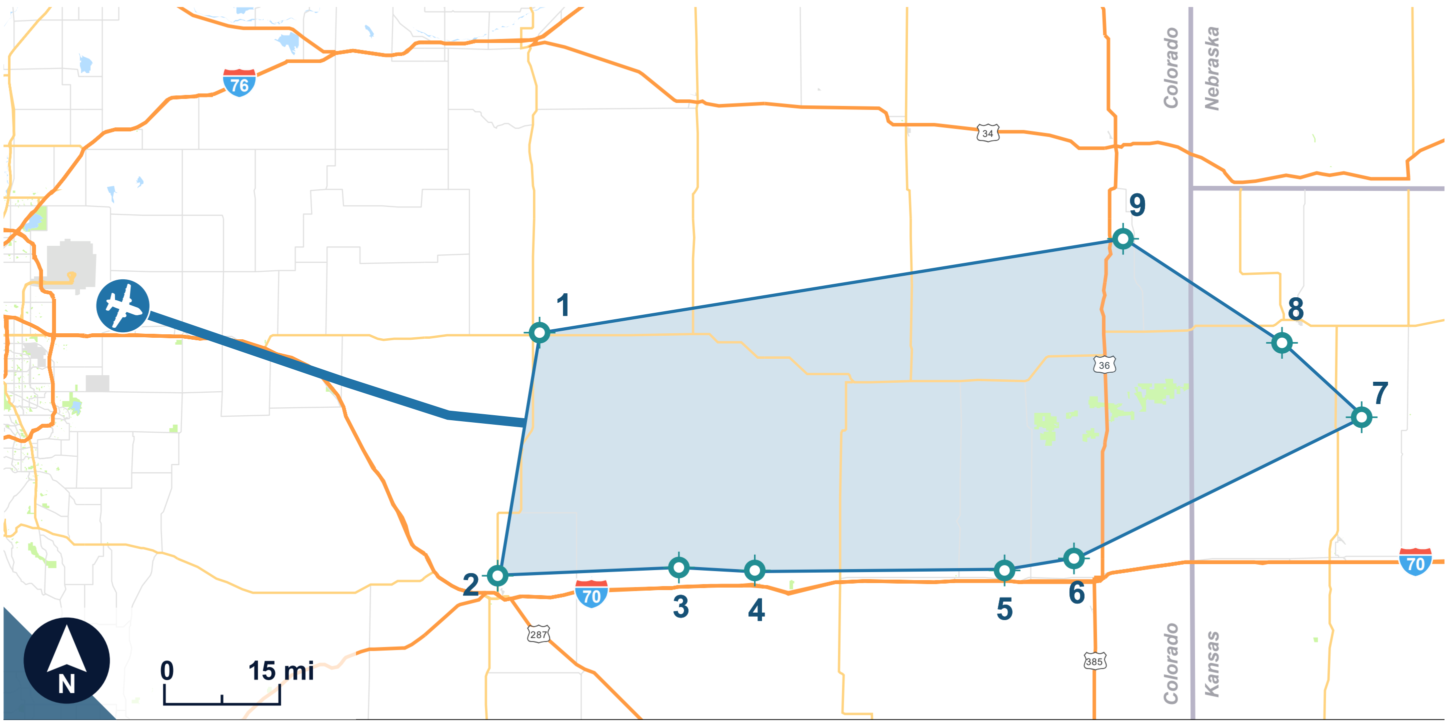
Proposed Launch Operating Area

During the FAA licensing process, a Letter of Agreement (LOA) was prepared to outline the procedures for issuing a Notice to Airmen (NOTAM) prior to a licensed or permitted launch operation. The airspace within the vicinity of CASP and Denver International Airport (DEN) was analyzed in an attempt to minimize potential airspace impacts on both departing and arriving flights at CASP and DEN. A proposed launch operating area was developed in coordination with FAA-AST and Denver Air Route Traffic Control Center (ARTCC) and is located southeast of CASP. This launch operating area is shown in **Figure 2-6**.

It is important to note that this proposed launch operating area is only notionally defined and does not provide a guarantee of use for launch activity. Any future licensed or permitted launches must obtain approval from FAA and further analysis must be conducted.

This section describes the existing conditions of the airspace and proposed launch operating area in the vicinity of CASP.

Figure 2-6. Proposed Launch Operating Area



Point	Latitude	Longitude
1	39° 44' 45.85" N	103° 34' 16.73" W
2	39° 18' 20.88" N	103° 39' 44.10" W
3	39° 19' 17.23" N	103° 14' 14.81" W
4	39° 18' 54.19" N	103° 3' 59.84" W
5	39° 19' 04.09" N	102° 28' 47.65" W
6	39° 20' 21.09" N	102° 18' 57.35" W
7	39° 35' 30.56" N	101° 38' 33.00" W
8	39° 43' 44.77" N	101° 49' 42.71" W
9	39° 55' 19.01" N	102° 12' 00.06" W

Legend

- Colorado Air and Space Port
- Operating Area
- Arrival and Departure Route
- Major Highways
- State Line

Source: Colorado Air and Space Port

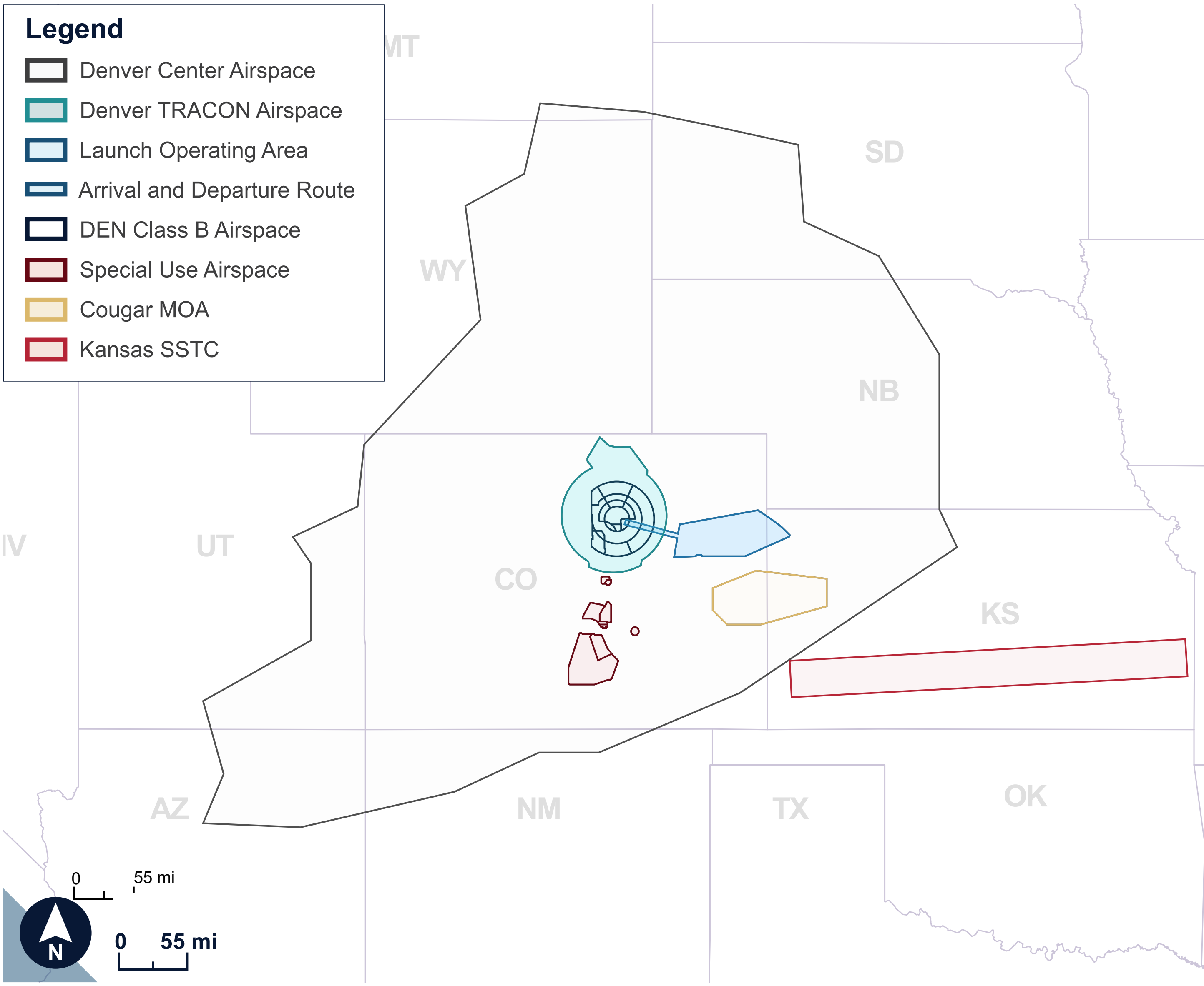
Airspace Structure

The airspace structure in and around CASP is within the Denver ARTCC (Denver Center) airspace, as shown in **Figure 2-7**. CASP sits directly below a shelf of Class B airspace that encompasses the region around DEN. Air traffic within the Class B airspace is coordinated to minimize potential operational interactions between airports. A proposed launch operating area exists to the southeast of CASP.

Launch operations originating from CASP are planned to depart east from Runway 8 or west from Runway 17 to minimize potential conflicts due to runway centerline crossings and to provide direct access to the launch operating area.

In December 2020 Kansas Department of Transportation signed an agreement with FAA to establish a Supersonic Transportation Corridor (SSTC) that would enable testing of aircraft up to Mach 3.

Figure 2-7. Airspace Structure in and around Colorado Air and Space Port



Source: Colorado Air and Space Port, Kimley-Horn

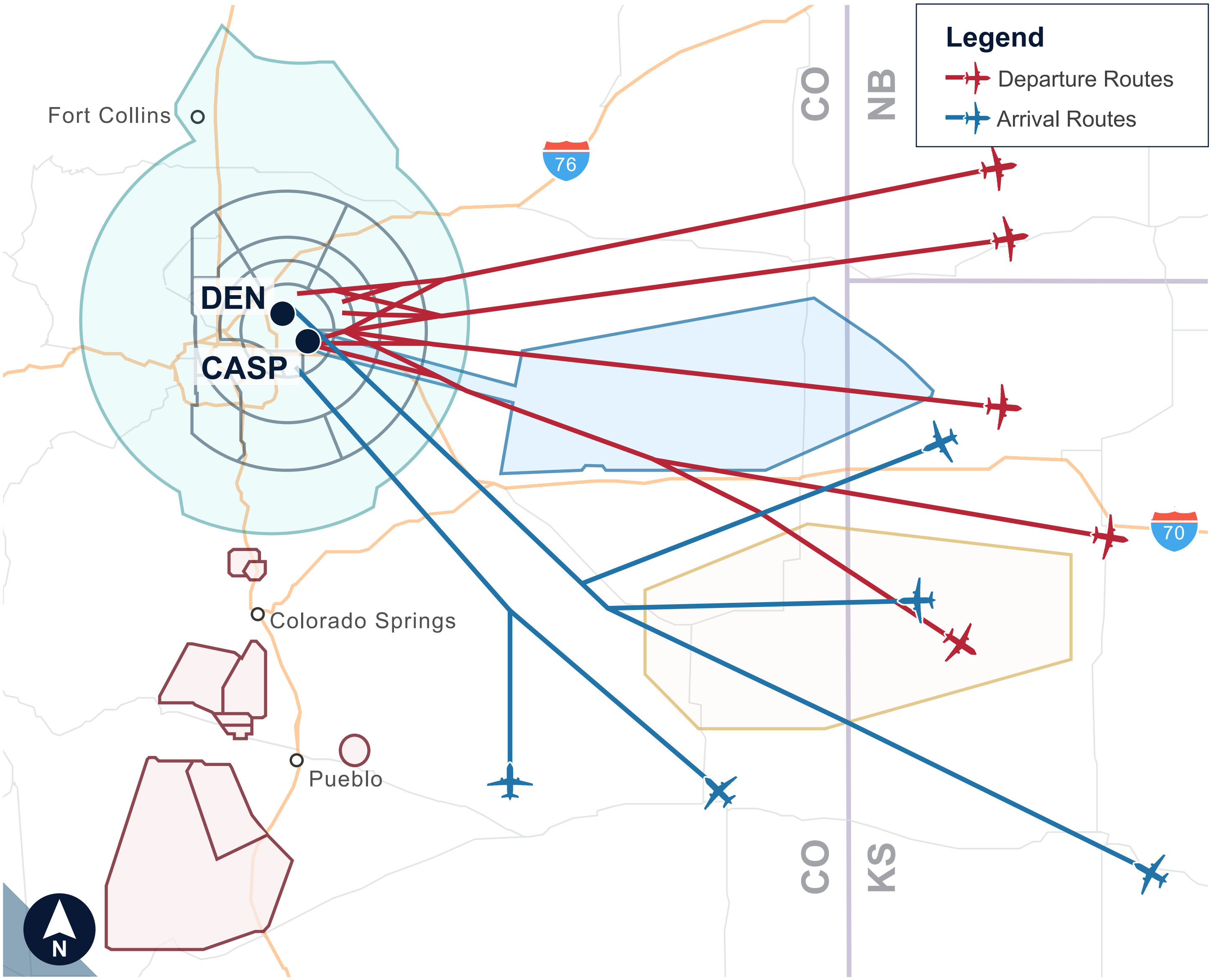
Air Traffic

Air traffic operations in the Denver TRACON airspace, which encompasses CASP, consist of several Standard Instrument Departures (SIDs) and Standard Terminal Arrival Routes (STARs) to and from DEN to the Denver Center enroute airspace. **Figure 2-8** shows the relative locations of the SIDs and STARs to the Denver TRACON airspace, the CASP arrival and departure route, the proposed launch operating area, and the Cougar Military Operating Area (MOA).

Given the location of the proposed launch operating area, it is important to note the following:

1. Two DEN SIDs, which utilize three different fixes, fly directly through the proposed launch operating area. This requires facility coordination to issue appropriate reroutes.
2. Current southeast SIDs, if rerouted, could deconflict the arrival and departure route for operations enroute to the proposed launch operating area.
3. The southeast STARs do not appear to be impacted by the proposed launch operating area.

Figure 2-8. Denver Departure and Arrival Routes



Source: TARGETS Software, Kimley-Horn

Approach Capability

Approach operations within Class B airspace at CASP require coordination with the DEN airport traffic control tower (ATCT). Depending on wind conditions, arrivals on Runway 17 and Runway 26 at CASP provide for the least amount of potential interaction with current DEN operations. It should be noted that these conditions may vary depending on timing of relevant arrival and departure schedules at DEN.

Aviation/Aerospace Activity Data

This section provides a brief description of activity data for CASP.

Aviation

CASP is defined as a GA airport and has approximately 430 based aircraft including single-engine aircraft, multi-engine aircraft, jet / turboprop aircraft, helicopters, and other types of aircraft [3]. In 2018, CASP supported approximately 91,600 operations (approximately 59 percent local GA, 38 percent itinerant GA, 3 percent military, and less than 1 percent air carrier) [3]. For additional information on both historical and forecasted aviation activity at CASP, refer to the current Airport Master Plan [1] or Colorado Aviation System Plan [3].

Aerospace

There have not been any aerospace related launch operations at CASP since obtaining an LSOL in 2018. The active license proposed up to 52 launches per year of Concept X type RLVs.

Environmental Conditions

A comprehensive environmental review was completed during the FAA licensing process for CASP. A Final Programmatic Environmental Assessment (PEA) for the Front Range Airport Launch Site Operator License was prepared by the FAA and a Finding of No Significant Impact (FONSI) was issued in 2018. A CATEX for rocket engine testing was issued in February 2021.

This section provides a basic summary of the environmental conditions and community resources on and near CASP that could potentially be affected by spaceport development. The information in this section was collected through a general review of existing reports, GIS data, studies, and environmental documents.

Air Quality and Climate

Under the Clean Air Act, the United States Environmental Protection Agency (USEPA) has established National Ambient Air Quality Standards (NAAQS) for pollutants of concern known as “criteria pollutants” (40 CFR part 50). The Colorado Department of Public Health and Environment, Air Pollution Control Division has adopted the NAAQS and also maintains two state air quality standards. Areas that are currently and have historically been in compliance with the NAAQS are designated by the Environmental Protection Agency (EPA) as attainment areas. Areas that violate a NAAQS are designated as non-attainment areas. Areas that have transitioned from non-attainment to attainment are designated as maintenance areas and are required to adhere to maintenance plans to ensure continued attainment.

The Metropolitan Denver Intrastate Air Quality Control Region, which includes Adams County, is designated as a moderate non-attainment area for ozone (40 CFR § 81.306). It is also designated as a maintenance area for Carbon Monoxide (CO) and Particulate Matter of 10 micrometers or smaller (PM10). The region is designated as an attainment/unclassifiable area for the following remaining criteria pollutants [7]:

- Sulfur Dioxide (SO_2)
- Particulate Matter of 2.5 micrometers or smaller (PM2.5)
- Lead (Pb)
- Nitrogen Dioxide (NO_2).

Biological Resources

Biological resources include terrestrial and aquatic plant and animal species and their habitats, including special status species (federally- or state-listed threatened or endangered species, species proposed for listing, species that are candidates for federal listing, marine mammals, and migratory birds) and environmentally sensitive or critical habitats.

Property within the CASP boundaries has been highly modified; therefore, none of the native plains grassland ecosystem remains. Landcover in undeveloped areas primarily consists of mowed grass and cultivated cropland. Wildlife at CASP includes a variety of birds, mammals, reptiles, and amphibians. According to the United States Fish and Wildlife Service (USFWS), seven federally-protected species may be present at CASP [8]. In addition to the federally protected species, three state-listed species with the potential to have habitats near CASP were identified in the 2018 PEA, but they are not currently known to be present at CASP [9]. In the broader Adams County region, nine additional threatened and endangered species are identified in the 2019 Airport Master Plan.

CASP maintains a Wildlife Hazard Management Plan that was completed in 2015.

Farmlands

The area surrounding CASP is primarily agricultural. It is an upland prairie setting with open rolling grasslands in what is known as the Platte River Basin. Much of the area that would be affected by the installation of additional infrastructure at CASP has already been disturbed by previous aviation development activities. Land within the CASP boundary has been designated by Natural Resources Conservation Service as either not prime farmland or prime farmland if irrigated (see **Figure 2-9**. **Farmland Soils**). Currently, there is no plan to irrigate the land within the CASP property. As shown in **Figure 2-9**, there is some Farmland of Statewide Importance outside of the CASP boundary to the west and the north of Runway 8/26.

Hazardous Materials, Solid Waste, and Pollution Prevention

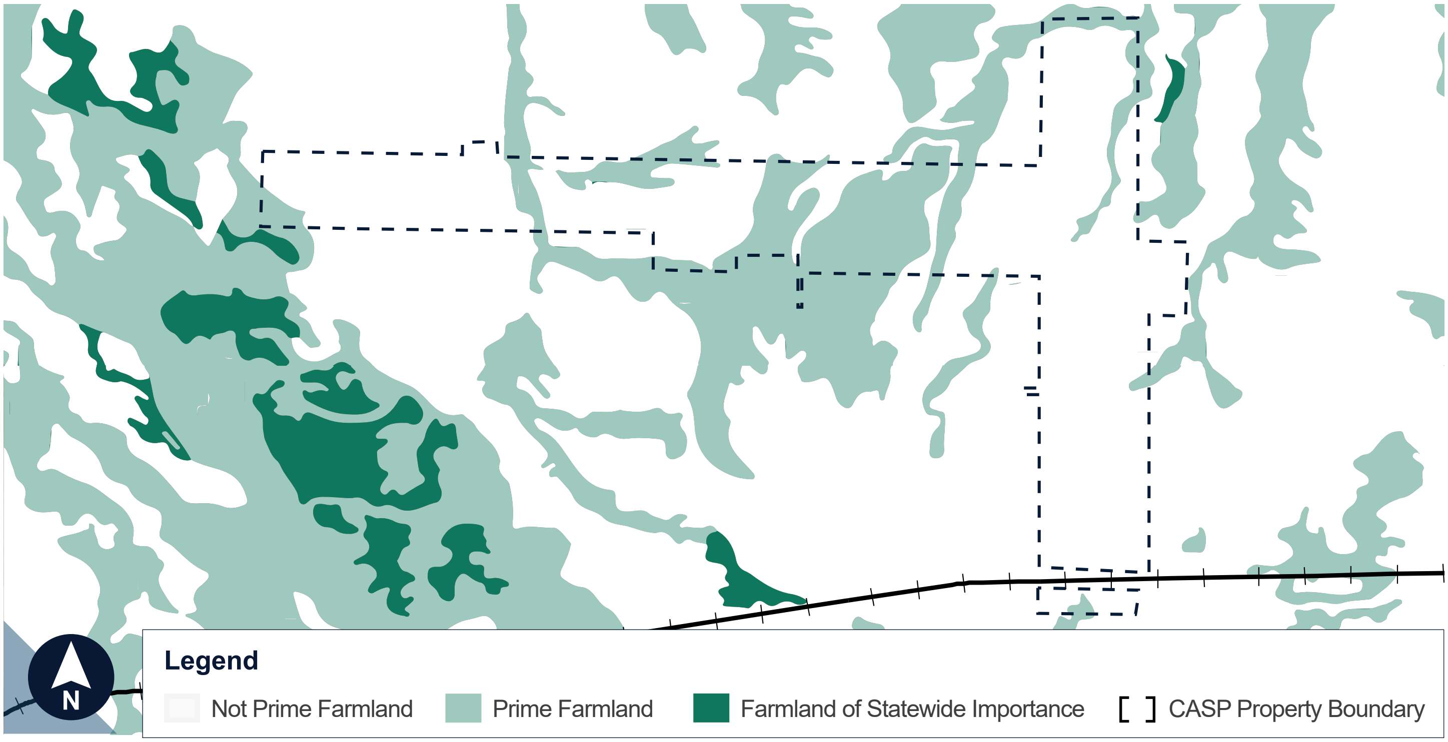
The routine hazardous waste generation associated with the aircraft maintenance and fueling operations and with the maintenance of the CASP facilities and grounds is currently at a level that classifies CASP as a conditionally exempt small quantity generator of hazardous waste. Aviation fuel is currently stored in two locations: adjacent to the terminal apron and at a dedicated fuel farm located on Cessna Way, southeast of the terminal area [1]. Several hazardous waste generators, petroleum release sites, commercial/industrial storage tanks, and solid waste facilities are located at or in the vicinity of CASP (see **Figure 2-10**). Future propellant storage areas have been identified to support spaceport operations and are presented in **Figure 2-1**.

Water Resources

CASP is located within the Middle South Platte-Cherry Creek Watershed. There are no Wild and Scenic Rivers in the vicinity of CASP. Water resources within the CASP property boundary include wetlands, surface waters, floodplains, and the regulatory floodway. As shown in **Figure 2-11**. Water Resources10, the majority of these water resources are located to the west of Runway 8/26 along Bear Gulch.

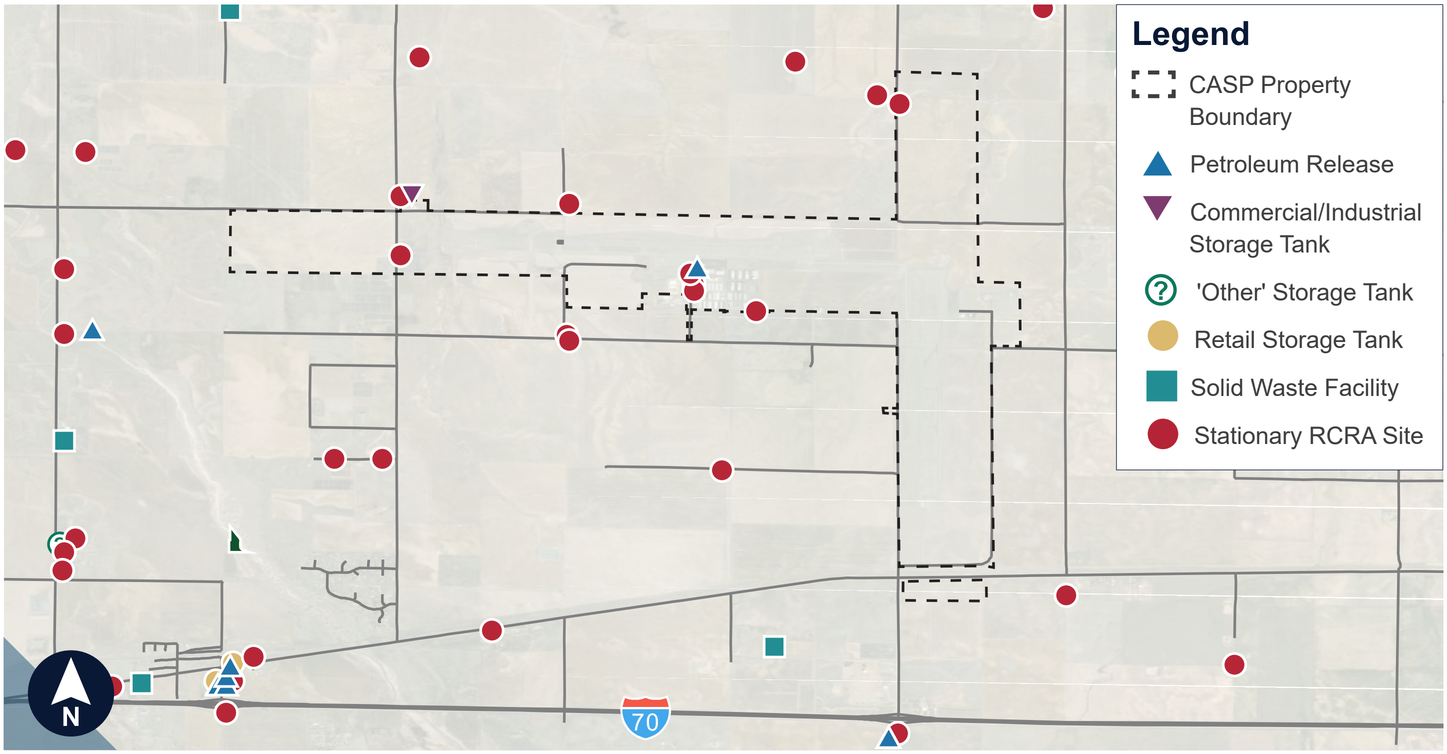
There is an industrial area at CASP that is located primarily in the Box Elder Creek Drainage Basin. The existing drainage system within this CASP industrial area consists of storm sewer inlets and pipes that collect flows and convey them to either Bear Gulch Basin or to an unnamed tributary basin that leads to Newcomb Gulch Basin. The industrial area is located primarily in the Box Elder Creek Drainage Basin. According to the 2018 PEA, CASP has a Stormwater Management Plan and a state stormwater permit for discharge of stormwater associated with industrial activities (Permit Number COR900211). In addition, a Spill Prevention, Control, and Countermeasures plan pursuant to 40 CFR Part 112 was developed for, and is incorporated into, the Emergency Response Manual. The plan covers procedures for the prevention and clean-up of spills of fuels and other related materials and meets all requirements of the General Stormwater Permit.

Figure 2-9. Farmland Soils



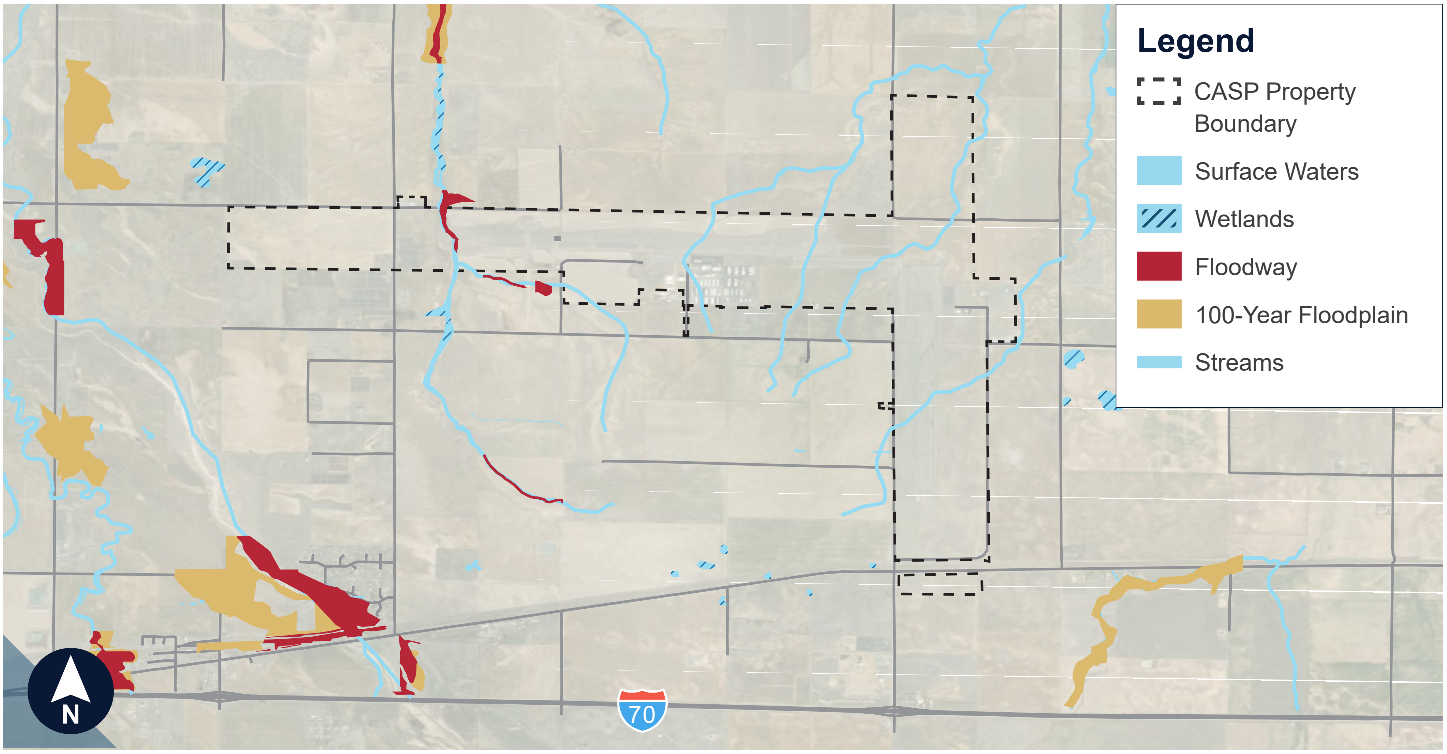
Source: Kimley-Horn

Figure 2-10. Hazardous Materials



Source: Kimley-Horn

Figure 2-11. Water Resources



Source: Kimley-Horn

Land Use, Zoning and Socioeconomic Profile

This section describes the land use and zoning data as well as the socioeconomics of the area surrounding CASP.

Vicinity Land Use and Zoning Data

CASP is located six miles from DEN, is easily accessible from the interstate, and is proximate to a rail line. CASP is surrounded by multiple jurisdictions, including unincorporated Adams County, the City of Aurora, the Town of Bennett, and the City and County of Denver. Each of these jurisdictions play a key role in the development around CASP.

Most local units of government have comprehensive plans, which are long-range planning documents that delineate land use policy, zoning designations and jurisdictions, and other pertinent land use planning initiatives. The most recent Adams County Comprehensive Plan was adopted in 2012. Although the document has not been updated since the Front Range Airport changed its name to the Colorado Air and Space Port, specific policies pertaining to the facility include:

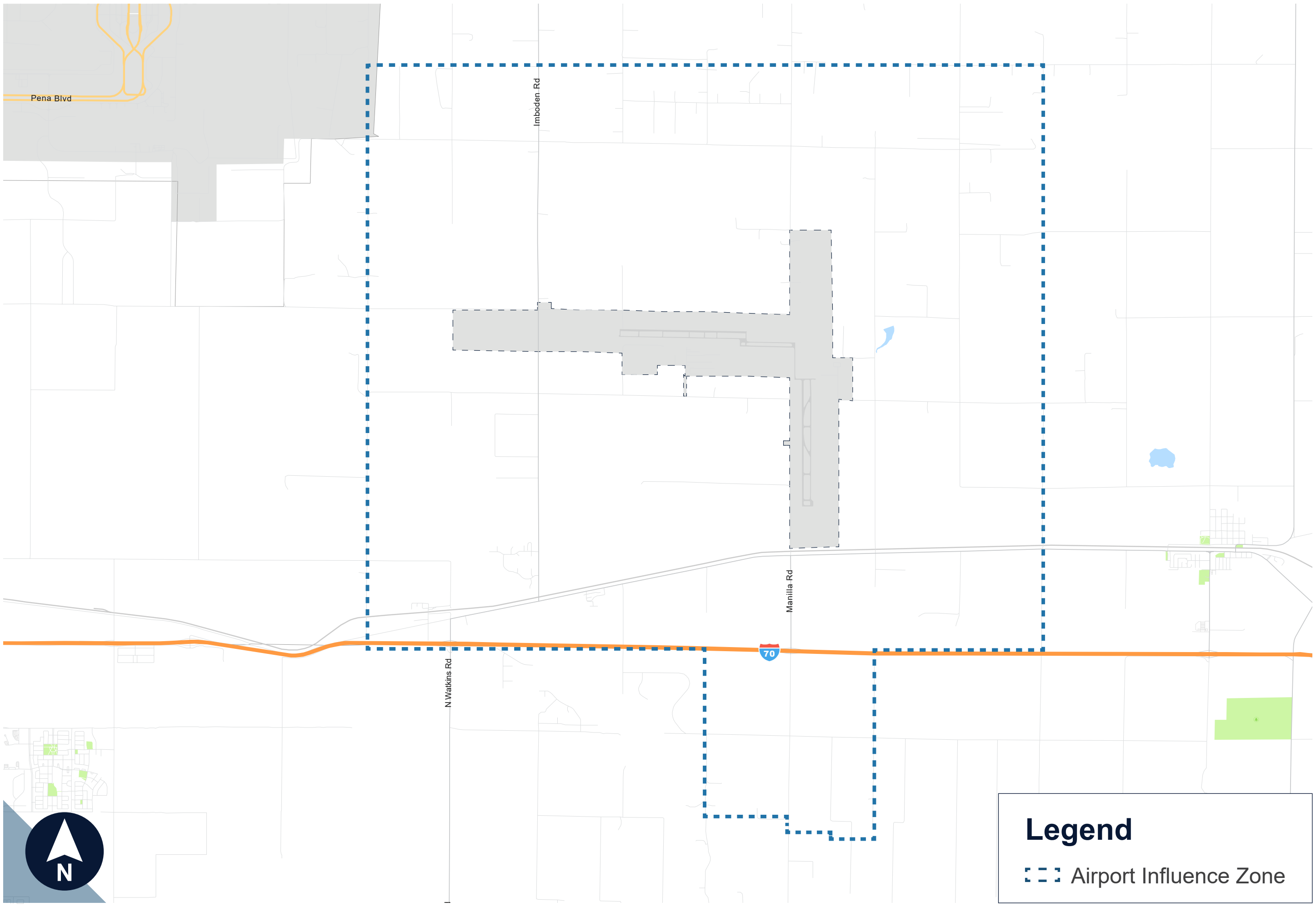
- **Policy 11.4: INFORM DEVELOPMENT OF POTENTIAL AIRPORT-RELATED IMPACTS –** Continue to require avigation easements and/or notice to prospective purchasers of residential property located within two miles (or other appropriate distance) of the 60 Ldn noise contour associated with the full build out of Front Range and Denver International Airports.
- **Policy 18.1: SUPPORT THE EXPANSION OF THE FRONT RANGE AIRPORT –** Continue to support and develop the Front Range Airport to accommodate large aircraft, as a general aviation and intermodal cargo hub for the state and region.
- **Policy 18.2: SUPPORT COMPATIBLE COMMERCIAL AND INDUSTRIAL DEVELOPMENT –** Support compatible commercial and industrial development around the Front Range Airport.
- **Policy 18.3: ENSURE COMPATIBLE SURROUNDING USES –** Ensure that land uses outside the Airport Influence Zone surrounding the Front Range Airport are compatible with airport operations and impacts.

Adams County adopted the development of a Subarea Plan for the CASP area in 2021. The purpose of the Subarea Plan is to provide a vision for the desired future for this area and to serve as a guide for review of future development proposals. The Subarea Plan offers greater detail about the intended future of the area around CASP, including land uses, infrastructure requirements, and development policies and standards.

Airport Influence Zone (AIZ)

Land in the vicinity of the CASP has been identified as an Airport Influence Zone (AIZ). The AIZ is a 9-mile by 9-mile area surrounding the CASP (see **Figure 2-12**) and includes land impacted by the location of CASP and the noise created by low-flying aircraft [14].

Figure 2-12. 2021 Airport Influence Zone

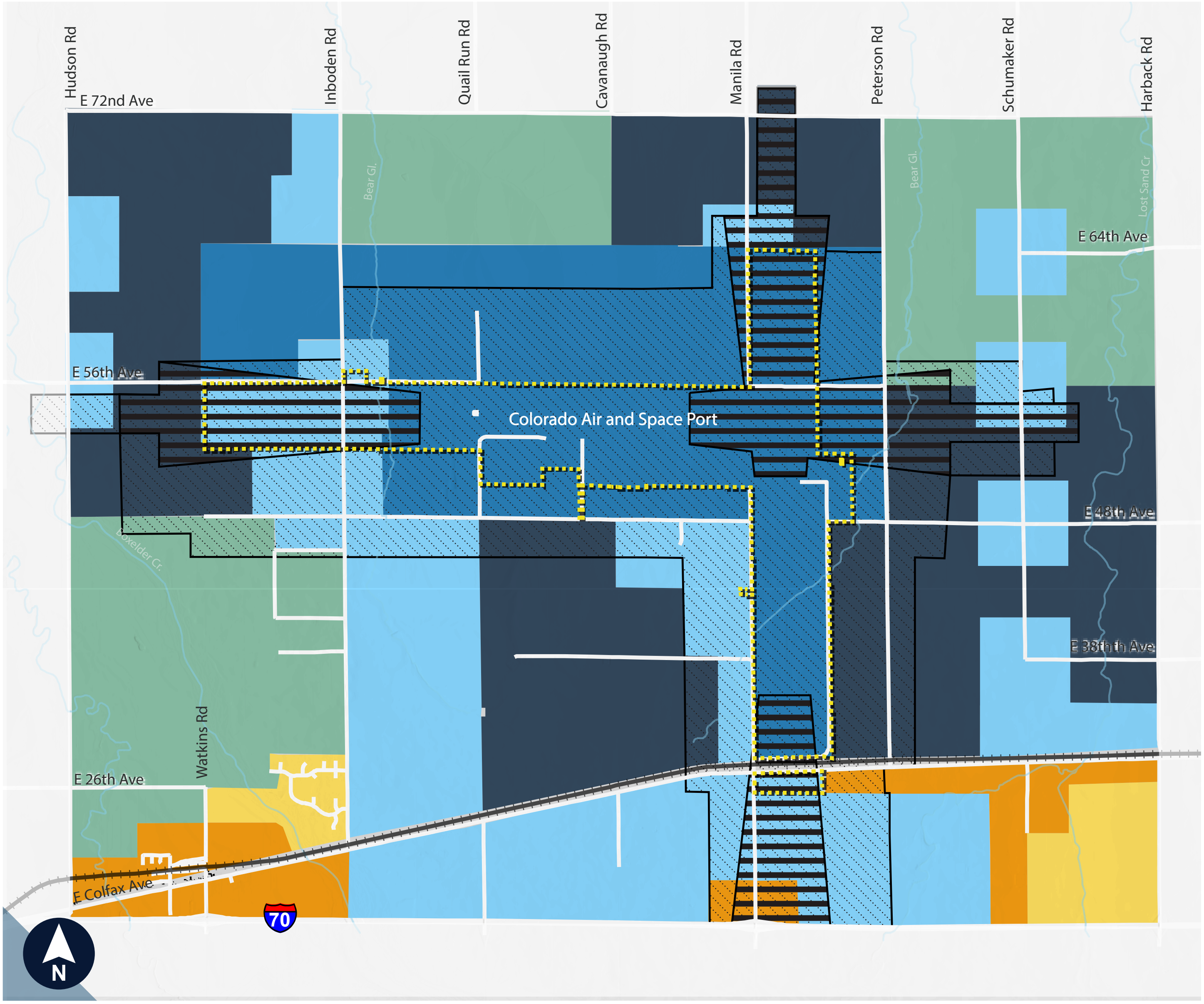


Source: Adams County

Subarea Land Use Planning

In 2021 Adams County adopted land use planning guidance for the Subarea in the immediate vicinity of the air and space port. The Subarea Plan's land use vision shifts from today's primarily agricultural focus to a future based on employment and innovative land uses, while accommodating existing uses and minimizing impacts on nearby residential neighborhoods. A major theme of the Future Land Use Plan (see **Figure 2-13**) is the "nodal" development pattern which concentrates future mixed-use development (mixed-use industrial and community hub character areas) in the vicinity of existing and future intersections. The Future Land Use Plan also considers appropriate buffers and transitions from existing and future residential areas and higher intensity industrial and aerospace uses to limit potential noise and traffic conflicts. For additional information on the Subarea, see the Colorado Air and Space Port Subarea Plan (Source: [6]).

Figure 2-13. Future Land Use Plan for Subarea



Character Areas

- Industry Hub
- Aerospace and Innovation
- Green Energy and Sustainable Agriculture
- Mixed-Use Industrial
- Community Hub
- Neighborhood Residential

Restriction Areas

- Restriction Area 2
- Restriction Area 1

Source: Adams County [6]

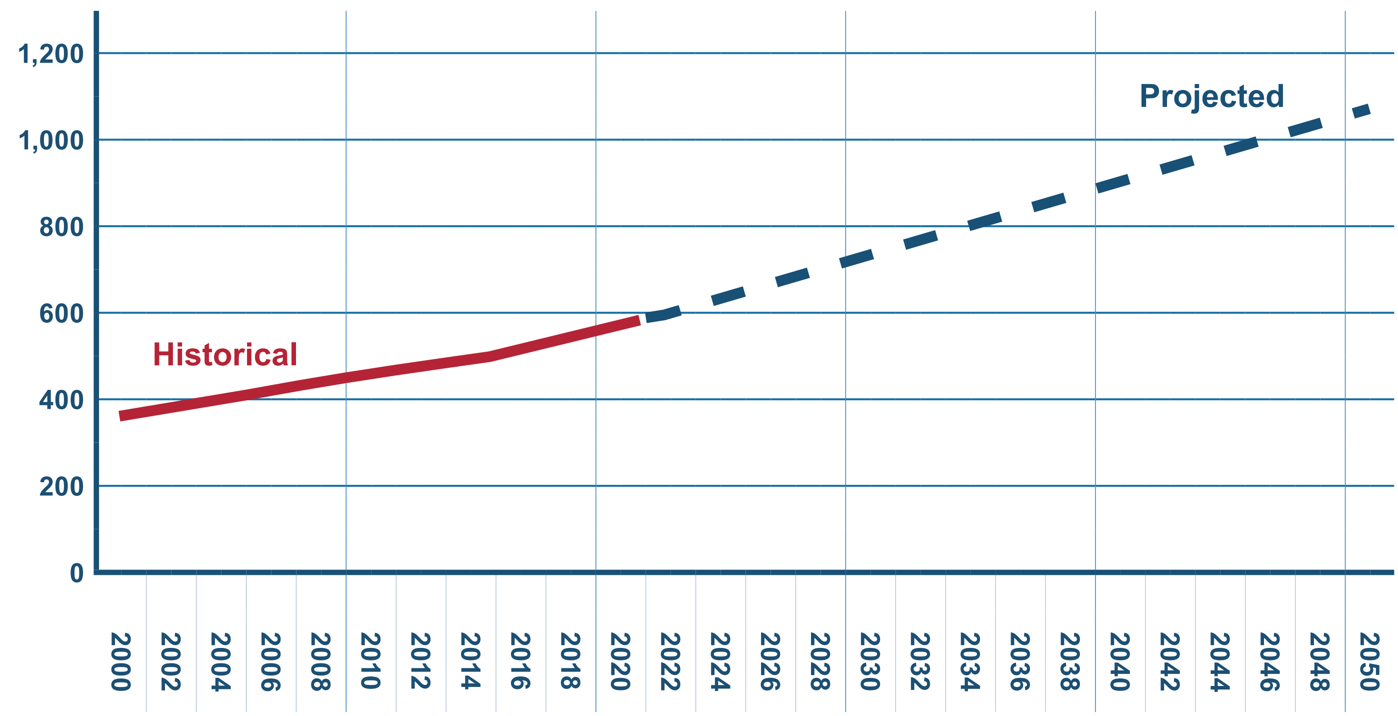
Socioeconomics

The socioeconomic characteristics of an area contribute to the nature of the surrounding economy and the industries present. The types of services provided at an airport or spaceport, and the extent to which those services are demanded, is also related to the socioeconomic characteristics of an area. Socioeconomic data from the Colorado Department of Local Affairs (CDLA) and Bureau of Economic Analysis (BEA) were reviewed to identify historical and current population, income, employment, and other demographic characteristics of Adams County, where CASP is located. These data will be incorporated into the forecasting models and master planning efforts for CASP.

Population and Population Growth

According to the CDLA, Adams County was estimated to have a population of over 511,000 people in 2018, which is the most recent population data available. The County is the state's fifth most populous, representing about nine percent of the state's total population of 5.7 million. The population of Adams County has increased 1.8 percent annually since 2010, when the population was approximately 443,000. This growth rate was 0.3 percent greater than the statewide growth rate over the same ten-year period. Over the next 30 years the population of Adams County is projected to grow to 852,000. Adams County experienced a net migration of 3,600 people in 2018, and it has experienced a total net migration of 36,000 people since 2010. Adams County was one of only 10 counties in Colorado to experience positive net migration greater than 10,000 between 2010 and 2017, as shown in **Figure 2-14**. All 10 of the top counties were along the I-25 corridor in north-central Colorado.

Figure 2-14. Adams County Population Growth (In Thousands)



Source: Colorado Department of Local Affairs

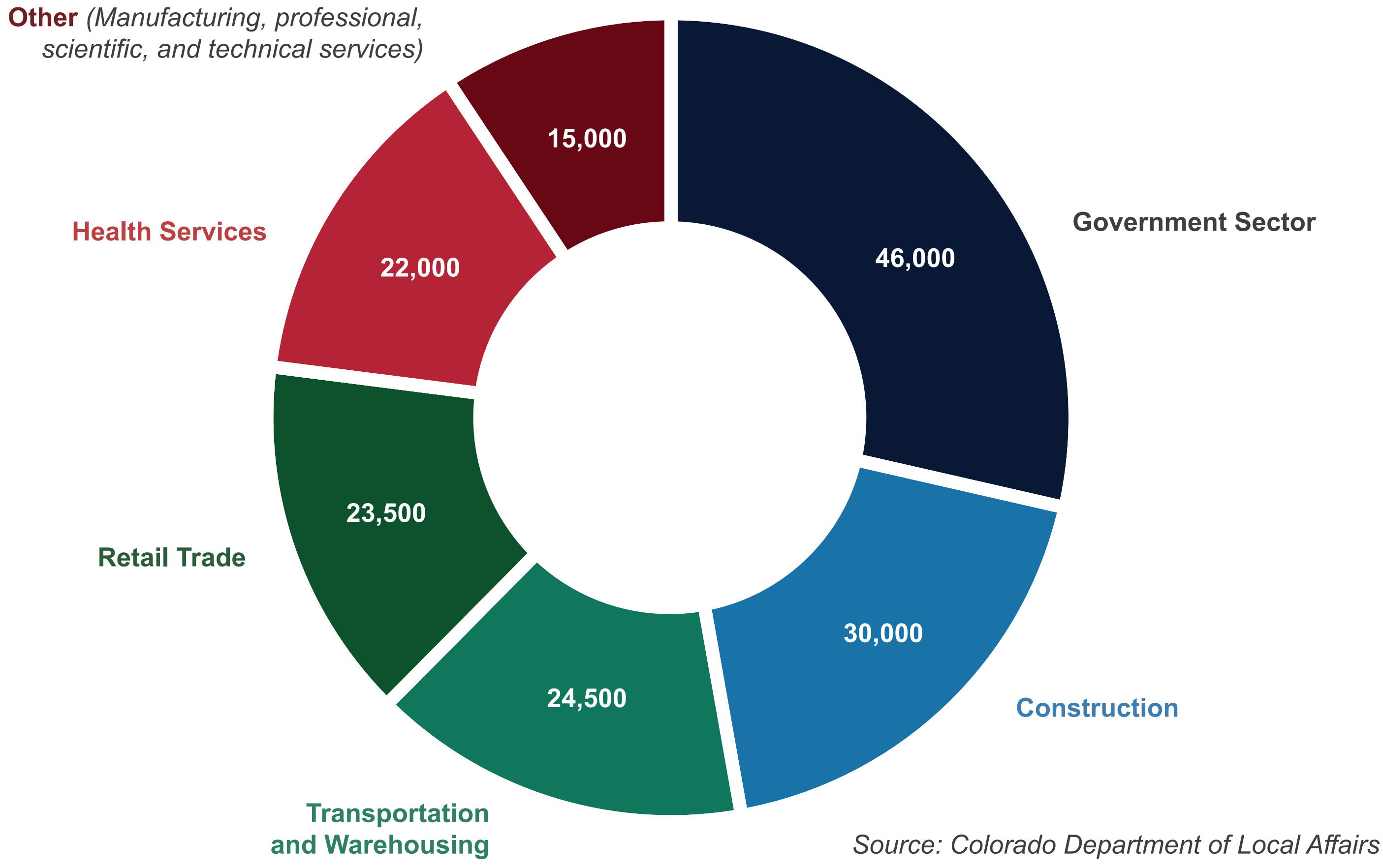
Income and Employment

As of 2018, the gross domestic product (GDP) for Adams County was approximately $26.8 billion which accounted for about seven percent of the state's $371.7 billion GDP. The GDP in Adams County grew steadily between 2015 and 2018 at a rate of about four percent each year, outpacing the growth rate of both Colorado and the United States during the same time period. The largest industries in Adams County by contribution to the total GDP were government ($4.5 billion), trade ($4 billion), manufacturing ($3 billion), and construction ($2.8 billion)[1].

The per capita personal income level in Adams County was approximately $43,000 in 2018, and the average earnings per job in the same year was $60,000 across a total employment level of 287,000 jobs[2]. The per capita income level rose by four percent and five percent respectively in the two preceding years, which also outpaced the United States by about a quarter of a percent each year. However, this increase trailed Colorado's growth rate by 1.6 percent and 0.4 percent in 2017 and 2018, respectively.

In 2018 the labor force in Adams County was comprised of about 269,000 people, which represented a 69.5 percent participation rate. The government sector employed the largest number of people (46,000). Other sectors which employed more than 200,000 people in 2018 included construction (30,000), transportation and warehousing (24,500), retail trade (23,500), and health services (22,000). Other sectors which included manufacturing, professional, scientific, and technical services employed about 15,000 people in 2018.

Figure 2-15. Adams County Labor Force



Source: Colorado Department of Local Affairs

1 Industry specific GDP data for agriculture, forestry, fishing and hunting, utilities, educational services, and natural resources and mining were not available to avoid disclosure of confidential information.
2 The per capita personal income is calculated as the total personal income of Adams County divided by the total population of Adams County. The average earnings per job is calculated as the total earnings by place of work in Adams County divided by the total number of jobs in Adams County.

Local Development

CASP is located within an unincorporated area of Adams County about thirty minutes east of downtown Denver and ten minutes west of the Town of Bennett. These areas are all located within the Denver-Aurora-Lakewood Metropolitan Statistical Area (MSA), an area that generated $214 billion in GDP in 2018. In addition to numerous developments in the Denver area, the unincorporated area of Adams County surrounding the CASP has also seen hundreds of rezoning, PUD, and other development applications submitted within the last five years. Some of the proposed developments listed on the Adams County Development Services website that are immediately adjacent to the include:

- 620-acre Rocky Mountain Rail Park PUD industrial park with 11 lots
- Rail terminal and services facility off Union Pacific rail line
- Precision Building Systems 294,600 square foot industrial facility within the Rocky Mountain Rail Park
- Rezoning plots of 78 acres, 40 acres, and 35 acres from Agricultural to Industrial uses
- Copeland Precast concrete manufacturing facility
- Multiple ground mounted solar array fields
- 5.5-mile long 230 kV electrical transmission line
- Food processing facility

These proposed developments are consistent with the Imagine Adams County Comprehensive Plan (2012) 5 which described “significant future growth potential…in the Front Range Airport environs” within the I-70 corridor. This plan outlined policies and strategies for the I-70 corridor and CASP area which included:

- Supporting the expansion of the Front Range Airport by reviewing zoning provisions to ensure that aviation-related commercial and employment uses are permitted within the AIZ and reviewing and updating the Airport Master Plan at least every five years.
- Supporting compatible commercial and industrial development by reviewing and updating permitted uses within the Airport Overlay Zone District to encourage development of commercial and industrial uses, providing economic incentives to attract new businesses or redevelopments, and investing in infrastructure required to attract and support new industrial and commercial developments.
- Ensuring compatible surrounding uses by reviewing and amending the AIZ boundary and requiring proposed developments within the AIZ to be approved by CASP.

While the area nearest to CASP is focused on industrial and commercial development, the neighboring Town of Bennett is focused on accommodating future urban growth by securing reliable infrastructure including a water supply. The 2012 Comprehensive Plan outlined strategies to concentrate growth in employment and neighborhood centers within the town’s Area of Planning Interest and to encourage intergovernmental coordination between Adams County and the Town of Bennett to support regional infrastructure improvements, revenue sharing, development nodes, and joint development standards.

3

Chapter 3

Spaceport Activity Forecast

SPACEPORT ACTIVITY FORECAST

Understanding forecast activity is an important part of any master planning process. Forecast activity is often the basis for identifying future facility requirements. However, due to the nature of the commercial space industry it is difficult to forecast both the timing and magnitude of space activities. As part of the Spaceport Master Plan process for CASP, Bryce Space and Technology (Bryce) developed a 20-year forecast of suborbital horizontal launch and reentry activity.

This chapter summarizes the Bryce forecast analysis and incorporates additional considerations related to market opportunities. Additional details of the analysis are included in the report Forecast and Market Analysis of Horizontal Space Launch and Reentry at Colorado Air and Space Port (CASP) included in **Appendix C**. After reviewing existing available forecasts, the Bryce analysis identified factors that will influence markets, reviewed peer US spaceports, described CASP's critical suborbital vehicles, and characterized manufacturing, infrastructure, and transportation modes supporting suborbital vehicles.

Launch Systems Review

As discussed in Chapter 1, CASP currently has an LSOL to serve Concept X suborbital RLVs. Suborbital RLVs are reusable space vehicles that carry humans, cargo, and/or experiments to suborbital altitudes. They typically follow a four-phase mission profile: 1) launch phase, 2) parabolic trajectory phase, 3) reentry phase, and 4) landing phase. During the second phase, the RLV reaches its apogee, or peak, and passengers, cargo, or experiments experience several minutes of microgravity. Concept X vehicles are one of the three main types of HTHL suborbital RLVs, as classified by the FAA:

- Concept X suborbital RLVs take off from and land on a runway using jet engines but use rocket engines to reach their apogee.
- Concept Y suborbital RLVs take off from a runway using a rocket engine and make an unpowered landing.
- Concept Z suborbital RLVs use an air-drop design where a jet powered airplane releases a rocket powered launch vehicle that may make an unpowered landing.

In addition to HTHL suborbital RLVs, other commercial launch/reentry systems include:

- Reentry vehicles
- High-altitude balloons
- Vertical Takeoff Vertical Landing (VTVL) systems

A selection of potential launch systems, reentry systems, and support vehicles in various stages of development, at the time of this report, are presented in **Figure 3-1**.

Figure 3-1. Launch, Reentry and Support System

	Vehicle Description	Carrier Aircraft	Estimated Development Progress					Status
			Preliminary				Operational	
			1	2	3	4	5	
X	RocketPlane XP	None	■	■				Canceled
X	Airbus Defence and Space SpacePlane	None	■					On Hold
X	Bristol Ascender	None	■					Active
X	PD Aerospace Spaceplane's	None	■					Active
X	SABRE Development Vehicle	None	■					Active
X	Reaction Engines Skylon	None	■					Active
Y	XCOR Lynx	None	■	■	■			Canceled
Y	Dawn Aerospace Mk-II Aurora	None	■	■	■			Active
Y	Dawn Aerospace Mk-III	None	■					Active
Z	Northrop Gumman Pegasus XL	L-1011	■	■	■	■	■	Active
Z	Coleman Aerospace	C-17	■	■	■	■	■	Active
Z	Coleman Aerospace	C-130	■	■	■	■	■	Active
Z	Virgin Orbit LauncherOne	B747-400	■	■	■	■	■	Active
Z	Virgin Galactic SpaceShipTwo	WhiteKnightTwo	■	■	■	■		Active
Z	Stratolaunch Talon-A	Roc	■	■	■	■		Active
Z	Generation Orbit X-60A	NASA C-20A	■	■	■			Active
Z	Aevum	Ravn X	■	■				Active
Z	Bristol Spacecab	Custom	■					Active
Z	Bristol Spacebus	Custom	■					Active
Z	Orbital Access Orbital 500R	MD-11	■					Active
Z	S3 SOAR Spaceplane	A300	■					Canceled
Reentry Vehicle	Boeing X-37B	Vertical Rocket	■	■	■	■	■	Active
Reentry Vehicle	Sierra Space Dream Chaser	Vertical Rocket	■	■	■	■		Active
Support Vehicle	Zero-G (727-200)	None	■	■	■	■	■	Active
Support Vehicle	Super Guppy	None	■	■	■	■	■	Active
Support Vehicle	F-104 Starfighter	None	■	■	■	■	■	Active
Super Sonic	Boom XB-1	None	■	■	■	■		Active
Super Sonic	Aerion AS2	None	■	■				Canceled
Super Sonic	Spike S-512	None	■	■				Active
Super Sonic	Boom Overture	None	■					Active
Balloon	World View Stratollite	Balloon	■	■	■	■	■	Active
Balloon	Space Perspectives Neptune	Balloon	■	■	■			Active
VTVL	Masten Xodiac	None	■	■	■	■	■	Active
VTVL	Blue Origin New Shephard	None	■	■	■	■	■	Active
VTVL	SpaceX Starship	None	■	■				Active
VTVL	New Frontier Aerospace	None	■					Active

Source: Kimley-Horn

Active Suborbital Programs

There are currently two suborbital RLV systems in service that address both the suborbital tourism and research and technology demonstration markets:

- Virgin Galactic's system is composed of the WhiteKnightTwo carrier aircraft and SpaceShipTwo spacecraft. It is expected to be operational by the end of 2022 and will operate from Spaceport America in New Mexico.
- Blue Origin's New Shepard launches and lands vertically and operates from a site owned by Blue Origin in rural Texas. It began operations in 2021.

Review of Previous Forecasts

Bryce completed a thorough review of previously published forecasts for the suborbital RLV market. A summary of the reviewed forecasts is presented in **Table 3-1**. Bryce concluded that several previous forecasts and market assessments provided useful background information but lacked sufficient support for the methodology or supporting evidence, were outdated, and/or included unprecedented or unrealistic growth rates. However, Bryce had a high level of confidence in one of the forecasts given the detail provided in the forecast and supporting methodology. Therefore, Bryce used this study as the baseline for its own forecasts. Additional information on this report is provided below. Bryce also reviewed the launch and reentry estimates included in nine spaceport environmental reviews. These forecasts were useful for understanding anticipated activity limits, but the forecasts themselves were obsolete.

Table 3-1. Previous Forecasts Review Matrix

	Projection(s)
Suborbital Reusable Vehicles: A 10-Year Forecast of Market Demand (2019 update)	Three forecast scenarios, all growth
Space Tourism Market Study: Suborbital Study with Update (2002, 2006)	S-shaped growth curve
Commercial Viability Evaluation of the Suborbital Space Tourism Industry (2019)	No specific projections
Space Tourism and Travel Markets (2020)	Proprietary
Great Expectations: An Assessment of the Potential for Suborbital Transportation (2008)	Adopts Tauri Group forecast
Market Demand Methodology for US Suborbital Reusable Launch Vehicle Industry (2014)	Forecasts level of tech development necessary for commercial market
Feasibility Study and Future Projections of Suborbital Space Tourism at the Example of Virgin Galactic (2008)	Focused forecast, with growth projection for Virgin Galactic
Next Generation Suborbital Activities: Assessment of a Commercial Stepping Stone (2010)	Projects increased investment in suborbital activity as risk perception falls

Source: Bryce Space and Technology

Source: Kimley-Horn

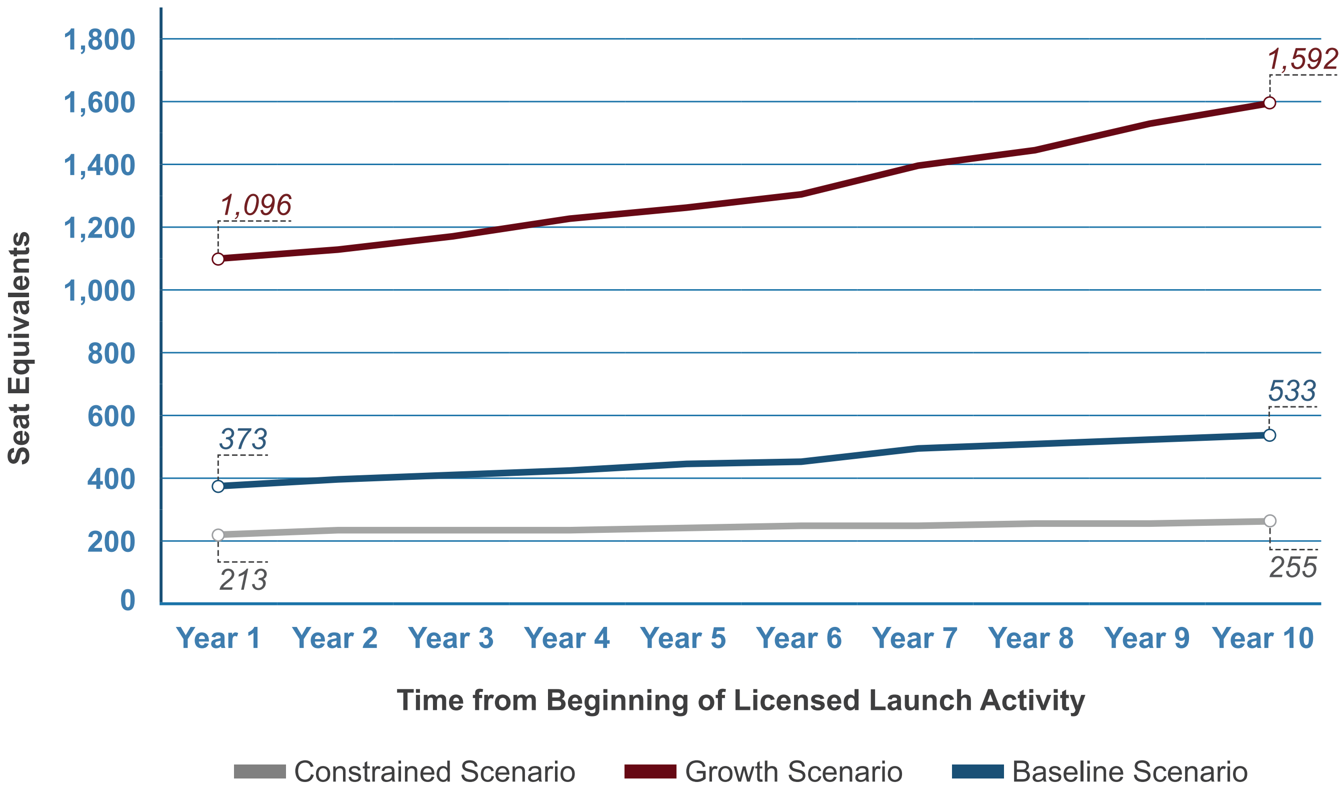
Source	Headline(s)	Source Type	Forecast Confidence
Bryce Space and Technology	Growing demand for commercial human spaceflight and basic/applied research once operations begin	3rd party	✓
Futron Corporation	Demand for sub-orbital tourism is strong, and revenues depend on uncertain supply	3rd party	~
Guerster, Crawley, and de Neufville	Market is very risky, and many approaches will fail	Academic	~
Northern Sky Research	Proprietary	3rd party	?
International Space University	Policy focused	Academic	~
Six authors from The Aerospace Corporation and NASA Armstrong	Costs must decrease and reliability must increase for a feasible sub-orbital tourism market	3rd party	?
Matthias Otto, Cologne Business School Köln	Overview of sub-orbital tourism market, with case study forecast of Virgin Galactic	Academic	?
Lackner and al-Midani, ALPS Ventures	With increased suborbital activities come reduced risk, and a broader investor base	3rd party	?

Suborbital Reusable Vehicles: A 10-Year Forecast of Market Demand (with 2019 update)

This 10-Year Forecast study was originally published in 2012 by the Tauri Group and updated in 2019 by Bryce. The study was jointly funded by the FAA and Space Florida. This study forecasted 10-year demand for suborbital RLVs by analyzing dynamics, trends, and areas of uncertainty in eight distinct markets these vehicles could address. This study combined primary research with open source materials to build a full and objective picture of suborbital RLV market dynamics. The forecast combined passenger and cargo demand by presenting the results in seat/cargo equivalents based on average capacity of suborbital RLVs. Three scenarios were forecast – baseline, growth, and constrained – to reflect the possibility of changes in the market.

As shown in **Figure 3-2**, this study resulted in a baseline forecast ranging from around 370 seat/cargo equivalents in Year 1 to over 500 seat/cargo equivalents in the 10th year, a total demand of $600 million over 10 years. However, the Year 10 forecasts ranged from 255 to nearly 1,600 seat/cargo equivalents in the constrained and growth scenarios, respectively. The study found that the largest source of demand for suborbital RLVs is the commercial human spaceflight market led by high-net-worth individuals (HNWI).

Figure 3-2. Forecast Results from Suborbital Reusable Vehicles: A 10-Year Forecast of Market Demand



Source: Tauri Group

Trends and Factors Impacting Spaceport Demand

This section focuses on market considerations that impact spaceport demand, including two primary markets identified by Bryce in relation to licensed launch and reentry activities. Additionally, a discussion of services and infrastructure provided by peer spaceports, other factors supporting the suborbital RLV market, and barriers to entry into the market are provided in this section.

Suborbital Launch Market Assessment

The 10-Year Forecast study identified eight suborbital markets that may be addressed by the various launch vehicles in development. Of the eight markets, Bryce concluded that only two of the markets projected high forecasts for the number of flights and associated revenue: 1) suborbital tourism and 2) suborbital research and technology demonstration. Flights and revenue associated with the other six markets are either considered minor in comparison, are not expected within the analysis timeline (before 2040), or it is probable that these markets are not sustainable due to competing alternatives. Additional details on these other six markets are provided in the Bryce report included as **Appendix C** to this Spaceport Master Plan.

Suborbital Tourism

Suborbital tourism is the use of suborbital RLVs by individuals who have purchased tickets to fly aboard these vehicles for pleasure. The advertised price per seat is in the low six figures and expected to rise to mid six figures after 2020. Two companies have planned commercial service for suborbital RLVs: Virgin Galactic and Blue Origin. Virgin Galactic sold over 600 tickets between 2004 and 2014. In August 2021, the company reopened ticket sales for $450,000 per seat. It is expected that Blue Origin opened a reservation system selling tickets in 2021. According to Bryce the first tickets are expected to cost “hundreds of thousands of dollars.”

Source: Virgin Galactic

Target Market. The target market for suborbital tourism is HNWI plus enthusiasts with a lower net worth. The number of HNWI with a net worth over $5 million increased over the five-year period between 2014-2019, with an estimated 5.7 million HNWI in 2019. Historically only a few HNWIs have expressed strong interest in suborbital tourism flights – mostly individuals who engage in other extreme or high-risk activities. Enthusiasts with lower net worths have also expressed strong interest in suborbital spaceflights and are sometimes willing to spend a large portion of their income or even borrow money for the experience. According to Bryce, demand is somewhat elastic and as the price of a ticket drops from $250,000 to $100,000 the demand doubles.

US Government Policy. US government policy is a key driver of the suborbital tourism market. The regulatory authority for commercial suborbital RLV activity is the FAA, which has taken a “light approach” to regulation in order to foster this emerging industry. Regulatory reform activities began in 2018 and are ongoing. New launch and reentry regulations were published on September 30, 2020. Continued changes to the regulations will need to be monitored although industry is expecting the FAA to continue its “light approach” to regulation.

Demand. As discussed above, there are two main groups driving demand for space tourism: HNWI and enthusiasts. For HNWI, the interest in space tourism is driven by the level of exclusivity and luxury. Enthusiasts, on the other hand, are more emotionally invested in the idea of spaceflight and are sometimes willing to spend outside their means for the experience.

Competing Markets. Competing markets to suborbital tourism contend with CASP for demand but also provide potential alternative markets for CASP:

- Large scale point-to-point operations like SpaceX’s Starship could compete with small suborbital RLV missions for tourism.
- Other experiences using planes and balloons can provide elements of the space experience such as a view of the curvature of earth or a period of microgravity. These experiences could be supported by CASP but would need to be evaluated for compatibility due to the proximity to DEN and the Class B airspace above.

Suborbital Research and Technology Demonstration

Suborbital research and technology demonstration is the use of crewed and uncrewed suborbital RLVs to access the space environment to support scientific research and the development and testing of technologies. Suborbital RLVs and their operators provide a low-cost, rapid, and repeatable alternative to other options such as orbital platforms and sounding rockets. Suborbital RLVs provide a period of microgravity, a near vacuum environment, and immediate access to payloads after the flight. Operators also provide a "one-stop-shop" for administration, processing, and management of payloads.

Target Market. The market for suborbital research and technology demonstration includes government, private companies, and academia conducting space-related scientific research and technology test and demonstration missions. Colorado is one of the largest centers of space-related activity in the US, which provides a source of potential suborbital RLV users for CASP.

US Government Policy. National Aeronautics and Space Administration (NASA) support for suborbital RLV flights plays a role in this market. The NASA Flight Opportunities Program has flown science payloads on traditional suborbital RLVs and other commercial microgravity flights and it is expected to continue to do so. In 2020, NASA furthered the development of a program to train astronauts and potentially procure and system qualify suborbital RLVs.

Demand. The demand for this market is driven by several advantages provided by suborbital RLVs compared to other alternatives. Some of these advantages include:

- Shorter scheduling lead time
- Quick access to results compared to orbital options
- Continuous microgravity for up to seven minutes compared to non-orbital options
- Ability to fly several times in one day (repeatability)
- Affordability

Bryce outlines several types of research generating demand for suborbital RLVs including atmospheric research, suborbital astronomy, longitudinal human research, and microgravity research. Demand for technology test and demonstration missions will be led by NASA and other civil space agencies.

Competing Markets. There are several other platforms for space-related research including airplanes or aerial systems with attached sensors and instruments, parabolic flights, balloons, sounding rockets, and orbital platforms like the International Space Station (ISS). However, Bryce states that suborbital RLVs have the benefit of combining many of the advantages of these individual alternatives at a price that will be competitive as the market matures. Furthermore, some types of research cannot be conducted using other platforms or do not perform as well as they do using suborbital RLVs.

Source: Blue Origin

Non-Launch Markets

Before licensed launch operations can begin, a significant investment is required by commercial space operators to design, test, and manufacture their vehicles and components. Another complementary market is training for astronaut and space flight participants, such as the National Aerospace Training and Research (NASTAR) Center in Pennsylvania. Over the past decade, a wide range of commercial space companies have utilized spaceports to establish and expand their businesses. These markets were not addressed by Bryce or included in Bryce's forecast, but they present additional market opportunities for CASP. Additional non-launch markets include research and development, testing, manufacturing, training, support systems, and unmanned aerial systems.

Source: Masten Space Systems (Left), Virgin Orbit (Right)

Research and Development

Many commercial space startups require incubator space to begin developing their technologies and building their companies. While this process can occur anywhere, clusters tend to form in certain locations, such as the San Francisco Bay Area and Mojave Air and Space Port. These clusters benefit from partnerships between industry, government, investment groups, and universities. Some spaceports are developing exploration parks and technology centers that provide an environment that fosters the entrepreneurial spirit in hopes of attracting commercial space startups.

Vehicle, Payload, and Component Testing

Both established and upcoming commercial space companies require locations and infrastructure to conduct rocket engine testing. While it's common for this infrastructure to be built at commercial spaceports or federal ranges, there are many locations around the US where rocket engine testing occurs independent of launch facilities. Test facilities at Mojave Air and Space Port and Spaceport America are excellent examples of compatible testing that can occur at a commercial spaceport. In addition, test facilities previously developed by SpaceDev's in Poway, California and ORBITEC in Baraboo, Wisconsin offer examples of off-spaceport test facilities that could also be located at or near commercial spaceports.

Vehicle, Payload, and Component Manufacturing

Manufacturing of launch vehicles, payloads, and components is an important element of the commercial space industry. The supply chain that supports this industry is broad and geographically diverse. Recently there has been a desire by some manufacturers to locate final manufacturing at or near spaceports. For example, the Spaceship Company chose to locate their manufacturing facility at Mojave Air and Space Port while Blue Origin and OneWeb both chose to build their manufacturing facilities in Exploration Park at Kennedy Space Center (KSC).

Workforce and Spaceflight Participant Training

Spaceports can also act as a hub for both workforce training and spaceflight participant training. In 2019, Houston Spaceport partnered with San Jacinto College to develop an Aerospace Technical Training Program to train technicians in a variety of on-demand aerospace skills. Similar programs can be developed at other spaceports by partnering with local colleges or universities. The Boulder-Denver-Colorado Springs area already has a high concentration of industry and aerospace education activity that supports launch vehicle and spacecraft development, satellite services, and scientific research.

Basic spaceflight training for participants is often viewed as a prerequisite to flights on commercial launch systems. While most of the pre-flight training is expected to be conducted by the launch vehicle operators, some spaceports have evaluated the potential of providing training facilities to support both spaceflight participants and space enthusiasts.

Space Support Systems

The operation of space support systems might fall outside of licensed launch activities, but it is an additional capability that a commercial spaceport could provide. Operating these systems provides added value to spaceport customers and additional opportunities for revenue generation for the spaceport. Examples of these space support systems and the services they support include:

- Zero-G (Airbus A300, microgravity parabolic flights)
- Virgin Galactic (WhiteKnightTwo, spaceflight participant training)
- Starfighters Aerospace (F-104, high performance and high-altitude flights)

Source: Zero-G

Supersonic Systems

A variety of supersonic aircraft by companies like Boom Aerospace and Spike Aerospace are in various stages of development and include technology demonstrators as well as commercial and passenger aircraft. In December 2020, it was announced that the Kansas Department of Transportation signed an agreement with the FAA to establish a Kansas Supersonic Transportation Corridor (SSTC) that would enable the testing of aircraft up to Mach 3. The corridor is bi-directional and approximately 770 nm spanning from Garden City, Kansas to approximately Pittsburg, Kansas. The proximity of the proposed corridor to CASP could enable supersonic aircraft operators to utilize CASP as and arrival or departure site for testing of their vehicles in the Kansas SSTC.

Unmanned Aerial Systems

Spaceports provide opportunities for the development, testing and operations of emerging technologies such as unmanned aerial systems (UAS). Several launch vehicle providers and aerospace companies are developing systems that operate autonomously. Spaceport infrastructure, including runways, can be utilized by both traditional UAS and emerging systems such as Urban Air Mobility (UAM) systems, such as Joby Aviation, enabling rapid connectivity between spaceports and urban environments.

US Commercial Spaceport Network

There are 12 FAA licensed commercial spaceports in the US, of which nine can offer their sites to support the launch of HTHL type RLVs. Information about these nine spaceports, including CASP, is provided in **Table 3-2** and their locations are shown in **Figure 3-3**. In addition to the nine licensed HTHL spaceports, there are additional proposed sites in Alabama, Arizona, Guam, Hawaii, Maine, Michigan, Mississippi, New Jersey, Puerto Rico, and Texas that may compete with CASP for HTHL operations in the future.

Bryce points out that the most crucial requirement for spaceports is the ability to safely operate within their airspace. Additionally, most US spaceports are co-located with airports or landing strips so that site operations can be handled by the airport operator.

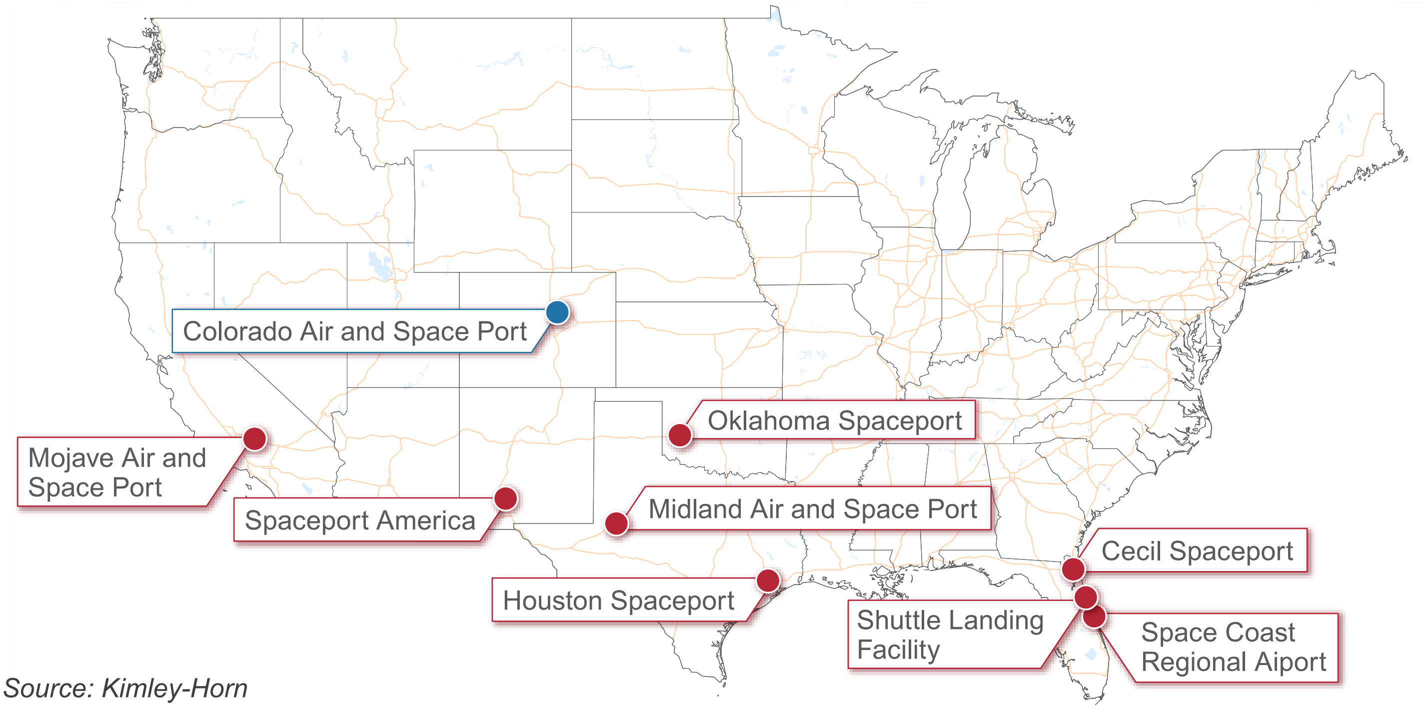
The level of support services provided by spaceports varies. Some spaceports focus on infrastructure such as ARFF, office space, hangar infrastructure, access control, utilities, government liaison services, and public transportation. Other spaceports offer tenants additional services such as facility maintenance, marketing, and engineering support. Bryce did note that in almost all cases spaceport tenants operate their own vehicle integration facilities, payload processing facilities, and propellant handling.

Additional information on the roles and capabilities of the peer spaceports that either complement or compete with CASP can be found in the Bryce report in **Appendix C**.

Table 3-2. US Licensed HTHL Spaceports

Spaceport	Max Runway Length (ft)	Runway Width (ft)	X	Y
Shuttle Landing Facility	15,001	300		✓
Oklahoma Space Port	13,503	200	✓	✓
Mojave Air and Space Port	12,503	200	✓	✓
Cecil Spaceport	12,503	200	✓	
Spaceport America	12,000	200	✓	✓
Midland Air and Space Port	9,501	150		✓
Houston Space Port	9,001	150	✓	
Colorado Air and Space Port	8,000	100	✓	
Space Coast Regional Airport	7,319	100	✓	✓

Figure 3-3. US Licensed HTHL Spaceports



Source: Kimley-Horn

Z	Reentry	Active Test Facilities	Active Commercial Space Companies
✓	✓		Sierra Space, Boeing, Starfighters
✓			None
✓		✓	Virgin Galactic, Virgin Orbit, Stratolaunch, Masten, Interorbital, more
✓		✓	Generation Orbit, Aevum
✓		✓	Virgin Galactic, EXOS Aerospace, Sugarhouse Aerospace, UP Aerospace
			AST, Kepler Aerospace
			Intuitive Machines, Axiom, Collins Aerospace
		✓	Reaction Engines, PD Aerospace, New Frontier Aerospace
✓			Space Perspective

Source: Kimley-Horn

Other Factors Supporting the Suborbital RLV Market

Bryce also discussed other factors that support the suborbital RLV market. A key factor in market demand is the price of using suborbital RLVs. Several changes and advancements in the manufacturing of suborbital RLVs may help reduce market costs in the future. These factors include simplifying designs, using composites, and using additive manufacturing (AM), which is the fabrication of three-dimensional objects using a computer aided design (CAD) model fed into a printer or printers. Demand for suborbital RLVs at a specific location is also impacted by access to maintenance related services, infrastructure, and various transportation modes.

Industry Barriers to Market Entry

There are significant barriers to entry to the suborbital RLV market, particularly for suborbital tourism, as discussed by Bryce:

- **Technology.** The development of a suborbital RLV capable of carrying spaceflight participants is technically challenging, especially for companies without access to the substantial resources available to the US government. This is evidenced by the long development timelines of existing RLVs such as those of Virgin Galactic and Blue Origin.
- **Capital investment.** Bryce considered the need for high capital investment to be the most significant barrier to entry in the suborbital RLV market. Developing and operating suborbital RLVs requires sophisticated hardware and software, significant testing, and a highly skilled and specialized workforce, all of which demand significant investment of funds.
- **Economies of scale.** Although there may be more economies of scale as the industry grows, allowing for reduced operating costs and ticket prices, in the near term the market is relatively small with only modest growth anticipated. Bryce also mentions that customer demographics and the geographical location of HNWI interested in suborbital tourism may limit the size of the market in the US.
- **Government policy.** There is a moratorium on regulation of commercial human spaceflight by the FAA until at least 2023 in order to allow the market to grow and collect data to inform appropriate regulations. However, government policy and regulation could impact the growth of the research and technology demonstration market. European access to US suborbital RLV operators has also been limited due to local government policies and processes.
- **Environmental Review.** The environmental review process typically results in significant delays in spaceport development.


Source: Kimley-Horn

Commercial Space Launch and Reentry Forecasts

Based on research into previous forecasts and the suborbital RLV market, Bryce used a research- and analysis-based approach to forecast 20-year demand for suborbital RLVs. This section briefly summarizes Bryce's methodology and then discusses the results of the forecast. A more detailed description of Bryce's methodology and results can be found in the *Forecast and Market Analysis of Horizontal Space Launch and Reentry at Colorado Air and Space Port (CASP)* report included in **Appendix C**.

Forecasting Methodology and Assumptions

Bryce used both primary research and publicly available data to inform its analysis. The analysis focused on the two markets discussed above: suborbital tourism and suborbital research and technology demonstration.

The analysis was run for four combinations of ticket prices and growth assumptions. The first ticket price of $250,000 was based on the ticket price for the first round of sales on commercially available Virgin Galactic flights, while the second ticket price of $100,000 was an "aspirational target" within the 20-year forecast period. The two growth scenarios were a baseline scenario and a growth scenario. The growth scenario assumed a larger and faster growth in the population of HNWI interested in suborbital flight and in demand for suborbital research payloads across all sectors compared to the baseline scenario.

For the suborbital tourism market, Bryce looked at demand from HNWI and space enthusiasts. Because there is a lot of uncertainty surrounding the long-term impacts of the COVID-19 pandemic, Bryce incorporated a general economic impact of the pandemic by including a one-time reduction in HNWI followed by a period of depressed growth for several years. Bryce did not include any potential impacts on the spending behaviors of HNWI, the population of space enthusiasts, or the development of suborbital RLVs.

Bryce also estimated the number of experiments or technology demonstration missions that might use suborbital RLVs. This demand was converted into seat equivalents in order to allow the demand to be combined and compared with the suborbital tourism demand. Test flights as part of the suborbital RLV development process were not included in this market forecast.

Launch and Reentry Forecast Results

Suborbital RLV Market

Bryce's forecasts for the suborbital RLV market resulted in between 9,167 and 55,611 seat equivalents over the 20-year forecast horizon (2021-2040). The near-, mid-, and long-term demand under each of the four scenario and price combinations are shown in **Table 3-3**. All four forecasts followed a similar pattern with the number of seats and seat equivalents remaining relatively low in the near-term, beginning to increase significantly during the mid-term, and continuing to grow and then level off during the long-term. As expected, the growth scenario with a $100,000 ticket price resulted in the highest projections, substantially higher than any of the others.

Table 3-3. Total Forecast Seat and Seat Equivalents by Scenario and Price Point

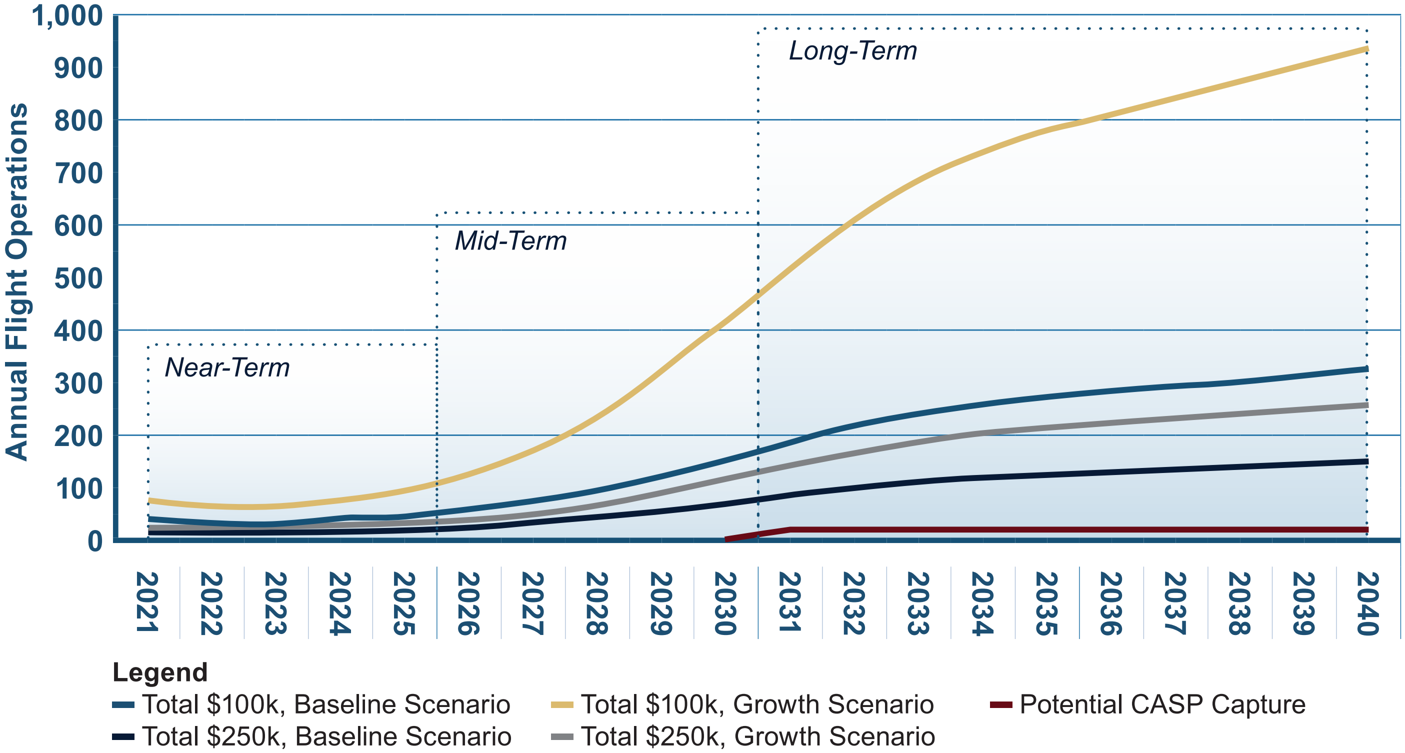
Scenario and Price Point	Near-term (2021-2025)	Mid-term (2026-2030)	Long-term (2031-2040)	Total (2020-2040)
Baseline scenario, $250K	427	1,329	7,411	9,167
Baseline scenario, $100K	995	2,934	15,975	19,904
Growth scenario, $250K	639	2,169	12,652	15,460
Growth scenario, $100K	1,996	7,594	46,021	55,611

Source: Bryce Space and Technology

The forecast market for suborbital tourism is significantly larger than the market for suborbital research and technology demonstration, though the split between the two markets differs in each scenario and price combination.

Bryce also converted the demand for seats and seat equivalents to a number of flight operations. Virgin Galactic's SpaceShipTwo and Blue Origin's New Shepard both support up to six passengers per flight, and these are the only suborbital launch systems nearing commercial operation. However, Bryce assumes that in the early years of operation neither provider will operate at full capacity. This assumption is based on information from the companies and an understanding of the market. The resulting forecasts of total flight operations per year are shown in **Figure 3-4**.

Figure 3-4. Total Forecast Annual Flight Operations by Scenario and Price Point



Source: Bryce Space and Technology

Bryce's forecast model, and therefore the numbers above, do not consider the launch system (horizontal or vertical) or the vehicle type (Concept X, Y or Z). It is difficult to estimate the split between these launch systems and vehicle types as there are many influencing factors. Bryce explains that the "division of demand will largely be driven by the differentiation of offerings between providers and the cost and availability of flight opportunities". Virgin Galactic is planning a horizontal launch and landing system using a Concept Z vehicle, while Blue Origin is planning a vertical launch and landing system.

The inaccuracy of previous development timelines makes it difficult to predict when service will begin for each company, but publicly available information suggests Virgin Galactic is more likely to begin commercial service first. Still, data suggests the two companies will have close to the same number of launches in the first year of commercial operations. Factors including each company's target market, the overall experience, and differences in the flight profiles of the two vehicles will affect the proportion of the suborbital tourism market captured by each company. Bryce suggests that initially the market is likely to be about evenly split in the first ten years (2021-2030), but then various factors may lead to a less even distribution between the two companies. At the same time, Blue Origin probably has an advantage in the research and technology demonstration market because it offers a longer period of microgravity per flight at a lower cost, and the company has a greater focus on this market.

Other competing systems could be developed and enter the market, but this is considered unlikely to occur before 2040.

Orbital Air-Launch Market

The orbital air-launch market, for vehicles such as Virgin Orbit's Launcher One or Northrop Grumman's Pegasus, was not assessed as part of this market forecast due to the inland location of CASP. The nearest range capable of supporting orbital air-launch for missions originating at CASP is the "Western Range" located in the Pacific Ocean off the coast of California and is approximately 1,000 miles from CASP. It's likely that operators would choose a spaceport closer to the Western Range, such as Mojave Air and Space Port, for orbital air-launch from the Pacific Ocean.

Orbital Reentry Forecast Results

Another market that CASP could potentially serve is for reentry events by orbital winged spacecraft. These are vertically launched, so only the landing is relevant for CASP, and this is a separate market from the suborbital RLV markets discussed above. There are three sources of demand in this market:

- Air Force's classified X-37B Orbital Test Vehicle (OTV) is operational and assumed to remain operational during the forecast period.
- Sierra Space's Dream Chaser vehicle is expected to become operational in 2022 and will deliver cargo to the ISS at least once per year.
- UK-based Reaction Engines' Synthetic Air Breathing Rocket Engine (SABRE) Development Vehicle is a sub-scale version of the Skylon orbital launch vehicle that Bryce assumes will be developed during the forecast period to test the company's SABRE in a real-world operational environment.

Bryce's forecast demand for this market is shown in **Table 3-4** and **Figure 3-5**. Although CASP could serve these reentry events, it is unlikely that CASP would be a primary reentry site. Bryce says that it is more likely that CASP could serve as an alternate (backup) landing site for the X-37B and Dream Chaser, and as a US landing site for the SABRE Development Vehicle if testing requires point-to-point scenarios. Additional information on anticipated flights and reentry sites are provided in Bryce's report.

Table 3-4. Total Forecast Reentry Events

Spacecraft	Near-term (2020-2025)	Mid-term (2026-2030)	Long-term (2031-2040)	Total (2020-2040)
Dream Chaser (Cargo)	5	5	10	20
X-37B	3	2	5	10
SABRE Development Vehicle	0	1	10	11
Total	**8**	**8**	**25**	**41**

Source: Bryce Space and Technology

CASP Addressable Market

The numbers above are for the overall suborbital RLV market, but CASP is only a portion of this market. CASP is not suitable for suborbital vertical launch systems which Bryce estimates to be about half of the market in the near- to mid-term. CASP is also not currently licensed for Concept Z-type horizontal suborbital systems, but CASP could get the appropriate FAA license modifications. These Concept Z-type flights are expected to be approximately half of the market through 2030. Their long-term share of the market will depend on factors discussed above and the potential, though unlikely, entrance of other vehicles into the market (potentially including Concept X-type horizontal launch vehicles that could operate at CASP).

Although Virgin Galactic could operate out of CASP with the appropriate license modifications, it is still unlikely that the company would operate a significant number of launches out of CASP. Under its current lease terms at Spaceport America, Virgin Galactic must operate a minimum number of flights there and at least 75% of total flights. Based on the company's own estimates, Bryce states Virgin Galactic will not operate enough flights to exceed the lease minimum during the term of the lease through 2028. In addition, Bryce points out that memoranda of understanding to operate in Italy and the United Arab Emirates indicates that expansion outside of Spaceport America will likely be focused internationally rather than on other US spaceports.

A summary of the forecast for the total number of licensed, permitted, and testing operations, spaceflight participants, and vehicles based at CASP are shown in **Table 3-5**.

Table 3-5. Summary of CASP Licensed, Permitted, and Testing Operation

<table>
<tr><th>Operations</th><th>Prior to 2021</th><th>2021-2025</th><th>2026-2030</th><th>2031-2040</th><th>Remarks</th></tr>
<tr><td>Licensed Launches and Reentry of HTHL Suborbital RLVs</td><td>0</td><td>0</td><td>0</td><td>15-50</td><td rowspan="3">Operations of Licensed Launch Systems at CASP is unlikely within the next 10 years. Developmental operations could include taxiway/runway maneuvers, test flights of aviation systems, or drop/glide tests. Reentry vehicle operations, such as for a future Saber Development Vehicle, could potentially occur at CASP.</td></tr>
<tr><td>Licensed Reentry of Reentry Vehicles</td><td>0</td><td>0</td><td>0</td><td>0-5</td></tr>
<tr><td>Licensed Orbital Air-Launch</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>Development Operations of HTHL RLVs</td><td>0</td><td>0-10</td><td>0-10</td><td>0-20</td><td rowspan="2">Partnership with PD Aerospace could result in initial development operations in the near-term and mid-term. Partnership with NFA could result in up to 300 low thrust engine tests and low-altitude hover tests in the near-term . Reaction Engines has recently completed aerospace testing at its test facility at CASP.</td></tr>
<tr><td>Engine Tests / Low Altitude VTVL</td><td>2</td><td>50-300</td><td>50-200</td><td>100-400</td></tr>
<tr><td>Space Support Vehicles or Supersonic Aircraft Operations</td><td>0</td><td>0-10</td><td>0-60</td><td>20-120</td><td>Missions conducted by supersonic aircraft or space support vehicles have the potential to operate from CASP.</td></tr>
</table>

Summary	Prior to 2021	2021-2025	2026-2030	2031-2040	Remarks
Total Operations	0	50-320	50-230	135-595	Mix of licensed, permitted, and test activities
Total Spaceflight Participants	0	0-60	0-60	0-300	Assume up to 6 spaceflight participants per vehicle. An FAA AST license is required for commercial operations to carry spaceflight participants. An Experimental Permit enables testing of vehicles, but commercial operations are not authorized. Space Support Vehicles, such as Zero-G can support training programs for spaceflight participants.
Total Based Aerospace Vehicles	0	1-2	2-3	3+	PD Aerospace and NFA are likely operators at CASP.

Source: Bryce Space and Technology, Kimley-Horn

In addition to licensed launches, it is likely that ground-based testing, lower altitude tethered VTVL test flights, and altitude restricted VTVL test flights could occur at CASP. While these activities are not licensed operations, they do provide economic benefits to CASP and revenue generating opportunities. Since receiving the LSOL in 2018, several commercial aerospace companies have already approached CASP regarding the building of aerospace test facilities at the Air and Space Port.

Vehicle Compatibility Considerations

Due to the nascent nature of the commercial space industry and the variety of launch systems in development, selecting a single "critical aircraft" for evaluating the spaceport infrastructure is insufficient for this Master Plan. It is recommended that the range of vehicles identified earlier be evaluated at a broad level to establish compatibility trends. The vehicles evaluated within this Spaceport Master Plan represent a diverse mix of the overall market (including suborbital and orbital vehicles) but do not include all launch systems in development that could potentially operate from an air and space port. In addition to the three traditional horizontal RLV concept categories (X, Y, and Z), Reentry Vehicle, VTVL, High Altitude-Balloon, and Support Vehicle categories are also evaluated.

Concept X

Since Concept X launch systems take off and land under jet power similar to traditional aircraft, they represent one of the most compatible launch systems for air and space ports. Currently there are no Concept X vehicles in operation, although several systems are under development, including the PD Aerospace Spaceplane, or have been under development in the past. CASP previously utilized the Rocketplane XP as the representative Concept X vehicle in its LSOL application. While the Rocketplane XP program was cancelled in 2010, the vehicle was under development for quite some time and the system designer provided baseline operation details to CASP. In 2019 CASP signed a letter of intent with PD Aerospace for a Concept X RLV to evaluate partnership opportunities.

Concept Y

Concept Y launch vehicles take off from a runway under rocket power and rapidly climb in the immediate airspace near the air and space port. A Concept Y launch system (XCOR Lynx Mark II) was one of the systems originally proposed to operate from CASP. Due to concerns expressed by airspace stakeholders near CASP regarding rocket powered flight in close proximity to Denver International Airport (DEN), the licensing proposal was altered to focus on Concept X type vehicles. Development in Concept Y launch systems appeared to have stalled following the bankruptcy of XCOR in 2017, however current progress by Dawn Aerospace is encouraging. Dawn Aerospace is currently developing the Mark II Aurora spaceplane. Once the program achieves operational status it may be worth revisiting potential Concept Y operations at CASP.

Concept Z

Concept Z launch systems represent the most active category of launch vehicles at air and space ports. Both orbital and suborbital missions are supported by Concept Z systems. The Pegasus launch system has been in service for several decades and additional providers such as Virgin Galactic and Virgin Orbit are operational. By utilizing both traditional and nontraditional jet aircraft as the carrier aircraft for various launch vehicles, the Concept Z launch system has high compatibility with traditional aviation operations at air and space ports. Virgin Galactic's WhiteKnightTwo carrier aircraft and suborbital SpaceShipTwo launch vehicle is an active Concept Z vehicle that Bryce recommended for consideration and evaluation by CASP.

Reentry Vehicle

Reentry vehicles compatible with air and space ports can be launched to space by a variety of methods. For example, a reentry vehicle could be launched as a payload on a vertical launch system at one spaceport and perform the reentry and horizontal landing at another spaceport. Both the Boeing X-37B and Sierra Space's Dream Chaser Cargo System are examples of reentry vehicles that are in active development. It is recommended that orbital reentry vehicles be evaluated for computability at CASP.

VTVL

VTVL launch systems require compatible airspace for their operations. While some air and space ports may not be able to accommodate high altitude VTVL flights, low altitude and tethered flights may be compatible. Medium and Large VTVL vehicles such as the Blue Origin New Shepard, SpaceX Grasshopper, and the SpaceX Starship are not anticipated to be compatible with air and space ports. A variety of small VTVL systems have been in development over the years with the Masten Space Systems' Xodiac being the most active to date. It is recommended that low altitude and tethered VTVL launch system operations be evaluated for compatibility at CASP.

High-Altitude Balloon

High-altitude balloons can provide a near-space environment that is useful for experimentation, tourism, and orbital launch. Two development programs evaluated in this Spaceport Master Plan include the World View's Stratollite and the Space Perspectives Spaceship Neptune. The Stratollite is an active uncrewed high-altitude balloon launch vehicle with headquarters located in Tucson, Arizona. World View currently launches the Stratollite from locations across the globe. Space Perspectives is developing a tourism-focused near-space flight experience that allows spaceflight participants to hover in a near-space environment for several hours. Several companies are developing balloons with orbital launch capabilities, such as the Leo Aerospace Rockoon and the Zero2Infinity Bloostar. For CASP it is recommended that non-orbital launch high-altitude balloons be evaluated for operational compatibility at CASP.

Support Vehicles

While space support vehicles do not necessary go to space, they can fly a variety of missions in support of commercial space operations. One example of a space support vehicle is the ZeroG G-FORCE ONE, which is a modified 727-200 that conducts parabolic flights to simulate a microgravity environment that is useful for training and experimentation. The Startfighters F-104's represents another type of space support vehicle that can mimic the high-g loading during launch and achieve near-space altitudes. It is recommended that a range of space support vehicles be evaluated for operational capability at CASP.

Forecast Summary

As further detailed in the report "Forecast and Market Analysis of Horizontal Space Launch and Reentry at Colorado Air and Space Port (CASP)", included in **Appendix C**, Bryce reviewed previous forecasts and analyzed the suborbital RLV markets to develop a forecast of the operations that could occur at CASP in the future. Near-term forecasted demand for licensed suborbital RLV flight operations at CASP is low, but there are opportunities for CASP to serve other supporting and related markets within the space industry.

Given the current state of suborbital RLV development, CASP is unlikely to capture a significant portion of the near-term licensed tourism or research and technology demonstration markets. Bryce identified two suborbital RLV operators anticipated to be operational during the forecast period. The first operator is Blue Origin, but CASP is not suitable for high-altitude suborbital vertical launch systems such as this. The second operator is Virgin Galactic who operates a Concept Z-type vehicle, and while CASP could obtain the proper license to operate Concept Z-type vehicle. While Virgin Galactic is unlikely to operate additional US launch sites outside of Spaceport America and Mojave Air and Space Port during this time period. While other commercial suborbital RLVs capable of supporting licensed operations from CASP are in development, it is unlikely that they will enter commercial service during the near-term and mid-term forecast periods.

One area of opportunity for CASP is that vehicles in development during the forecast period will require facilities for development, testing, and demonstration flights, which CASP could support with the appropriate planning. Bryce estimated that an average of less than ten test flight operations per year could be expected, based on the historical testing conducted by Virgin Galactic. In addition, other tests, such as propulsion ground tests, taxi, and captive carry tests, may be required.

Bryce also addressed the potential for CASP to serve as a backup site for reentry operations for vertically launched orbital winged spacecraft. There are three vehicles anticipated to operate during the forecast period, including one already in operation. Landing sites have already been identified for the two US based systems, but CASP could be evaluated as a backup. With its existing partnership with Reaction Engines, CASP could potentially serve as a US based landing site for the Reaction Engines' notional SABRE-based test article. It is unclear, though, if this vehicle will require a runway longer than 8,000 feet.

CASP could also serve other non-launch markets such as education and training for the space industry. The Boulder-Denver-Colorado Springs area already has a high concentration of industry and aerospace education activity. Companies that provide training for spaceflight participants could establish a presence at CASP, and complementary companies could use CASP as a flight location. Bryce suggests that CASP could "serve as a soup-to-nuts spaceflight experience that combines classroom instruction with real-world training and actual flights into space".

Over the next 10 years, the primary markets available to CASP include research, development, testing, and manufacturing. CASP can leverage the market delay to develop facilities necessary to support suborbital launch systems when demand increases in 2030+ timeframe.

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Chapter 4

Facility Requirements

FACILITY REQUIREMENTS

A gap analysis was performed that evaluated the existing conditions (**Chapter 2**) with the market forecast and demand assessment (**Chapter 3**) to assess the ability of the existing infrastructure at CASP to support aerospace and spaceport activities. This chapter presents the results of the gap analysis as it relates to future facility requirements. The facility requirements provided in this chapter are structured to provide scalable options depending on how the aerospace and launch market matures.

Launch Systems Characteristics

A range of potential launch, reentry and support vehicles were evaluated to determine their compatibility with CASP's existing, near-term, and long-term infrastructure plans. Publicly available information was utilized to approximate traditional aircraft characteristics utilized for aviation planning, such as the Aircraft Approach Category (AAC), Airplane Design Group (ADG) and Taxiway Design Group (TDG) (see **Table 4-3**). Representative tables from FAA Advisory Circular (AC) 150/5300-13A Change 1 are referenced here for guidance (see **Table 4-1** and **Table 4-2**). The ADG and TDG are utilized to evaluate runway/taxiway compatibility. The ADG is a classification method that groups aircraft by wingspan and tail height and is typically used in the design of airfield geometry to provide separation between runways and taxiways to ensure adequate wingtip clearance by passing aircraft. The TDG evaluates the distance from the cockpit to main gear and the main gear width to establish taxiway geometry for turning and maneuvering around the airfield. It should be noted that the High-Altitude Balloons and VTVL vehicles were not assigned traditional aircraft characteristics as they are not applicable to the vehicle types.

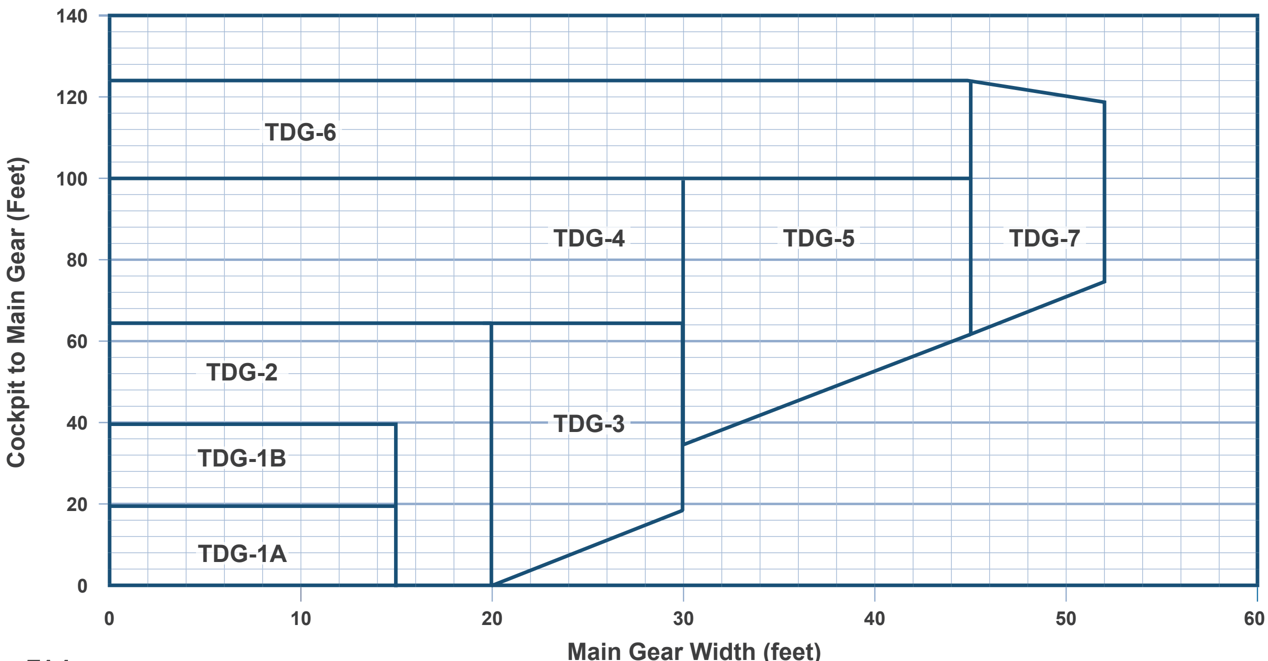
Table 4-1. Aircraft Approach Category (Table 1-1 from AC 150/5300-13A)

AAC	Approach Speed
A	Approach speed less than 91 knots
B	Approach speed 91 knots or more but less than 121 knots
C	Approach speed 121 knots or more but less than 141 knots
D	Approach speed 141 knots or more but less than 166 knots
E	Approach speed 166 knots or more

Table 4-2. Airplane Design Group (Table 1-2 from AC 150/5300-13A)

Group #	Tail Height (ft)	Wingspan (ft)
I	< 20'	< 49'
II	20' - < 30'	49' - < 79'
III	30' - < 45'	79' - < 118'
IV	45' - < 60'	118' - < 171'
V	60' - < 66'	171' - < 214')
VI	66' - < 80'	214' - < 262')

Figure 4-1. Taxiway Design Groups (Figure 1-1 from AC 150/5300-13A)



Source: FAA

Table 4-3. Launch System Airport Characteristics

Vehicle Description		AAC	ADG	TDG
X	RocketPlane XP	*	I	1A
	Airbus Defence and Space Spaceplane	*	II	1B
	Bristol Ascender	*	I	1B
	PD Aerospace X06	*	I	1A
	PD Aerospace X07	*	I	1A
	PD Aerospace X08	*	II	3
	SABRE Development Vehicle	*	II	2
	Reaction Engines Skylon	*	III	6
Y	XCOR Lynx	*	II	2
	Dawn Aerospace Mk-II Aurora	*	III	6
	Dawn Aerospace Mk-III	*	I	1A
Z	Northrop Grumman Stargazer (L-1011)	C	IV	5
	Coleman Aerospace (C-17)	*	IV	5
	Coleman Aerospace (C-130)	*	IV	1B
	Virgin Orbit Cosmic Girl (747-400)	D	V	5
	Virgin Galactic WhiteKnightTwo	*	IV	OTC
	Stratolaunch	*	OTC	OTC
	Generation Orbit Gulfstream (C-20A)	C	II	2
	Aevum RavnX	*	II	1B
	Bristol Spacecab	*	III	7
	Bristol Spacebus	*	IV	OTC
	Orbital Access (MD-11)	D	IV	6
	Swiss Space Systems (A300)	C	IV	5
Reentry Vehicle	Boeing X-37B	*	I	1A
	Sierra Space Dream Chaser	*	I	1A
Support Vehicle	Zero-G (727-200)	C	III	4
	Super Guppy	*	IV	OTC
	Starfighter (F-104)	*	I	1B
Super Sonic	Boom XB-1	E	I	1B
	Boom Overture	*	II	6
	Aerion AS2	*	III	4
	Spike S-512	*	II	2
Balloon	World View Stratollite	Not Applicable		
	Space Perspectives Spaceship Neptune			
VTVL	Masten Xodiac			
	New Frontier Aerospace Test Article			
	Blue Origin New Shepard			
	SpaceX Starship			

** Information unavailable* *OTC = Off the Chart* *Source: Kimley-Horn*

Airfield Pavements

CASP’s existing, future and ultimate runway and taxiway pavement capabilities are summarized in **Table 4-4**.

The “ultimate” classifications are recommended for long-term considerations. These are not endorsed by the FAA, which cannot issue approvals beyond the “future” planning range.

Table 4-4. Runway and Taxiway Pavement Capabilities

	Existing	Future	Ultimate
AAC	C	C	C
ADG	II	II	IV
TDG	2	2	3
Runway 8/26 (Length x Width)	8,000 ft x 100 ft	8,000 ft x 100 ft	10,000 ft x 150 ft
Runway 17/35 (Length x Width)	8,000 ft x 100 ft	8,000 ft x 100 ft	12,000 ft x 150 ft
Taxiway Widths (Required / Actual)	35 ft / 50 ft	35 ft	50 ft

Source: [1]

Figure 4-2. Runway 26 Looking West at Dawn

Source: Kimley-Horn

Figure 4-3. Runway 8 and Air Traffic Control Tower

Source: Kimley-Horn

Runways

CASP's current ALP indicates that both runways have an AAC of C and an ADG of II. This design category accommodates business jets up to models that include the Gulfstream G-280, G-350, G-450; Falcon 2000 and 900; Bombardier Challenger 300/604/600; Cessna Citation X; and the Embraer Legacy 500/600, among others. An ACC and ADG of C-II also allows operations by smaller aircraft such as the Cessna Citation 1, 2, and CJ-series; Learjet 31, 35, 36, 45; Beech King Air 90, 200, and 350; Pilatus PC-12; TBM- 850; as well as almost all piston engine aircraft. The ARC is used for planning and design only and does not limit the aircraft that may be able to operate safety at an airport.

While CASP will occasionally accommodate operations by larger corporate jets such as the Gulfstream G-550 and Bombardier 700/Global 6000/Global Express with ACC and ADG of C-III, these have not been categorized as the critical aircraft for CASP as they have not historically approached the FAA's 500 annual operation threshold for critical design aircraft status. This is an important distinction that could allow limited operations of launch systems that exceed the ARC of CASP as long as the vehicles can safety operate within the geometry and strength of CASPs pavements.

Runway Length

There are several variables that govern how much takeoff distance, or runway length, a launch, reentry or support vehicle requires including, but not limited to, vehicle wingspan, length, takeoff or landing weight, runway altitude, and other atmospheric/climactic conditions. Amongst the various launch, reentry, and support vehicles examined as part of this spaceport master plan, the many of the vehicles recommend a runway with at least 10,000 to 12,000 ft to perform takeoff and/or landing operations. CASP's elevation of approximately 5,500 feet above mean sea level provides vehicle operators the advantage of propellant and energy savings but simultaneously requires increased minimum takeoff distances due to the lower air density.

Runway Width

A vast majority of the vehicles analyzed require runway widths between 100 and 150 ft with a few exceptions that require a runway width of 200 ft. The existing runway width of 100 ft at CASP is capable of supporting about 50% of the vehicles analyzed in this master plan. An ultimate runway width of 150 ft would increase compatibility to about 90%.

Runway Pavement Strength

The existing pavement strength at CASP is based on a General Aviation (GA) fleet mix and is rated for a maximum of 34,000 lbs Single Wheel Gear or 75,000 lbs Dual Wheel Gear on Runway 17/35. About 50% of the vehicles evaluated in this master plan fall within these ranges. The remaining vehicles have maximum takeoff weights that range from approximately 100,000 lbs to over 1,000,000 lbs.

There are multiple factors that dictate an aircraft's compatibility with runway pavements. These include the vehicle's gross weight, landing gear configuration, tire contact area, tire pressure, and frequency of operations. Heavier aircraft, exceeding the listed ratings, may still be able to operate from CASP in a limited capacity but may impact the expected life of the pavement. For this reason, a custom pavement analysis should be performed if any of the larger / heavier launch, reentry or support vehicles are proposed to operate at CASP. This analysis would evaluate the runway pavement capacity and estimate impacts to the operational life of the pavement.

Runway Assessment

A high-level assessment of the compatibility of CASP's runways with various vehicles in development was conducted using a "stoplight evaluation." A stoplight evaluation has three rating levels: green, amber, and red. A rating of "green" indicates that the vehicle is compatible with the element being evaluated, a rating of "amber" indicates that the vehicle may be compatible but further evaluation is required, and a rating of "red" indicates that it is highly unlikely that the vehicle is compatible with the element being evaluated. The results of the stoplight evaluation for the runway compatibility is provided in **Table 4-5** for both the existing/future and ultimate runway configurations. It should be noted that High-Altitude Balloons and VTVL vehicles were not included in the evaluation, as their operations are not dependent on runway characteristics.

At its existing runway length and width of 8,000 ft x 100 ft, approximately 50% of the vehicles analyzed in this master plan could potentially operate from CASP's runway infrastructure. If the runway length, width and strength were increased to 12,000 ft x 150 ft, approximately 95% of the vehicles analyzed in this master plan could operate from the runway infrastructure.

Figure 4-4. End of Runway 26 Looking East at Dawn

Source: Kimley-Horn

Table 4-5. Runway Compatibility Assessment

Vehicle Description		Existing / Future: 8/26 and 17/35 (8,000 ft x 100 ft) L / W	Ultimate: 8 / 26 (10,000 ft x 150 ft) L / W	Ultimate: 17 / 35 (12,000 ft x 150 ft) L / W
X	RocketPlane XP	Potentially Compatible / Compatible	Compatible / Compatible	Compatible / Compatible
X	Airbus Defence and Space Spaceplane	Potentially Compatible / Compatible	Potentially Compatible / Compatible	Compatible / Compatible
X	Bristol Ascender	Potentially Compatible / Compatible	Potentially Compatible / Compatible	Compatible / Compatible
X	PD Aerospace X06	Compatible / Compatible	Compatible / Compatible	Compatible / Compatible
X	PD Aerospace X07	Compatible / Compatible	Compatible / Compatible	Compatible / Compatible
X	PD Aerospace X08	Potentially Compatible / Compatible	Potentially Compatible / Compatible	Compatible / Compatible
X	SABRE Development Vehicle	Compatible / Compatible	Compatible / Compatible	Compatible / Compatible
X	Reaction Engines Skylon	Not Compatible / Potentially Compatible	Not Compatible / Potentially Compatible	Not Compatible / Potentially Compatible
Y	XCOR Lynx	Compatible / Compatible	Compatible / Compatible	Compatible / Compatible
Y	Dawn Aerospace Mk-II Aurora	Compatible / Compatible	Compatible / Compatible	Compatible / Compatible
Y	Dawn Aerospace Mk-III	Compatible / Compatible	Compatible / Compatible	Compatible / Compatible
Z	Northrop Grumman Stargazer (L-1011)	Potentially Compatible / Potentially Compatible	Compatible / Compatible	Compatible / Compatible
Z	Coleman Aerospace (C-17)	Compatible / Compatible	Compatible / Compatible	Compatible / Compatible
Z	Coleman Aerospace (C-130)	Compatible / Compatible	Compatible / Compatible	Compatible / Compatible
Z	Virgin Orbit Cosmic Girl (747-400)	Not Compatible / Not Compatible	Potentially Compatible / Potentially Compatible	Compatible / Compatible
Z	Virgin Galactic WhiteKnightTwo	Potentially Compatible / Potentially Compatible	Potentially Compatible / Potentially Compatible	Compatible / Compatible
Z	Stratolaunch	Not Compatible / Not Compatible	Not Compatible / Not Compatible	Compatible / Not Compatible
Z	Generation Orbit Gulfstream (C-20A)	Compatible / Compatible	Compatible / Compatible	Compatible / Compatible
Z	Aevum RavnX	Compatible / Compatible	Compatible / Compatible	Compatible / Compatible
Z	Bristol Spacecab	Potentially Compatible / Potentially Compatible	Potentially Compatible / Compatible	Compatible / Compatible
Z	Bristol Spacebus	Not Compatible / Not Compatible	Not Compatible / Potentially Compatible	Potentially Compatible / Potentially Compatible
Z	Orbital Access (MD-11)	Not Compatible / Not Compatible	Compatible / Compatible	Compatible / Compatible
Z	Swiss Space Systems (A300)	Potentially Compatible / Not Compatible	Compatible / Compatible	Compatible / Compatible
Reentry Vehicle	Boeing X-37B	Not Compatible / Compatible	Potentially Compatible / Compatible	Compatible / Compatible
Reentry Vehicle	Sierra Space Dream Chaser	Not Compatible / Compatible	Compatible / Compatible	Compatible / Compatible
Support Vehicle	Zero-G (727-200)	Potentially Compatible / Potentially Compatible	Compatible / Compatible	Compatible / Compatible
Support Vehicle	Super Guppy	Not Compatible / Potentially Compatible	Compatible / Compatible	Compatible / Compatible
Support Vehicle	Starfighter (F-104)	Compatible / Compatible	Compatible / Compatible	Compatible / Compatible
Super Sonic	Boom XB-1	Potentially Compatible / Compatible	Compatible / Compatible	Compatible / Compatible
Super Sonic	Aerion AS2	Potentially Compatible / Not Compatible	Compatible / Compatible	Compatible / Compatible
Super Sonic	Spike S-512	Compatible / Compatible	Compatible / Compatible	Compatible / Compatible
Super Sonic	Boom Overture	Not Compatible / Compatible	Compatible / Compatible	Compatible / Compatible

OTC = Off the Chart — *Compatible* — *Potentially Compatible* — *Not Compatible*

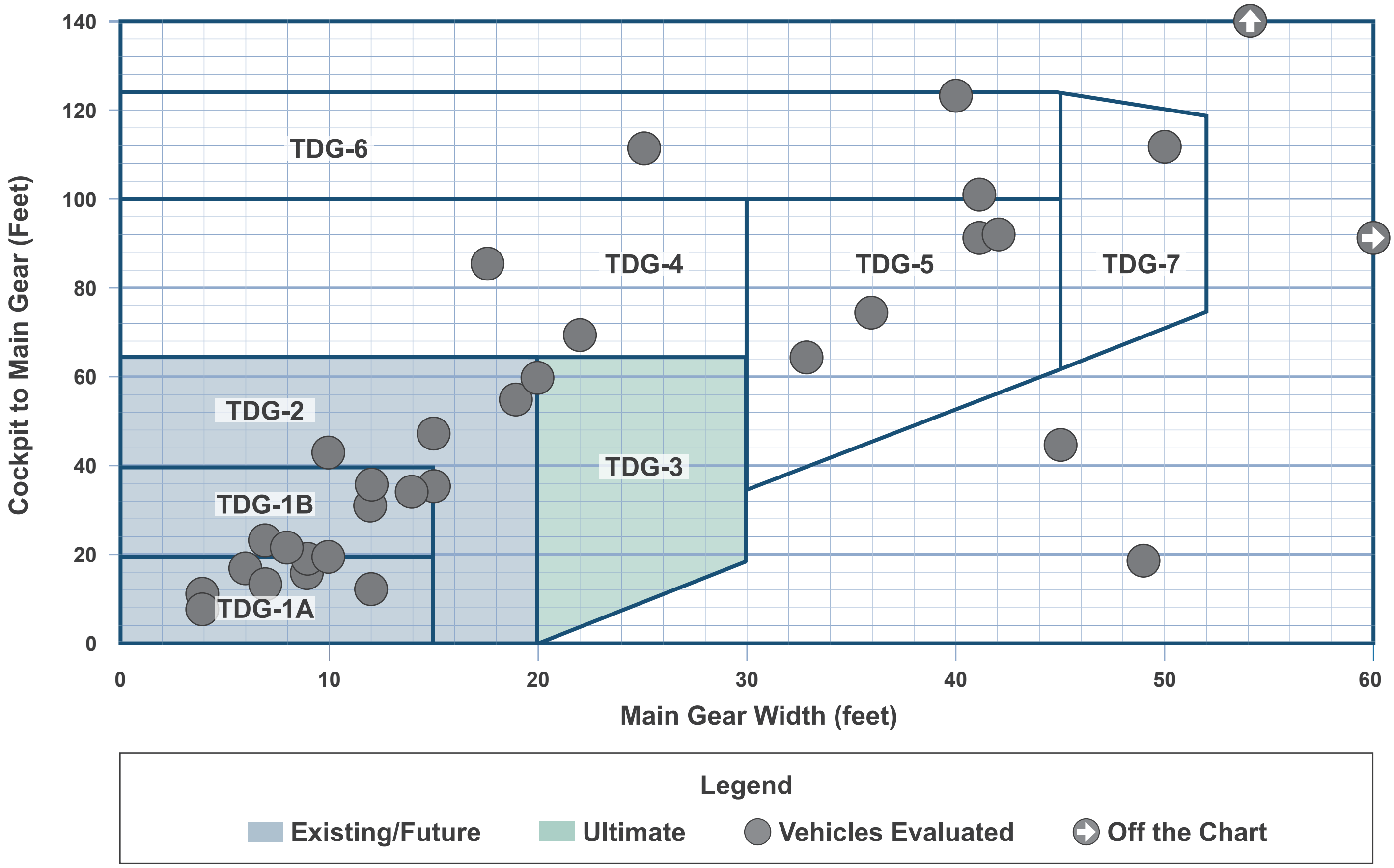
Source: Kimley-Horn

Taxiways

While the existing taxiways at CASP are 50 ft wide, they are operationally rated to the TDG-2 standard, which only require 35 ft of width. The existing taxiways can support TDG-1A/B and TDG-2 aircraft. These aircraft have a maximum Main Gear Width (MGW), which is distance from the outer edge to outer edge of the widest set of main gear tires, of 20 ft and make up between 50%-60% of the vehicles evaluated as part of this spaceport master plan.

At the current ADG of II and the ultimate ADG of IV, CASP meets the ADG criteria of approximately 55% and 95%, respectively, of the vehicles evaluated in this master plan. It may be possible to support larger vehicles on the existing taxiways, but it is recommended that the systems be evaluated on a case-by-case basis as unique considerations may be required for wingtip clearance, turning, and pavement strength.

Figure 4-5. Compatible Vehicle TDG Chart



Source: Kimley-Horn

Taxiway Assessment

A stoplight evaluation was conducted for the taxiway assessment. It should be noted that High-Altitude Balloons and VTVL vehicles were not included in the evaluation, as their operations are not dependent on taxiway characteristics.

The results of the evaluation are presented in **Table 4-6**. While increasing CASP's ADG from II to IV provides an increase in ADG compatibility from 55% to 95%, the modest increase in TDG from 2 to 3 only increases the TDG compatibility from 50% to 55%. To achieve a 90% TDG compatibility, a TDG of 7 would be required. Taxiway improvements would not be necessary for the entire airfield and may be strategically located to support spaceport infrastructure needs.

Table 4-6. Taxiway Compatibility Assessment

	Vehicle Description	Estimated ADG / TDG	Existing / Future: ADG II / TDG 2	Ultimate: ADG IV / TDG 3	Ultimate + TDG 7: ADG IV / TDG 7
X	RocketPlane XP	I / 1A	Green / Green	Green / Green	Green / Green
	Airbus Defence and Space Spaceplane	II / 1B	Green / Green	Green / Green	Green / Green
	Bristol Ascender	I / 1B	Green / Green	Green / Green	Green / Green
	PD Aerospace X06	I / 1A	Green / Green	Green / Green	Green / Green
	PD Aerospace X07	I / 1A	Green / Green	Green / Green	Green / Green
	PD Aerospace X08	II / 3	Green / Amber	Green / Green	Green / Green
	SABRE Development Vehicle	II / 2	Green / Green	Green / Green	Green / Green
	Reaction Engines Skylon	III / 6	Amber / Red	Green / Red	Green / Green
Y	XCOR Lynx	I / 1A	Green / Green	Green / Green	Green / Green
	Dawn Aerospace Mk-II Aurora	I / 1A	Green / Green	Green / Green	Green / Green
	Dawn Aerospace Mk-III	I / 2	Green / Green	Green / Green	Green / Green
Z	Northrop Grumman Stargazer (L-1011)	IV / 5	Amber / Red	Green / Red	Amber / Green
	Coleman Aerospace (C-17)	IV / 5	Amber / Red	Green / Red	Green / Green
	Coleman Aerospace (C-130)	IV / 1B	Amber / Green	Green / Green	Green / Green
	Virgin Orbit Cosmic Girl (747-400)	V / 5	Red / Red	Red / Red	Green / Green
	Virgin Galactic WhiteKnightTwo	IV / OTC	Amber / Red	Green / Red	Green / Green
	Stratolaunch	OTC	Red / Red	Red / Red	Red / Red
	Generation Orbit Gulfstream (C-20A)	II / 2	Green / Green	Green / Green	Green / Green
	Aevum RavnX	II / 1B	Green / Green	Green / Green	Green / Green
	Bristol Spacecab	III / 7	Amber / Red	Green / Red	Green / Green
	Bristol Spacebus	IV / OTC	Amber / Red	Green / Red	Green / Red
	Orbital Access (MD-11)	IV / 6	Amber / Red	Green / Red	Green / Green
	Swiss Space Systems (A300)	IV / 5	Amber / Red	Green / Red	Green / Green
Reentry Vehicle	Boeing X-37B	I / 1A	Green / Green	Green / Green	Green / Green
	Sierra Space Dream Chaser	I / 1A	Green / Green	Green / Green	Green / Green
Support Vehicle	Zero-G (727-200)	III / 4	Amber / Red	Green / Red	Green / Green
	Super Guppy	IV / OTC	Amber / Red	Green / Red	Green / Green
	Starfighter (F-104)	I / 1B	Green / Green	Green / Green	Green / Green
Super Sonic	Boom XB-1	I / 1B	Green / Green	Green / Green	Green / Green
	Aerion AS2	III / 4	Amber / Red	Green / Red	Green / Green
	Spike S-512	II / 2	Green / Green	Green / Green	Green / Green
	Boom Overture	II / 6	Green / Red	Green / Red	Green / Green

OTC = Off the Chart

Source: Kimley-Horn

Aprons

Aviation aprons provide pavement for aircraft storage and staging, equipment storage and staging, propellant storage and loading, aircraft maintenance, passenger loading, and various other functions. While asphalt pavements are generally sufficient, concrete aprons are recommended for spaceport applications where oxidizer storage or loading occurs because high concentration oxidizers, such as LOX, can have volatile reaction with asphalt. Additionally, aprons can provide either dedicated or multi-user functions. Dedicated aprons are constructed directly adjacent to hangar and processing facilities for use by that facility while multi-user aprons are positioned in commonly accessible areas. Examples of dedicated aprons include those abutting the Virgin Galactic hangar at Spaceport America and the Stratolaunch hangar at Mojave Air and Space Port.

The CASP LSOL proposes the siting of two spaceport-specific aprons labeled as Mission Preparation Area #1 and Mission Preparation Area #2. Mission Preparation Area #1 is a trapezoidal area on existing Taxiway E7, spanning 100 ft by 78.3 ft to 91.2 ft. Mission Preparation Area #1 is cited to accommodate jet fuel loading operations. Mission Preparation Area #2 is a proposed concrete apron, with connecting taxiway that is intended to serve as a location for jet fuel loading, liquid oxidizer loading, passenger loading, and hold for clearance to depart. Currently, Mission Preparation Area #2 can support all required propellant loading operations, and therefore it is anticipated that Mission Preparation Area #1 will not be utilized. In the near-term propellant loading for test operations may be feasible on a temporary basis using existing pavements. In the mid- to long-term a dedicated Mission Preparation Area and connecting taxiway should be constructed. For smaller launch systems a 100 ft x 100 ft concrete pad should be sufficient, while larger vehicles may require a pad up to 300 ft x 300 ft.

Aviation aprons can also support both low altitude VTVL vehicle testing and high-altitude balloon launch. For low altitude VTVL vehicle testing, apron pavements in the 20 ft x 20 ft to 40 ft x 40 ft range provide basic support for ground-based testing, tethered testing and low-altitude hover testing. For high-altitude balloon missions, pavement is required for the roll-out and inflation of the large balloon. For example, the World View facility in Tucson, AZ currently has a 700 ft diameter circular concrete pad to support the Stratollite program. In general, a 700 ft long x 50 ft wide prepared surface (concrete or asphalt) that is in-line with prevailing winds would be sufficient to support a broad range of high-altitude balloon missions. Potential spaceport support apron locations are evaluated in **Chapter 5**.

Figure 4-6. General Aviation Apron

Source: Kimley-Horn

Processing and Operations Facilities

Facilities that provide capacity for vehicle processing, payload processing, mission control operations, and propellant storage may be required by launch, reentry and support vehicle operators. The following subsections provide an overview of facility requirements for such operations.

In addition to standard requirements for operations facilities at CASP, facilities that support aerospace related operations should include appropriate security fencing and access control measures.

Vehicle Processing and Integration Facilities

Vehicle processing and integration facilities provide a diverse set of functions for spaceport users including vehicle storage and maintenance, vehicle assembly and integration, vehicle testing and checkout, and pre-flight and post-flight processing. For air and space ports, the processing and integration facilities are generally comprised of aircraft hangars with ancillary support facilities in the form of offices, restrooms, shops, high bays, and equipment rooms. Modular clean rooms may also be added to the hangars to enable the processing of small spacecraft, payloads or sensitive spaceflight hardware. The actual design and layout of each hangar varies from user to user and is often based on vehicle size and concept of operations.

As with typical aircraft, the size of these facilities is dependent on the type of aircraft anticipated to be processed within the hangar. The launch, reentry, and support vehicles analyzed in this spaceport master plan have a broad range of sizes and spatial requirements. **Table 4-7** provides an overview of the approximate hangar sizes for a range of different vehicles. It should be noted that ranges depicted in **Table 4-7** accommodate a single vehicle (or carrier and launch vehicle combination) as well as minimal office space. Due to some extreme variations in the wingspan to length ratio of some of the vehicles listed, the length and width of a required hangar may have unique proportions in some instances. In addition to winged vehicles, high altitude balloon and low-altitude VTVL vehicles were also evaluated for processing and integration needs. For supporting both low-altitude VTVL and high-altitude balloon missions, a facility or hangar that is 10,000 sqft or less is recommended for vehicle/payload processing and integration. In addition, a covered staging area approximately 100 ft x 100 ft would be recommended to support heavy equipment and other support hardware.

While the largest existing hangar facility at CASP is 38,600 sqft, roughly 42% of existing hangars at CASP envelope less than 10,000 sqft. Only approximately 16% of existing hangars have an envelope greater than 30,000 sqft. Currently, there is a wait list for hangars at CASP and the 2019 Airport Master Plan projected that there will be a hangar deficit into 2037. While some existing hangar facilities at CASP may be adequately sized to accommodate some of the launch, reentry and support vehicles evaluated in this master plan, the current lack of availability of these existing mid-sized hangars makes utilizing them unlikely for vehicle processing and integration operations.

To accommodate future launch, reentry or support vehicle processing, it is recommended that several dedicated hangars be developed. With the existing airfield configuration at CASP, a new 10,000 sqft hangar would be sufficient to accommodate approximately 40% of the potentially compatible vehicles, while a new 20,000 sqft hangar increases that compatibility to 60%. In the ultimate configuration, several hangars of various sizes, up to about 60,000 sqft should be considered to provide greater than 90% compatibility. Potential locations for hangar sites are evaluated in **Chapter 5**.

Table 4-7. Approximate Hangar / Processing Requirements

< 10,000 sqft
RocketPlane XP
Bristol Ascender
PD Aerospace X06
PD Aerospace X07
XCOR Lynx
Dawn Aerospace Mk-II
Dawn Aerospace Mk-III
Boeing X-37B
Sierra Space Dream Chaser
F-104 Starfighter
Boom XB-1
World View Stratollite
Space Perspectives Starship Neptune
Masten Xodiac
New Frontier Aerospace

10,000 sqft - 20,000 sqft
Airbus Defence and Space Spaceplane
PD Aerospace X08
SABRE Development Vehicle
Generation Orbit Gulfstream (C-20A)
Aevum RavnX
Spike S-512

20,000 sqft - 40,000 sqft
Aerojet Rocketdyne (C-130)
Virgin Galactic WhiteKnightTwo
Bristol Spacecab
Zero-G (727-200)
Super Guppy
Boom Overture
Aerion AS2

40,000 sqft - 60,000 sqft
Reaction Engines Skylon
Northrop Grumman Stargazer (L-1011)
Aeroject Rocketdyne (C-17)
Orbital Access MD-11
Bristol Spacebus
Swiss Space Systems (A300)

60,000 sqft - 80,000 sqft
Virgin Orbit Cosmic Girl (747-400)

> 80,000 sqft
Stratolaunch

Source: Kimley-Horn

Note: Footprints estimated by calculating minimum required hangar space plus 10% for support/office spaces. Due to the significant incompatibility with CASP, New Shepard and Starship are not included.

Figure 4-7. Private Hangar at Colorado Air and Space Port

Source: Colorado Air and Space Port

Payload Processing Facilities

Launch, reentry, and support vehicles may each require access to payload processing facilities (PPFs) to conduct integration and processing of payloads, spacecraft, and spaceflight hardware in a cleanroom environment. Operations typical within these facilities include delivery and receipt of the payloads, assembly and testing of the payloads, propellant loading, pre-flight packaging or encapsulation, and checkout. PPFs can either be purpose-built facilities, such as the Multi-Payload Processing Facility (MPPF) at Kennedy Space Center, or an integrated modular cleanroom facility co-located with a vehicle processing facility.

Purpose-built PPFs are often sited with adequate separation from other facilities given the possible presence of explosive hazards including propellants and ordinances. However, it is anticipated that payloads that are processed at CASP will generally be categorized as experimental and non-hazardous payloads for use in suborbital launches. If CASP eventually supports orbital missions, payloads with propulsion systems would require dedicated payload processing facilities capable of supporting hazardous operations.

Purpose-built PPFs typically contain the following capabilities:

- Payload processing bays/clean rooms
- Cranes or hoists
- Work benches
- Offices and workrooms for payload users
- Offices and workrooms for technical staff
- Storage rooms
- Restrooms
- Breakrooms
- Ground support equipment areas
- Hazardous propellant loading areas
- High pressure gas system control areas
- Laboratory spaces

The launch, reentry and support vehicles evaluated in this spaceport master plan typically support payloads that fall within the mass range of nano-satellite (2-20 lbs) to mini-satellite (< 1,100 lbs). It is anticipated that for microgravity experiments, that the typical payload mass would fall on the lower end of that range. Due to the smaller scale of these payloads from both a mass and size standpoint, a modular cleanroom may provide initial payload processing capabilities until a dedicated PPF is required.

A modular cleanroom is not a stand-alone facility, but rather a facility integrated within another facility. Modular cleanrooms offer the opportunity to conduct payload processing within existing hangar facilities, creating lower-cost, flexible spaces. Many of these such facilities provide a variety of enclosure solutions for cleanrooms (capable of offering the full spectrum of ISO classifications), dust control, sound control, safety and other applications. Modular cleanrooms are customizable and can be dismantled, relocated and reassembled in relatively short time frames.

Since no existing PPFs are present at CASP it is recommended that either a standalone or modular PPF be planned for future development when the demand for payload services is needed. In the near- to mid-term, while payload service demand is low, a 1,000 sqft modular clean room is recommended. In the long-term, as demand increases, a 10,000-30,000 sqft stand-alone PPF should be considered at CASP.

Mission Control Center

A common feature among spaceports is a Mission Control Center (MCC). An MCC is where administrative, engineering, and operations support personnel are located during launch, reentry, ground, and testing operations. The MCC often contains spaces for mission monitoring, mission communication, networking equipment, conference rooms, private offices, break rooms, and restrooms.

The primary role of an MCC is to serve as the location where vehicle and payload operators monitor their systems during mission operations. Therefore, the MCC must contain secure rooms with sufficient communications capabilities to support mission operations. During mission operations, coordination is required between mission control and air traffic control to ensure all aviation and aerospace operations are coordinated. CASP has an existing Air Traffic Control Tower (ATCT), so during mission operations communication between air traffic control and the launch or reentry operator will be directed through the CASP ATCT. Some spaceports, such as Cecil Spaceport, co-locate their MCC with their ATCT, however, this is not necessarily required as long as direct communication between the MCC and the ATCT is available. With the presence of CASP's ATCT and automated weather observation system, CASP has an advantage of housing existing infrastructure that would support many of the airspace and meteorological tracking functions an MCC requires.

While some operators choose to build their own dedicated MCCs in support of their unique missions, having MCC infrastructure available for potential use adds to the value proposition when attracting new users to the spaceport. At present, no dedicated spaceport MCC exists at CASP.

In the near- to mid-term approximate 1,000 - 2,500 sqft of existing office space is expected to be sufficient for mission control needs for small teams (5 - 10 people). In the long-term, up to 5,000 – 10,000 sqft of dedicated office space may be needed if a multi-tenant mission control center is developed capable of supporting between 20-50 people.

Figure 4-8. CASP Air Traffic Control Tower

Source: Kimley-Horn

Propellant Storage

Existing propellant storage at CASP is limited to aviation fuels and is provided by both underground and aboveground storage tanks. The existing tank capacities for 100 LL Avgas and Jet-A are 30,000-gallons each. The existing Explosive Site Plan has identified potential locations for rocket fuel and oxidizer storage on the eastern end of the airfield on an apron near existing hangars, however no permanent propellant storage infrastructure has yet been constructed. Liquid fuels and oxidizers that are commonly utilized by launch vehicles are included in **Table 4-8**.

Table 4-8. Common Propellants

Propellant Types	Existing Infrastructure	In LSOL
Liquid Fuels		
Jet A Fuel	●	●
Kerosene (RP-1)	○	●
Liquid Hydrogen (LH2)	○	○
Liquid Methane (LCH4)	○	●
Liquid Propylene	○	○
Liquid Oxidizers		
Liquid Oxygen (LOX)	○	●
Hydrogen Peroxide (H2O2)	○	○
Dinitrogen Tetroxide (N2O4)	○	○
Nitrous Oxide (N2O)	○	○
Solid / Hybrid Propellants		
HTPB	○	○
ABS	○	○
Nylon	○	○

● *Included* ○ *Excluded* *Source: Kimley-Horn*

Based on the findings of the Bryce report, consistent operations of licensed suborbital RLV flights are not anticipated in the near- to mid-term. However, an average of 10 test flights or less per year are anticipated to occur at CASP within the same period. In the near-term, research, development and testing activities are likely to account for a majority of the aerospace related activity. The testing frequency documented in the CASP LSOL states that up to 100 static hot fire engine tests may occur per year. The quantity of propellant and type of infrastructure associated with the propellant storage (temporary versus permanent) is dependent on user demand (i.e. engine testing, launch operations, and test flights) and testing infrastructure (fixed vs. mobile).

It is anticipated that early testing and launch activity at CASP can be accommodated by temporary storage of propellant in the form of tanker truck delivery. As demand for these activities increases, the importance of installing permanent propellant storage tanks, cross country piping and other supporting equipment also rises. The development of such permanent infrastructure is unlikely to be needed in the near-term and mid-term horizon, however it may be needed in the long-term horizon as the number of launch operations and testing increase. Some users may choose to develop fixed testing infrastructure that merit fixed propellant tanks for which the user will likely assume responsibility. Storage of hybrid solid rocket motors does not pose a significant explosive hazard without the presence of an oxidizer. Therefore, hybrid solid rocket motors can be stored within the RLV processing facilities as long as proper planning and controls in place. If solid propellants are considered for use at CASP, storage and processing facilities that house the solid propellants will need to be identified. This change will also require a modification to the Explosive Site Plan.

Incubator Spaces for Startup Companies

As mentioned in the Bryce report, many commercial aerospace startups require incubator space to begin developing their technologies and building their companies. Incubator space can be developed specifically for an individual company or developed with the intention of supporting multiple companies. One example of a multi-user incubator space is the Space Florida Space Life Science Lab located in Exploration Park, adjacent to NASA's Kennedy Space Center. The following amenities are common to include in incubator facilities.

- Research Laboratories
- Hardware Laboratories (for small payload processing)
- Clean rooms
- Machine Shop with traditional and rapid prototyping capabilities
- Workshop Space
- Storage Space
- Office Space
- Conference Rooms
- Breakrooms
- Restrooms

Currently there are no facilities at Colorado Air and Space Port that can serve as a permanent incubator space for startup companies. It is recommended that incubator space be provided within the property of CASP or within the Subarea around CASP. Initially, 5,000 sqft to 10,000 sqft of incubator space could provide several startups with room to develop new aerospace technologies.

Test Facilities

Since the market forecast highlighted that licensed launch operations are not expected to realize significant activity within the 20-year forecast period of this master plan, research, development and testing provide near-term and mid-term opportunities for CASP. Many of the vehicle systems evaluated in this master plan are in the early development and testing stages. While small scale testing can currently be supported at CASP, the facility does not have adequate infrastructure in place to accommodate multiple testing users or fixed engine test stands.

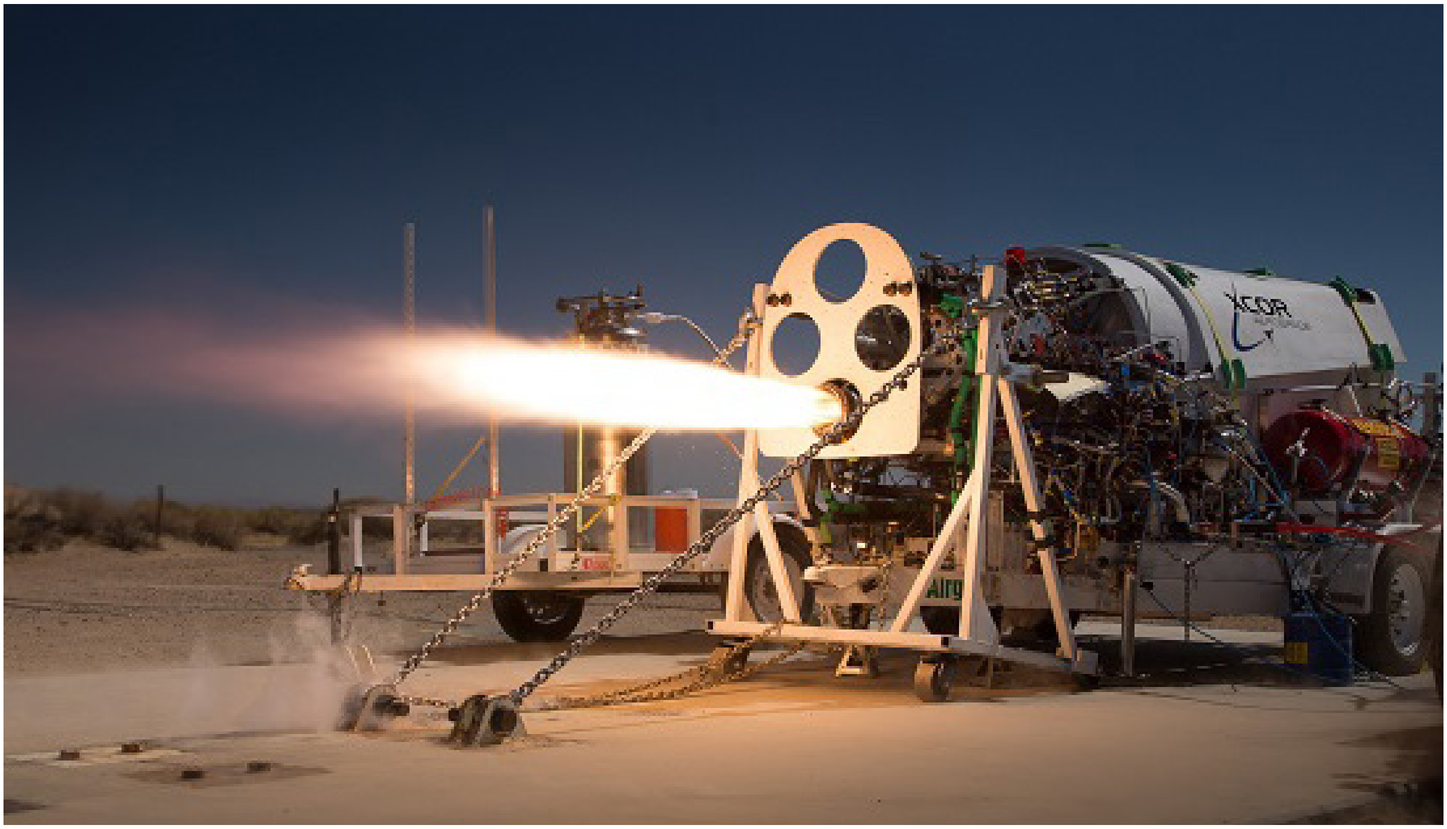
Two recent examples of businesses that conduct aerospace testing at CASP include Reaction Engines, Inc. and New Frontier Aerospace. Reaction Engines built a dedicated test facility at CASP to support testing of their high temperature heat exchanger. New Frontier Aerospace developed a testing program to utilize an existing apron at CASP to support small scale engine testing for their vertical takeoff and vertical landing (VTVL) demonstrator. In addition to these two companies, other aerospace companies have approached CASP to inquire about infrastructure and testing opportunities. With proper planning and infrastructure improvements, opportunities exist for CASP to address the anticipated testing demand within the forecast period.

Testing facilities at spaceports vary greatly however some common examples include hot fire engine test stands, tethered or untethered testing for VTVL vehicles, and component testing. Engine test stands can be indoor or outdoor, vertical or horizontal, and mobile or fixed depending on the class of engine and user. Tethered VTVL testing is typically performed outdoors over concrete pads where the test vehicle is physically constrained by use of a tether, usually attached to a mobile crane. In accordance with 14 CFR Part 400.2(c)(2), tethered testing must abide by specific criteria including a maximum flight altitude of 75 feet above ground level and maximum propellant quantity of 5,000 pounds on the test vehicle. For untethered VTVL testing a concrete pad is typically provided for takeoff and landing, however areas for free flight may pass above unpaved surfaces. All testing activities must be appropriately analyzed and separated from non-compatible operations to protect the uninvolved public and facilities in the event of a testing anomaly. Some non-traditional launch systems may have unique testing requirements not covered here.

Mobile Engine Testing

Mobile test stands require minimal permanent infrastructure and are appropriate for operators that only need to conduct short-term testing and have the ability to transport their testing infrastructure to the test site. At minimum, typical permanent infrastructure includes a concrete pad with tiedowns/anchors in a location with sufficient separation distances per the size of the test article. In some cases, temporary concrete barriers are placed near the test article and a mobile command center, located in a Conex box, is provided. For mobile test stands, the operator is responsible for delivering the infrastructure and propellants necessary for their testing operations and removing the infrastructure after the testing program is completed. Mobile test stands generally accommodate small or medium engine testing. An example mobile test stand is the one utilized by XCOR Aerospace at Mojave Air and Space Port for testing a range of small rocket engines, including their 5K18 engine that produced between 2,500 to 3,000 pounds of thrust.

Figure 4-9. Lynx Engine Hot Fire



Source: XCOR

VTVL (Tethered / Untethered) Test Sites

In general, small VTVL tethered and untethered testing sites require minimal permanent infrastructure. Common required infrastructure includes concrete pads and a nearby mission control center. For tethered testing, a physical means to constrain the test vehicle to the ground, such as a tether attached to an aerial work platform, is required. Precedent exists for tethered testing sites to be located adjacent to runways at air and space ports. Mojave Air and Space Port, for example, has hosted multiple tethered and untethered point-to-point test flights for Masten Space Systems for their terrestrial VTVL vehicles. Mobile propellant storage and loading systems are typically utilized for small VTVL test sites. Many of the same considerations identified for mobile engine testing apply for VTVL test sites.

Fixed Static Engine Testing

Fixed static engine test sites typically require permanent infrastructure to support frequent testing for a singular user. At a minimum, these sites include a permanent structure to hold the rocket engine, permanent run tanks to feed propellant to the engine during testing, cameras and data acquisition hardware, and a control center for managing the testing operations. Additional infrastructure may include flame deflectors and high flow water systems.

Two static engine test facilities were examined to provide examples of potential testing activities that could be expected at CASP and the infrastructure required to support the testing operations. The two examples are the Badger Propulsion Test Facility in Wisconsin and the Firefly Test Site in Texas.

Badger Propulsion Test Facility (Wisconsin)

Orbital Technologies Corporation (ORBITEC), a wholly-owned subsidiary of Sierra Nevada Corporation (SNC), operates a propulsion test site within the property of the decommissioned Badger Army Ammunition Plant, located in Baraboo, Wisconsin. This test site contains a series of test cells used to perform static hot fire tests, most recently used for SNC's patented VORTEX engines. The test cells at the Baraboo facility are rated to accommodate thrusts from 30,000-pound force (lbf) to 150,000-lbf. The site has undergone modifications over the past decade, but onsite supporting infrastructure has generally comprised of propellant storage areas, test cells, a control room, and water storage tanks. To account for testing during all four seasons, two interior test cells have been developed that include roll up doors that can be opened prior to engine testing. The Badger Propulsion Test Facility has the advantage of being located in a remote location where explosive safety separation distances can be easily maintained from public areas, roads and inhabited buildings.

Figure 4-10. ORBITEC's 30,000 Pound Thrust Vortex Engine

Source: ORBITEC

Firefly Test Site (Texas)

Firefly Aerospace operates a rocket engine testing facility on 200-acres of land in in Briggs, Texas. There are two test stands at the site, Test Stand 1 and Test Stand 2. The former is a horizontal static hot fire test stand equipped with foundations extending 40 feet below grade and is capable of testing rocket engines with up to 450,000-lbf of thrust. Test Stand 2 is a 100-ft tall vertical test stand capable of accommodating thrust in excess of 165,000-lbf. Fuel and oxidizer storage areas are provided at the site for both test cells utilizing cross-country piping for delivery to the stands. The Briggs test site also includes several other facilities including a 2,500 sqft surface finish shop, a 30,000 sqft production shop, and a 10,000 sqft test control and fabrication building. Like the Badger Propulsion Test Facility, the Firefly test site can accommodate larger safety setbacks on its 200-acre site.

Figure 4-11. Firefly Test Stand 2

Source: Firefly Aerospace

CASP Test Stand Siting

When siting a test stand at an air and space port, the physical test infrastructure and the associated safety separation distances should ideally remain within the property boundary and away from public areas, roads, runways, inhabited buildings, and Part 77 imaginary surfaces. The typical propellant quantities on small to medium engine test cells trigger quantity distances (QDs), or safety separation distances, of up to 1,250 feet (see **Table 4-9**). Within the existing CASP property boundary, there are a limited number of areas where QDs of 1,250 ft or large can be entirely contained within the existing property boundary.

For aerospace users interested in small engine test stands or small VTVL test flights, QDs of less than 1,250 ft are possible due to the low quantities of propellant on the test articles. As the QDs decrease, the number of areas within the existing property boundary where testing can safely occur increases.

Table 4-9 provides examples of QDs associated with various quantities a Net Explosive Weight (NEW), or TNT equivalent, commonly identified as Hazard Division (HD) 1.1. For comparison purposes an equivalent weight of the common propellant combination LOX and RP-1 is also provided. It is anticipated that many potential future users at CASP could complete testing operations on small or medium test stands with a NEW up to 30,000 lbs. Larger test stands may be require land acquisition and custom siting to be supported at CASP.

It is recommended that CASP provides basic siting and infrastructure to support at least one shared Mobile / VTVL test site in the near-term and one area dedicated to future fixed engine testing. Additional test sites should be considered as mid-term and long-term developments when demand increases, as identified in **Table 4-10**.

Table 4-9. Quantity Distances (QD) for Test Stands

NEW (lbs)	LOX/RP-1 (lbs)	PAD (ft)	PTRD (ft)
Small Test Stands			
2	20	346	208
10	100	474	284
50	500	601	361
Medium Test Stands			
100	1,000	658	395
200	2,000	927	556
300	3,000	1,085	654
450 to 30,000	4,500 to 300,000	1,250	750
Large Test Stands			
50,000	500,000	1,474	884
75,000	700,000	1,649	984
100,000	1,000,000	1,857	1,114

Note: PAD = Public Area Distance, PTRD = Public Traffic Route Distance

Source: Kimley-Horn

Table 4-10. Proposed Number of Test Sites

Test Sites	Near-Term	Mid-Term	Long-Term
Mobile Test Site VTVL Test Site	One Shared Site	Two Shared Sites	Two to Three Shared Sites
Fixed Test Site	One Dedicated Site	One Dedicated Site	One to Three Dedicated Sites

Source: Kimley-Horn

Facility Requirements Summary

As shown in **Table 4-11** the current configuration and infrastructure at CASP can support about 50% of the vehicle systems evaluated in this master plan. It is important to note that a transition from the existing configuration to the future configuration does not increase the compatibility of CASP. In addition, improvements to the ultimate configuration would only increase CASPs compatibility by about 5% unless the TDG was also increased to 7, which would result in a compatibility of approximately 90%. Vehicle compatibility is listed in **Table 4-12** and CASP infrastructure recommendations are provided in **Table 4-13**.

Table 4-11. Vehicle System Compatibility

Configuration	Compatibility	Runway Length	Runway Width	ADG	TDG	Hangar (sqft)
Existing / Future	35%	8,000	100	I	1B	< 10,000
	40%	8,000	100	II	1B	10,000 – 20,000
	45%	8,000	100	II	1B	10,000 – 20,000
	50%	8,000	100	II	2	10,000 – 20,000
Ultimate	55%	9,000	100	II	3	20,000 – 40,000
Ultimate + TDG 5	60%	9,000	150	III	4	20,000 – 40,000
	65%	10,000	150	IV	5	20,000 – 40,000
	70%	10,000	150	IV	5	20,000 – 40,000
	75%	10,000	150	IV	5	20,000 – 40,000
Ultimate + TDG 7	80%	12,000	150	IV	6	40,000 – 60,000
	85%	12,000	150	IV	6	40,000 – 60,000
	90%	12,000	150	IV	7	40,000 – 60,000
Custom	95%	12,000	150	IV	OTC	40,000 – 60,000
	100%	16,500	200	V	OTC	> 100,000

Source: Kimley-Horn

The following facility requirements are identified for consideration in development alternatives.

Table 4-12. Vehicle System Compatibility

Vehicle Description		Current Licensing Compatibility	Existing / Future Infrastructure Compatibility	Ultimate Infrastructure Compatibility
X	RocketPlane XP	Compatible	Potentially Compatible	Compatible
X	Airbus Defence and Space Spaceplane	Compatible	Potentially Compatible	Compatible
X	Bristol Ascender	Compatible	Potentially Compatible	Compatible
X	PD Aerospace X06	Compatible	Compatible	Compatible
X	PD Aerospace X07	Compatible	Compatible	Compatible
X	PD Aerospace X08	Compatible	Potentially Compatible	Compatible
X	SABRE Development Vehicle	Compatible	Compatible	Compatible
X	Reaction Engines Skylon	Compatible	Not Compatible	Not Compatible
Y	XCOR Lynx	Not Compatible	Compatible	Compatible
Y	Dawn Aerospace Mk-II Aurora	Not Compatible	Compatible	Compatible
Y	Dawn Aerospace Mk-III	Not Compatible	Compatible	Compatible
Z	Northrop Grumman Stargazer (L-1011)	Not Compatible	Potentially Compatible	Potentially Compatible
Z	Coleman Aerospace (C-17)	Not Compatible	Potentially Compatible	Potentially Compatible
Z	Coleman Aerospace (C-130)	Not Compatible	Potentially Compatible	Compatible
Z	Virgin Galactic WhiteKnightTwo	Not Compatible	Potentially Compatible	Potentially Compatible
Z	Virgin Orbit Cosmic Girl (747-400)	Not Compatible	Not Compatible	Potentially Compatible
Z	Stratolaunch	Not Compatible	Not Compatible	Not Compatible
Z	Generation Orbit Gulfstream (C-20A)	Not Compatible	Compatible	Compatible
Z	Aevum RavnX	Not Compatible	Compatible	Compatible
Z	Bristol Spacecab	Not Compatible	Potentially Compatible	Potentially Compatible
Z	Bristol Spacebus	Not Compatible	Not Compatible	Potentially Compatible
Z	Orbital Access (MD-11)	Not Compatible	Not Compatible	Potentially Compatible
Z	Swiss Space Systems (A300)	Not Compatible	Not Compatible	Potentially Compatible
Reentry Vehicle	Boeing X-37B	Not Compatible	Not Compatible	Compatible
Reentry Vehicle	Sierra Space Dream Chaser	Not Compatible	Not Compatible	Compatible
Support Vehicle	Zero-G (727-200)	Not Applicable	Potentially Compatible	Compatible
Support Vehicle	Super Guppy	Not Applicable	Potentially Compatible	Potentially Compatible
Support Vehicle	Starfighter (F-104)	Not Applicable	Not Compatible	Compatible
Super Sonic	Boom XB-1	Not Applicable	Potentially Compatible	Compatible
Super Sonic	Aerion AS2	Not Applicable	Not Compatible	Potentially Compatible
Super Sonic	Spike S-512	Not Applicable	Compatible	Compatible
Super Sonic	Boom Overture	Not Applicable	Not Compatible	Potentially Compatible
Balloon	World View Stratollite	Not Compatible	Compatible	Compatible
Balloon	Space Perspectives Spaceship Neptune	Not Compatible	Compatible	Compatible
VTVL	Masten Xodiac	Not Compatible	Compatible	Compatible
VTVL	Blue Origin New Shepard	Not Compatible	Not Compatible	Not Compatible
VTVL	SpaceX Starship	Not Compatible	Not Compatible	Not Compatible
VTVL	New Frontier Aerospace Test Article	Not Compatible	Compatible	Compatible
		General Compatibility	**35% - 65%**	**60% - 90%**

Compatible *Potentially Compatible* *Not Compatible*

Source: Kimley-Horn

Table 4-13. CASP Infrastructure Recommendations

Infrastructure	Near-Term	Mid-Term	Long-Term
Runways	Existing	Existing	Existing 8/26 Ultimate 17/35 12,000 ft x 150 ft
Taxiways	Existing	Existing	Existing 8/26 Ultimate ADG with TDG 7 for 17/35.
Aprons	Existing	Construct Dedicated 100' x100' concrete mission preparation area with 1,250 ft PAD	Construct Dedicated 300' x 300' concrete Mission Preparation Area with 1,250 ft PAD
Vehicle Processing Facility	One 20,000 sqft hangar	One Additional 20,000 sqft hangar	One 60,000 sqft hangar
Payload Processing Facility	None / User provided	1,000 sqft modular cleanroom	Additional 1,000 sqft modular cleanroom Or 10,000 to 30,000 sqft standalone PPF
Mission Control Center	1,000 to 2,500 sqft	1,000 to 2,500 sqft	5,000 to 10,000 sqft
Propellant Storage	Temporary storage on existing aprons	Temporary storage on existing aprons	Temporary storage on existing aprons
Incubator Space	1 company 2,500 - 5,000 sqft	2 companies 5,000 – 10,000 sqft	4+ companies 10,000 sqft to 20,000+ sqft
Mobile Engine Test Site	300 ft x 300 ft Test Area with 350 ft PAD	300 ft x 300 ft Test Area with 1,250 ft PAD	300 ft x 300 ft Test Area with 1,250 ft PAD
VTVL Test Site	300 ft x 300 ft Test Area with 460 ft PAD	300 ft x 300 ft Test Area with 1,250 ft PAD	One to Two 300 ft x 300 ft Test Areas with 1,250 ft PAD with connected operational flight corridor.
Fixed Engine Test Site	300 ft x 300 ft Test Area with 350 ft PAD	300 ft x 300 ft Test Area with 1,250 ft PAD	One to three 1-acre Test Areas with 1,250 ft PAD
Balloon Launch	700 ft x 50 ft Apron	700 ft x 50 ft Apron	700 ft x 50 ft Apron

Source: Kimley-Horn

The existing facilities are capable of supporting about 50% of the launch, reentry, and support systems analyzed in this master plan. Due to the limited number of licensed launch systems that are compatible with CASP, near-term R&D, testing, and manufacturing should be prioritized at CASP. Strategic long-term infrastructure improvements such as a runway extension, pavement strengthening, taxiway modifications, apron expansions, test area development, and hangar development can increase the facility compatibility to around 90% and provide the necessary facilities for a wide range of aerospace tenants and programs.

5

Chapter 5

Alternatives

ALTERNATIVES ANALYSIS

The objective of this chapter is to identify and assess alternative concepts for satisfying the requirements identified as part of **Chapter 4**, Facility Requirements, for the near-term, mid-term, and long-term planning horizons.

Different alternatives were developed to satisfy varying levels of vehicle system compatibility (see **Table 4-11**). Typically, the alternatives (other than the no action alternatives) presented in this chapter correlate to 50%, 75%, or 90% vehicle system compatibility.

Runways

The following subsections provide an overview of the alternatives to improve Runway 8/26 and Runway 17/35. Improvements that are proposed in the alternatives include increasing runway length, runway width, and runway pavement strength.

Runway 8/26

Alternative 1 – No Action Alternative

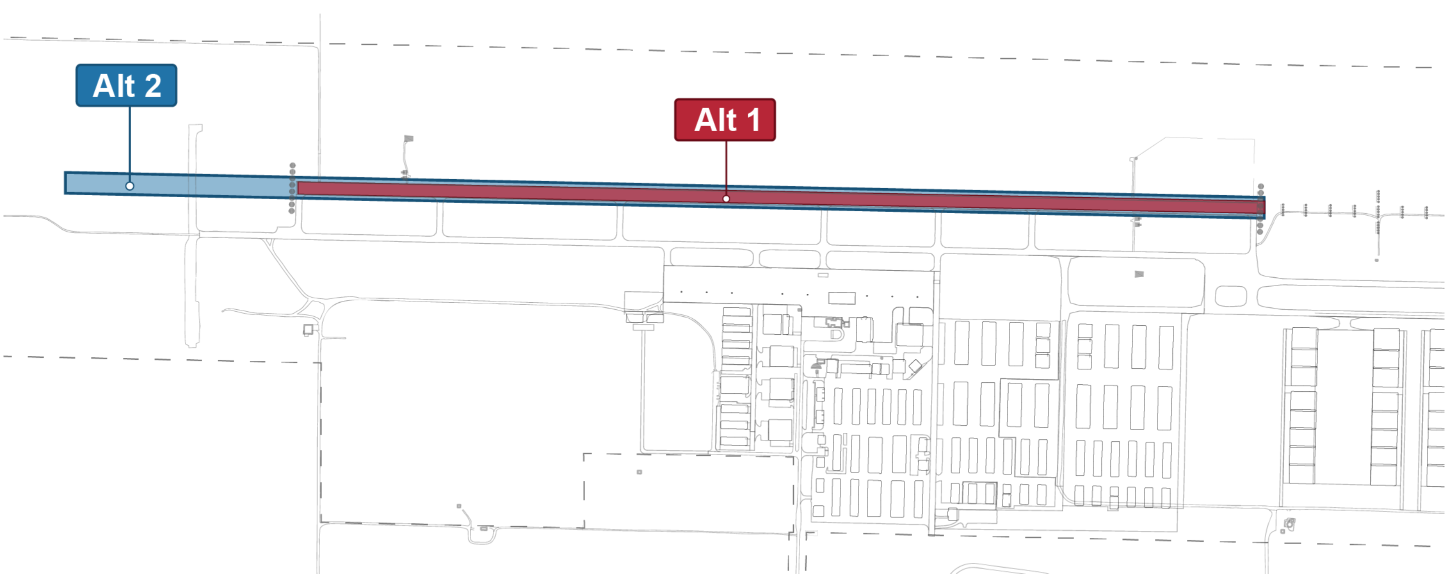
No improvements would be made to Runway 8/26 in Alternative 1. For this scenario, the runway would remain an 8,000 ft long by 100 ft wide asphalt runway with a published pavement strength of 28,000 lbs for single wheel gear (SWG) and 40,000 lbs for dual tandem wheel gear (DTWG). With the no action alternative, approximately 50% of the vehicles analyzed as part of this spaceport master plan could operate on the runway. However, there would need to be a pavement strength evaluation conducted to determine the impact of the vehicles on the life of the runway pavement. The results of the pavement strength evaluation may limit the number of aerospace operations that are allowed on Runway 8/26.

Alternative 2 – Ultimate Runway Extension and Widening

Alternative 2 involves extending Runway 8/26 to a length of 10,000 ft and widening to an overall width of 150 ft. The runway improvements would result in a new Runway Design Code (RDC) of C-IV-2400. In this alternative, the runway strength would be increased to support aircraft up to a Boeing 767-400 ER with a maximum takeoff weight of 450,000 pounds and a dual tandem main gear.

With the improvements proposed in this alternative, approximately 75% of the vehicles analyzed as part of this spaceport master plan could operate on the runway. It is anticipated that the pavement strengthening will also allow for vehicles to operate without significantly altering the runway pavement life. However, a pavement strength evaluation should be conducted to determine the impacts of vehicles that intend to operate on Runway 8/26.

Figure 5-1. Runway 8/26 Alternatives



Runway 17/35

Alternative 1 – No Action Alternative

Alternative 1 for Runway 17/35 does not include any proposed improvements for the runway. Runway 17/35 would remain an 8,000 ft long by 100 ft wide runway with a published pavement strength of 34,000 pounds SWG and 75,000 pounds DTWG. With the no action alternative, approximately 50% of the vehicles analyzed as part of this spaceport master plan could operate on the runway. However, there would need to be a pavement strength evaluation conducted to determine the impact of the vehicles on the life of the runway pavement. The results of the pavement strength evaluation may limit the number of aerospace operations allowed on Runway 17/35.

Alternative 2 - Intermediate Runway Extension

Alternative 2 involves extending Runway 17/35 to an overall length of 10,000 ft. In this alternative, the runway would remain the same width and strength as it is currently configured. With the improvements proposed in this alternative, approximately 50-55% of the vehicles analyzed as part of this spaceport master plan could operate on the runway. However, there would need to be a pavement strength evaluation conducted to determine the impact of the vehicles on the life of the runway pavement. The results of the pavement strength evaluation may limit the number of aerospace operations allowed on Runway 17/35.

Alternative 3 – Intermediate Runway Extension, Runway Widening, and Pavement Strengthening

Alternative 3 involves extending Runway 17/35 to an overall length of 10,000 ft, widening to an overall width of 150 ft, and strengthening the pavement to support aircraft up to a Boeing 767-400 ER with a maximum takeoff weight of 450,000 pounds and a dual tandem main gear. The runway improvements would result in a new RDC of C-IV-2400.

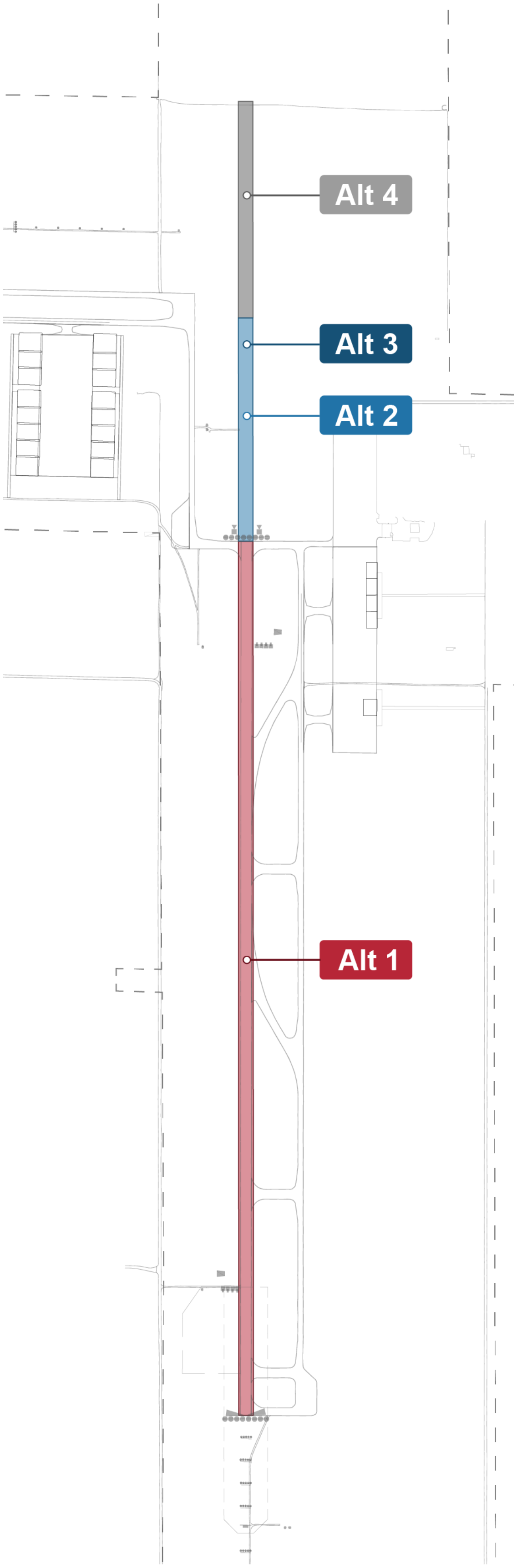
With the improvements proposed in this alterative, approximately 75% of the vehicles analyzed as part of this spaceport master plan could operate on the runway. It is anticipated that the pavement strengthening will also allow for vehicles to operate without significantly altering the runway pavement life. However, a pavement strength evaluation should be conducted to determine the impacts of vehicles that intend to operate on Runway 17/35.

Alternative 4 - Ultimate Runway Extension, Runway Widening, and Pavement Strengthening

Alternative 4 includes extending Runway 17/35 to an ultimate length of 12,000 ft and widening the runway to an ultimate width of 150 ft, and strengthening the pavement to support aircraft up to a Boeing 747-400ER with a maximum takeoff weight of 910,000 pounds and a dual tandem main gear. The runway improvements would result in a new RDC of D-V-2400.

With the improvements proposed in this alterative, approximately 95% of the vehicles analyzed as part of this master plan could operate on the runway. It is anticipated that the pavement strengthening improvements will allow for the vehicles to operate without significantly altering the life of the runway pavement. However, a pavement strength evaluation should be conducted to determine the impacts of the vehicles that intend to operate on Runway 17/35.

Figure 5-2. Runway 17/35 Alternatives



Taxiways

Alternative 1 – No Action Alternative

In the No Action Alternative, no improvements will be made to any of the taxiways on the air and space port. The current taxiways are designed to support TDG 1B and ADG II aircraft. Although the current width of the taxiways is 50 ft, under this alternative the taxiways will only be maintained to a width of 25 ft.

Although the current TDG designation for the taxiways is only TDG 1B, the current taxiway geometries exceed the requirements for TDG 1B taxiways. Therefore, the current taxiways are capable of supporting approximately 50% of the vehicles analyzed as part of this spaceport master plan. However, as the taxiways will only be maintained to 25 ft, the long-term compatibility of the taxiways to accommodate 50% of the vehicles will be reduced.

Alternative 2 – Modify Taxiways to support ADG III and TDG 3

Alternative 2 includes modifying existing taxiway geometries to support TDG 3 aircraft and matches what is proposed in the Ultimate ALP. The current width of the existing taxiways is at least 50 ft, which is the required width for a taxiway to support TDG 3 aircraft. However, the current geometry of the taxiway intersections at CASP do not meet the current geometric standards defined in Advisory Circular (AC) 150/5300-13A, Airport Design. In this alternative, the intersection geometry for the taxiways would be modified to meet the most current FAA design standards.

The geometric modifications would allow for larger vehicles to operate on the taxiways, but a pavement strength evaluation would need to be conducted to determine the impacts of the operations on the pavement life. If the results of the evaluation determine that larger aircraft regularly operating on the taxiway will significantly decrease the pavement life, CASP may decide to either limit the number of operations that are allowed or complete taxiway improvements to strengthen the taxiway pavements.

Currently, the taxiways have sufficient separation distances to support ADG III aircraft. However, the runways are not rated to support ADG III so there is no benefit of changing the taxiway designations until runway improvements are completed and a designation adjustment is merited.

The results of the geometric improvements would slightly increase the percent of aerospace vehicles that are compatible with the taxiways, and the taxiways would meet FAA standards for TDG 3 aircraft. It should be noted that taxiway improvements should only be considered for taxiways that serve the runway(s) being improved.

Alternative 3 – Modify Taxiways to support ADG IV and TDG 5

Alternative 3 includes modifying the existing taxiway geometry to support TDG 5 aircraft. This alternative would require both taxiway widening and taxiway intersection modifications to standard. Although the modifications would allow for larger vehicles to operate on the taxiways, a pavement strength evaluation would need to be conducted to determine the impacts of the larger vehicles on the pavement life. The results of the pavement strength evaluation may result in operational constraints or additional recommendations to strengthen the taxiway pavements.

Similar to Alternative 2, these modifications would not be beneficial unless one or more of the runways were improved such that larger aircraft could be accommodated on the airfield. It should be noted that the modifications proposed in this alternative exceed the magnitude of modifications that are proposed in the 2019 Ultimate ALP.

The improvements made in Alternative 3 would make the modified taxiways compatible with approximately 75% of the vehicles evaluated as part of this master plan.

Alternative 4 – Modify Taxiways to support ADG IV and TDG 7

Alternative 4 includes modifying the existing taxiway geometry for taxiways associated with Runway 17/35 to support TDG 7 aircraft. This alternative would require both taxiway widening and taxiway intersection modifications to standard. Although the modifications would allow for larger vehicles to operate on the taxiways, a pavement strength evaluation would need to be conducted to determine the impacts of the larger vehicles on the pavement life. The results of the pavement strength evaluation may result in operational constraints or additional recommendations to strengthen the taxiway pavements.

Similar to Alternatives 2 and 3, these modifications would not be beneficial unless one or more of the runways were improved such that larger aircraft could be accommodated on the airfield. It should be noted that the modifications proposed in this alternative exceed the magnitude of modifications that are proposed in the 2019 Ultimate ALP.

The improvements made in Alternative 4 would make the modified taxiways compatible with approximately 95% of the vehicles evaluated as part of this master plan.

Aprons

Alternative 1 – No Action Alternative

The No Action Alternative would result in no new apron development at CASP. Aerospace activities would utilize existing aprons. The current apron used for aerospace activities is 400 ft by 1,200 ft in size and is located near the Fire Station. All existing aprons at CASP are constructed from asphalt, which can have volatile reactions with high concentration oxidizers, such as LOX. In the no action alternative, operators will risk causing volatile chemical reactions with the pavement when loading oxidizer onto their vehicle.

Alternative 2 – Alternative 1 and New Apron within Support Aerospace Development Area

Alternative 2 constructs new apron facilities within the Aerospace Development Area in addition to retaining the existing apron area. The size of the new apron will vary based upon the individual operator(s) needs.

Alternative 3 – Alternative 1 and New Balloon Launch Apron

This alternative retains the existing apron area and constructs a 700-foot diameter balloon launch apron within the Aerospace Development Area. As balloon launches do not use high concentration oxidizers, the new balloon launch apron can be constructed with asphalt pavement.

Alternative 4 – Alternative 2 and New Balloon Launch Apron

Alternative 4 retains the existing apron area used for aerospace operations, develops new concrete apron within the Aerospace Development Area, and constructs a 700-foot diameter asphalt balloon launch apron also within the Aerospace Development Area.

Mission Preparation Area

Alternative 1 – No Action Alternative

The No Action Alternative retains the proposed use of Mission Preparation Area #1 west of Runway 17/35 and south of Taxiway E. This alternative does not construct a second Mission Preparation Area. If a second Mission Preparation Area was desired by an operator, they would be responsible for the development of the facility. The location of Mission Preparation Area #1 is defined in the LSOL Application.

Alternative 2 – Construct Mission Preparation Area #2

Alternate 2 includes the construction of Mission Preparation Area #2, a 100 ft by 100 ft concrete apron and connecting taxiway located west of the Terminal Apron. This includes construction of a new connector taxiway that would connect the new concrete apron to Taxiway A.

This alternative provides a location where final mission preparation and vehicle propellant loading can safely occur. Mission Preparation Area #2 is intended to serve as a location for fuel loading, oxidizer loading, passenger loading, and hold for clearance to depart. This location can also be used to safely offload propellants in the case of a scrubbed mission or a reentry. The location of Mission Preparation Area #2 is defined in the LSOL Application.

Alternative 3 – Construct New Mission Preparation Area #1, Northeast Option

In Alternative 3, a 300-ft by 300-ft new concrete Mission Preparation Area east of Runway 17/35, on the northern end of the Airport property, would be constructed instead of Mission Preparation Area #1 and serve as the primary Mission Preparation Area for Runway 17/35. This alternative would provide an area close to Runway 17/35 where propellant loading, passenger loading, and hold for clearance to depart could occur. This alternative is particularly desirable if a significant number of operations are to be conducted from Runway 17/35 because it minimizes fuel consumption due to taxiing and eliminates the need to top-off fuel immediately prior to takeoff. It should be noted that land acquisition would be necessary for development in this area.

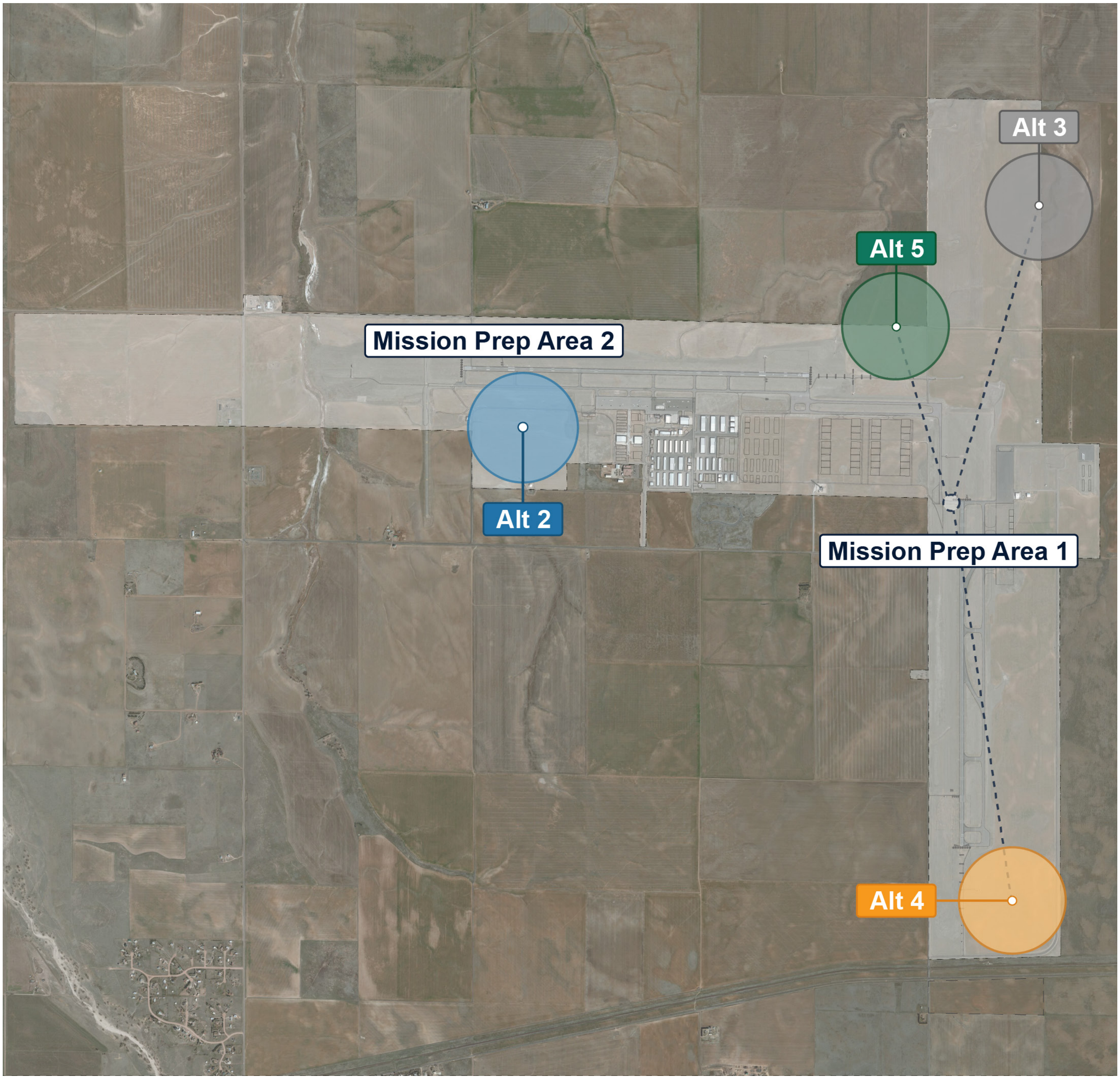
Alternative 4 – Construct New Mission Preparation Area #1, Southeast Option

In Alternative 4, a 300-ft by 300-ft new concrete Mission Preparation Area east of Runway 17/35, on the southern end of the Airport property would be constructed to replace Mission Preparation Area #1. This alternative would provide an area close to Runway 17/35 where propellant loading, passenger loading, and hold for clearance to depart could occur. This alternative is particularly desirable if a significant number of operations are to be conducted from Runway 17/35 because it minimizes fuel consumption due to taxiing and eliminates the need to top-off fuel immediately prior to takeoff.

Alternative 5 – Construct New Mission Preparation Area #1, Northwest Option

In Alternative 5, a 300-ft by 300-ft new concrete Mission Preparation Area west of Runway 17/35 and north of runway 8/26, on the northern end of the Airport property would be constructed to replace Mission Preparation Area #1. This alternative would provide an area close to Runways 8/26 and 17/35 where propellant loading, passenger loading, and hold for clearance to depart could occur. This alternative is particularly desirable if a significant number of operations are to be conducted from both runways because it provides a centrally located area and it minimizes fuel consumption due to taxiing and eliminates the need to top-off fuel immediately prior to takeoff. It should be noted that land acquisition would be necessary for development in this area.

Figure 5-3. Mission Preparation Alternatives



Source: Kimley-Horn

Dedicated Aerospace Development Area

All the proposed alternatives are located east of Runway 17/35. This location was strategically selected to separate aerospace and aviation activities at the CASP. Additionally, the ultimate runway length of Runway 17/35 is more conducive to aerospace operations than Runway 8/26. Therefore, logistically it is also advantageous to be located adjacent to the Runway 17/35.

Alternative 1 – No Action Alternative

In the No Action Alternative, no steps would be made by CASP to develop a dedicated Aerospace Development Area and future aerospace infrastructure would be developed consistent with the 2019 Airport Master Plan.

Alternative 2 – 450-acre Aerospace Development Area East of Runway 17/35

Alternative 2 dedicates approximately 450-acres to the east of Runway 17/35 as the Aerospace Development Area. This alternative allocates almost all the developable land east of the runway to aerospace development. This option anticipates that Runway 17/35 will be extended to the ultimate length of 12,000 ft. The proposed area would overlap infrastructure improvements that were included in the 2019 future and ultimate ALP. It should be noted that the ARFF and the associated infrastructure are located within the proposed area but will not be impacted by future aerospace development.

Alternative 3 – Develop 375-acre Aerospace Development Area East of Runway 17/35

Alternative 3 dedicates approximately 375 acres of land east of Runway 17/35 for aerospace development. This alternative anticipates that Runway 17/35 will be extended to a length of at least 10,000 ft. The proposed area would overlap infrastructure improvements that were included in the 2019 future and ultimate ALP. It should be noted that the ARFF and the associated infrastructure are located within the proposed area but will not be impacted by future aerospace development.

Figure 5-4. Development Area Alternative 2

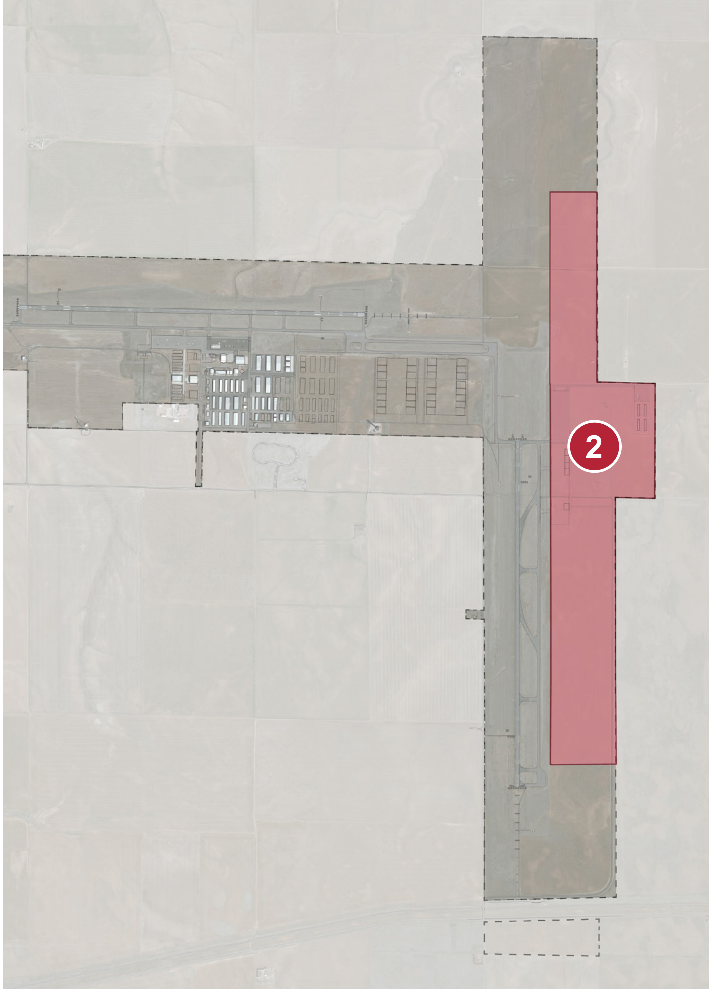
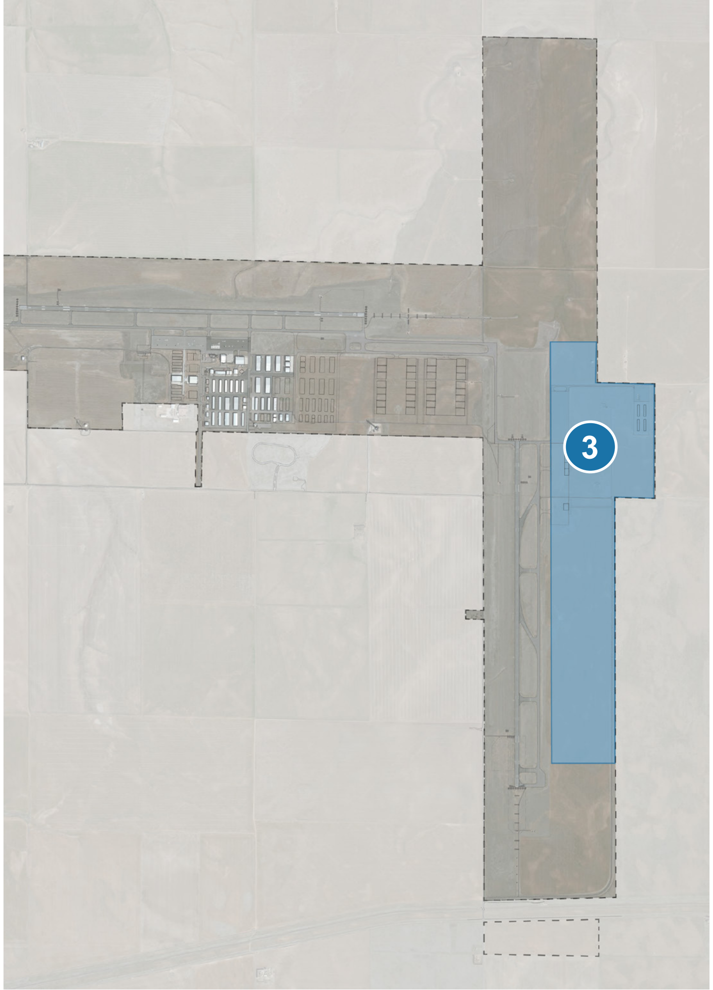


Figure 5-5. Development Area Alternative 3



Alternative 4 – Develop 180-acre Aerospace Development Area East of Runway 17/35

Alternative 4 allocates approximately 180 acres of land east of Runway 17/35 for aerospace development. This land is east of the existing runway and is not contingent on any runway extensions or airfield infrastructure improvements. The proposed area does overlap infrastructure improvements that were proposed as part of the 2019 ultimate ALP.

Alternative 5 – Develop 120-acre Aerospace Development Area East of Runway 17/35

Alternative 5 dedicates approximately 120 acres of land east of Runway 17/35 as the dedicated Aerospace Development Area. This land is east of the existing runway and is not contingent on any runway extensions or airfield infrastructure improvements. The proposed area does not overlap any proposed infrastructure improvements from the 2019 ALP.

Alternative 6 – Develop 100-acre Aerospace Development Area East of Runway 17/35

Alternative 6 allots approximately 100-acres to the east of Runway 17/35 as the Aerospace Development Area. This option anticipates that Runway 17/35 will be extended to the ultimate length of 12,000 ft. The proposed area would not interfere with any infrastructure improvements that were proposed in the 2019 ALP. Development in this area may be restricted by height due to Part 77 Surfaces.

Figure 5-6. Development Area Alternative 4

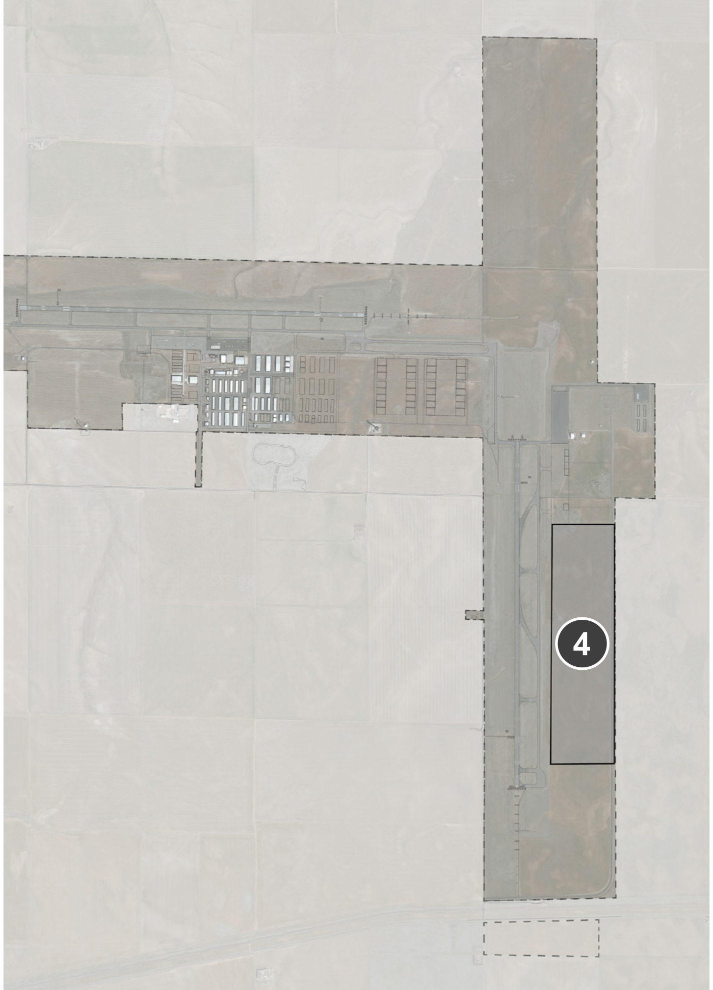
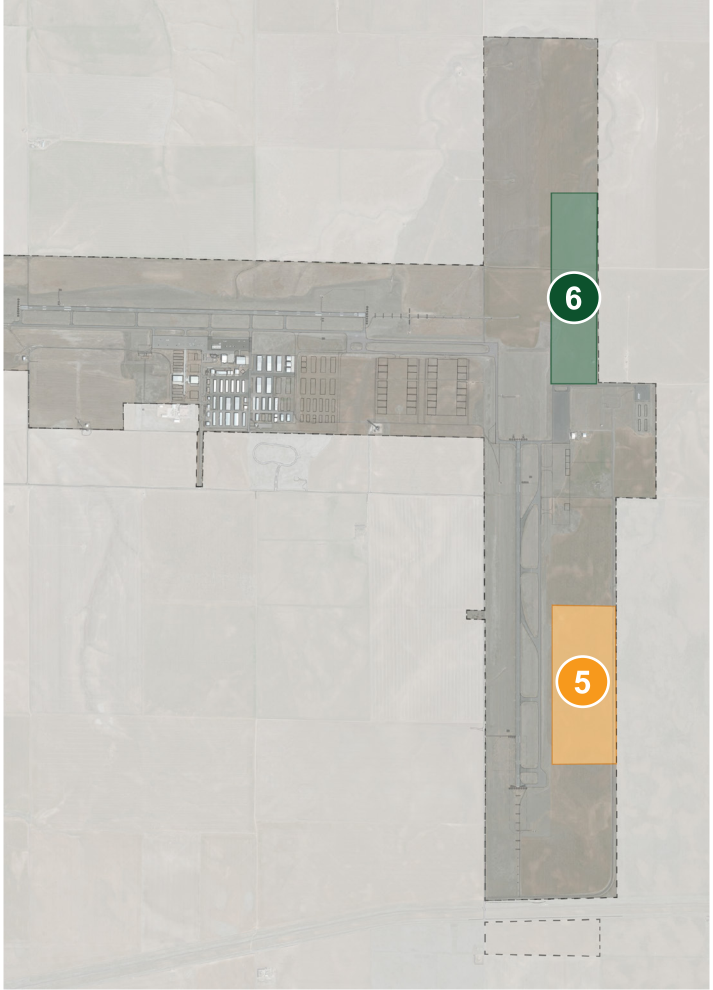


Figure 5-7. Development Area Alternatives 5 and 6



Vehicle Processing and Integration Facilities

This section describes the alternatives associated with development of vehicle processing and integration facilities. It should be noted that although it is not explicitly stated within each alternative, hybrid rocket motors can be safely stored within the facilities. However, if solid rocket motors are intended to be stored within the facilities, planning efforts will need to be conducted to ensure that adequate safety distances are applied.

Alternative 1 – No Action Alternative

In the No Action Alternative, no actions would be taken to plan for or develop vehicle processing and integration facilities. In this alternative, the planning and development of a vehicle processing facility would occur if developed by a future operator. Additionally, no land on the airfield would be allocated for spaceport development, meaning there would be no guarantee that land would be available for development by a future aerospace tenant.

Alternative 2 – Develop a 10,000 sqft hangar

Alternative 2 includes the development of a 10,000 sqft hangar to be reserved for a future aerospace operator. The configuration of the hangar will be such that it will be able to support approximately 35% of potential vehicles analyzed as part of this spaceport master plan. Ideally, the hangar will be developed in the dedicated Aerospace Development Area.

Alternative 3 – Develop a 20,000 sqft hangar

Alternative 3 includes the development of a 20,000 sqft hangar to be reserved for a future aerospace operator. The configuration of the hangar will be such that it will be able to support approximately 50% of potential vehicles analyzed as part of this spaceport master plan. Ideally, the hangar will be developed in the dedicated Aerospace Development Area.

Alternative 4 – Develop a 40,000 sqft hangar

Alternative 4 includes the development of a 40,000 sqft hangar to be reserved for a future aerospace operator or multiple operators. For a single user operator, the hangar will be configured such that it will be able to support approximately 75% of potential vehicles analyzed as part of this spaceport master plan. For a multi-user hangar, the hangar will be configured such that it can support multiple tenants. The ability to accommodate multiple tenants will limit the size of the vehicles that can be supported in the single hangar. For the multi-user configuration, it is estimated that approximately 50% of the potential vehicles analyzed as part of this master plan could be accommodated. Ideally, the hangar will be developed in the dedicated Aerospace Development Area.

Alternative 5 – Develop a 60,000 sqft hangar

Alternative 5 includes the development of a 60,000 sqft hangar that is to be reserved for a future aerospace operator or multiple operators. For a single user operator, the hangar will be configured such that it will be able to support approximately 95% of potential vehicles analyzed as part of this spaceport master plan. For a multi-user hangar, the hangar will be configured such that it can support multiple tenants. The ability to accommodate multiple tenants will limit the size of the vehicles that can be supported in the single hangar. For the multi-user configuration, it is estimated that approximately 50% to 75% of the potential vehicles analyzed as part of this master plan could be accommodated. Ideally, the hangar will be developed in the dedicated Aerospace Development Area.

Figure 5-8. Existing Hangers at CASP

Source: Colorado Air and Space Port

Payload Processing Facility

Alternative 1 – No Action Alternative

In the No Action Alternative, no steps would be made by CASP to develop a standalone Payload Processing Facility (PPF) or acquire a modular PPF. If a PPF was desired by an operator, they would be responsible for the fabrication and installation of the facility.

Alternative 2 – Acquire a Modular PPF

In Alternative 2, CASP would acquire a 1,000-sqft modular cleanroom that would serve as a PPF. As mentioned in Chapter 4, a modular PPF is not a standalone modular system, but rather a facility integrated within another facility. In this alternative, the modular PPF would need to be located within an existing or new hangar that will be dedicated for aerospace use. This alternative will enable the final preparation and integration of small payloads prior to mission operations. In this alternative there will be no permanent infrastructure, such as a crane or hoist, to help maneuver the payload.

Alternative 3 – Develop a Standalone Small Multi-User PPF

Alternative 3 includes the development of a standalone PPF that is meant to support only a few users at any given time. This standalone facility would enable additional amenities that would not be able to be incorporated within a modular PPF. Some of the additional amenities may include cranes or hoists (to help maneuver larger payloads), multiple workbenches, offices, storage rooms, restrooms, break rooms, Ground Support Equipment (GSE) areas, a high-pressure gas system control area, and laboratory space. As previously mentioned, the facility would be large enough to support a few users at a time and would likely be approximately 10,000 sqft.

Alternative 4 – Develop a Standalone Large Multi-User PPF

Alternative 4 is similar to Alternative 3 but would be increase the capabilities to support larger payloads and an increased number of concurrent users. Alternative 4 would include all of the amenities available within Alternative 3, but the amenities would be scaled to support the needs for larger payloads and additional users. It is anticipated that a standalone multi-user PPF would be approximately 30,000 sqft.

Alternative 5 – Develop a Cleanroom within a Multi-Use Facility

Alternative 5 integrates a dedicated 5,000-square foot cleanroom into a multi-use facility. This would not be a modular standalone unit inside a larger facility. Rather, it would be fully integrated into the facility. This integrated facility would enable additional amenities such as small cranes or hoists (to help maneuver larger payloads), multiple workbenches, a high-pressure gas system control area, and laboratory space. Other amenities such as offices, storage rooms, restrooms, break rooms, GSE areas could be incorporated into other areas of the multi-use facility.

Mission Control Center

Alternative 1 – No Action Alternative

Alternative 1 proposes that no new facilities be developed for the purposes of serving as a Mission Control Center (MCC). In this alternative, office space may be made available in existing facilities, like the Terminal Building, FBO facility, or the north office building, that could potentially serve as a temporary MCC during mission operations.

Alternative 2 – Incorporate MCC Infrastructure into Future Facility

In Alternative 2, an MCC would be incorporated within a future facility developed for aerospace operations. The types of facilities that may house an MCC include a dedicated aerospace hangar or a multi-use facility. As mentioned in Chapter 4, a dedicated MCC must be large enough to support administrative, engineering, and operations support personnel during mission related operations. Therefore, this alternative will require approximately 1,000 sqft to 2,500 sqft within a future facility be dedicated for an MCC and able to support approximately 5 to 10 people. The exact size and specifications of the integrated MCC should be reevaluated closer to when the facility will be constructed. Secured rooms may be a requirement to be included with facility improvements.

Alternative 3 – Develop a Standalone MCC

Alternative 3 includes the development of a standalone MCC that is capable of housing mission operations support for multiple tenants. The standalone MCC will include multiple secured rooms that are ideal for mission monitoring and communications. In addition to the secured rooms, the MCC will include conference rooms, private offices, break rooms, and restrooms. The stand-alone MCC should be large enough to support between 20 and 50 people and should be between 5,000 sqft and 10,000 sqft.

Propellant Storage

Alternative 1 – No Action Alternative

Alternative 1 is the no action alternative and would not include any facility improvements as it relates to aerospace propellant storage. Additionally, in this scenario temporary storage of aerospace propellants will be prohibited on the airfield.

Alternative 2 – Temporary Liquid Propellant Storage

In Alternative 2, fuel and oxidizer would be brought in on a temporary basis and stored in tanker trucks. In this alternative, propellant would not be stored for extended periods of time at the spaceport, but rather brought in for mission or testing specific activities by the operator. It is anticipated that up to two standard 5,000-gallon fuel trucks will be needed for RP-1 storage and up to three 5,000-gallon liquid oxidizer trucks will be required. These specifications may change when a user is identified, and the demands/requirements should be reevaluated at that time.

Alternative 3 – Install Permanent Liquid Propellant Storage Tanks – CASP Provided

Alternative 3 includes the installation of permanent propellant storage tanks and the associated infrastructure. For Alternative 3, all of the infrastructure would be paid for by CASP and could be utilized by multiple tenants or operators after development. The sizing of the permanent infrastructure will need to be evaluated at the time of development, as it will be highly dependent on the frequency of operations.

Alternative 4 – Install Permanent Liquid Propellant Storage Tanks – User Provided

Alternative 4 includes the installation of permanent propellant storage tanks and the associated infrastructure. For Alternative 4, all of the infrastructure would be paid for by a future operator and it is likely that the infrastructure would only be available to the operator that developed the capability. The sizing of the permanent infrastructure will be dependent on the individual user's needs and should be evaluated by the user prior to development.

Alternative 5 – Solid Rocket Motor Storage Facility

Alternative 5 includes the development of a permanent solid rocket motor storage facility. This facility will house HD 1.3 materials and therefore will have associated safety distances. Ideally, this facility will be located such that no other facilities are within the anticipated safety distances. The quantities of solid/hybrid propellants that will need to be stored are highly dependent on the vehicles that will be operating at CASP. Solid propellants were not included in the LSOL or explosive site plan. If solid rocket motors are utilized at CASP additional analysis and license modifications will be required.

Multi-Use Facility

The purpose of a multi-use facility is to provide a space for users that can be used for whatever need they may have. Some anticipated uses within a multi-use facility include incubator space of startup companies and MCC.

Alternative 1 – No Action Alternative

In the no action alternative, no multi-use facility would be developed at CASP. In this alternative, if a user desired either incubator space or space for an MCC, they would have to develop it on their own or include it within their facility.

Alternative 2 – Develop 15,000 sqft Multi-Use Facility

Alternative 2 includes the development of a 15,000 sqft multi-use facility. It is anticipated that this facility will be utilized as an incubator startup and potentially provide mission control capabilities to operators on a temporary basis. This multi-user facility may include amenities such as research laboratories, hardware laboratories, cleanrooms, machine shops, workshop space, storage space, offices, conference rooms, break rooms, and restrooms. A 15,000 sqft facility will likely support between 2 and 4 small startup companies or 1 medium company at any given time.

Alternative 3 – Develop 30,000 sqft Multi-Use Facility

Alternative 3 includes the development of a 30,000 sqft multi-use facility. The amenities in Alternative 3 would be similar to Alternative 2. The primary difference between Alternative 2 and Alternative 3 is that Alternative 3 has the ability to support either larger startups or more startups. It is anticipated that the facility developed in Alternative 3 would be capable of supporting between 4 and 8 small startup companies or 2 medium companies.

It should be noted that the 30,000 sqft facility proposed in Alternative 3 could be realized by expanding on a smaller facility. This may be the case if Alternative 2 is selected as a preferred alternative for the near-term but deemed insufficient for the long term. It is suggested that the multi-use facilities be designed in a way that enables expansion.

Terminal Facility

A terminal facility is a facility that can be used for commercial space passengers and the public. Such a facility can be iconic in design or more functional to support the needs of the users.

Alternative 1 – No Action Alternative

In this alternative no terminal facilities will be constructed, nor will the existing terminal building be refurbished.

Alternative 2 – Refurbish Existing Terminal

Alternative 2 refurbishes the existing airport terminal to accommodate commercial aerospace operations. The existing terminal building is not located within the Aerospace Development Area and serves as the terminal for other aviation users at the CASP. The existing terminal building is open to the public.

Alternative 3 – Operator Provided Terminals within or Connected to their Hangars

In Alternative 3, individual operators will develop terminals connected to or within their hangars. These facilities will be within the Aerospace Development Area and within very close proximity to other infrastructure supporting commercial space flight. Each individual operator would need to develop their own terminal facilities at their own cost.

Alternative 4 – Passenger Services within Multi-Use Facility

Alternative 4 provides terminal functions within a multi-use facility. This would provide a single terminal area for commercial space activities in a common facility that can be used by multiple operators.

Alternative 5 – New Standalone Spaceport Terminal Facility at Spaceport Development Area

This alternative includes a standalone and dedicated spaceport terminal within the Aerospace Development Area. This facility has the opportunity to be an iconic structure and include other amenities such as a gift shop, visitor center, and museum.

Test Facilities

Alternative 1 – No Action Alternative

In the no action alternative, no test sites will be developed and no areas on or near the air and space port will be designated as future test areas. In this alternative, if a user would like to conduct testing at the air and space port, areas where testing may be supported will need to be identified at the time of inquiry.

Alternative 2 – Utilize Existing Testing Areas

Alternative 2 includes dedicating a portion of the existing apron east of Runway 17/35 as one testing area (identified as area 2a below) and constructing a second rocket engine test site north of the apron (area 2b). This alternative can support two small sites, approximately 1 acre each. In this alternative, an access road and concrete pad would be constructed for the second test site. Future development around the test areas will be limited to ensure that adequate safety distances can be maintained during testing operations.

Alternative 3 – Establish a 325-acre Test Area North of Runway 8/26

Alternative 3 would establish a 325-acre test area north of Runway 8/26, capable of accommodating 2 large test sites. Testing infrastructure on the north end of CASP is ideally located to avoid Part 77 surfaces yet remain in proximity to existing runways which provides an advantage for noise pollution.

The area proposed is currently not within the air and space port boundary, so agreements would need to be made to acquire the land prior to designation. If agreements could be reached, basic land developments would be completed such that future users could more easily develop test sites. Basic land developments would include extension of basic utilities to proposed test site plots and a perimeter road providing basic access to the proposed test site plots.

Alternative 4 – Establish a 640-acre Test Area North of Runway 8/26

Alternative 4 would establish a 640-acre test area north of Runway 8/26 capable of supporting 4 large test sites. Testing infrastructure on the north end of CASP is ideally located to avoid Part 77 surfaces yet remain in proximity to existing runways which provides an advantage for noise pollution.

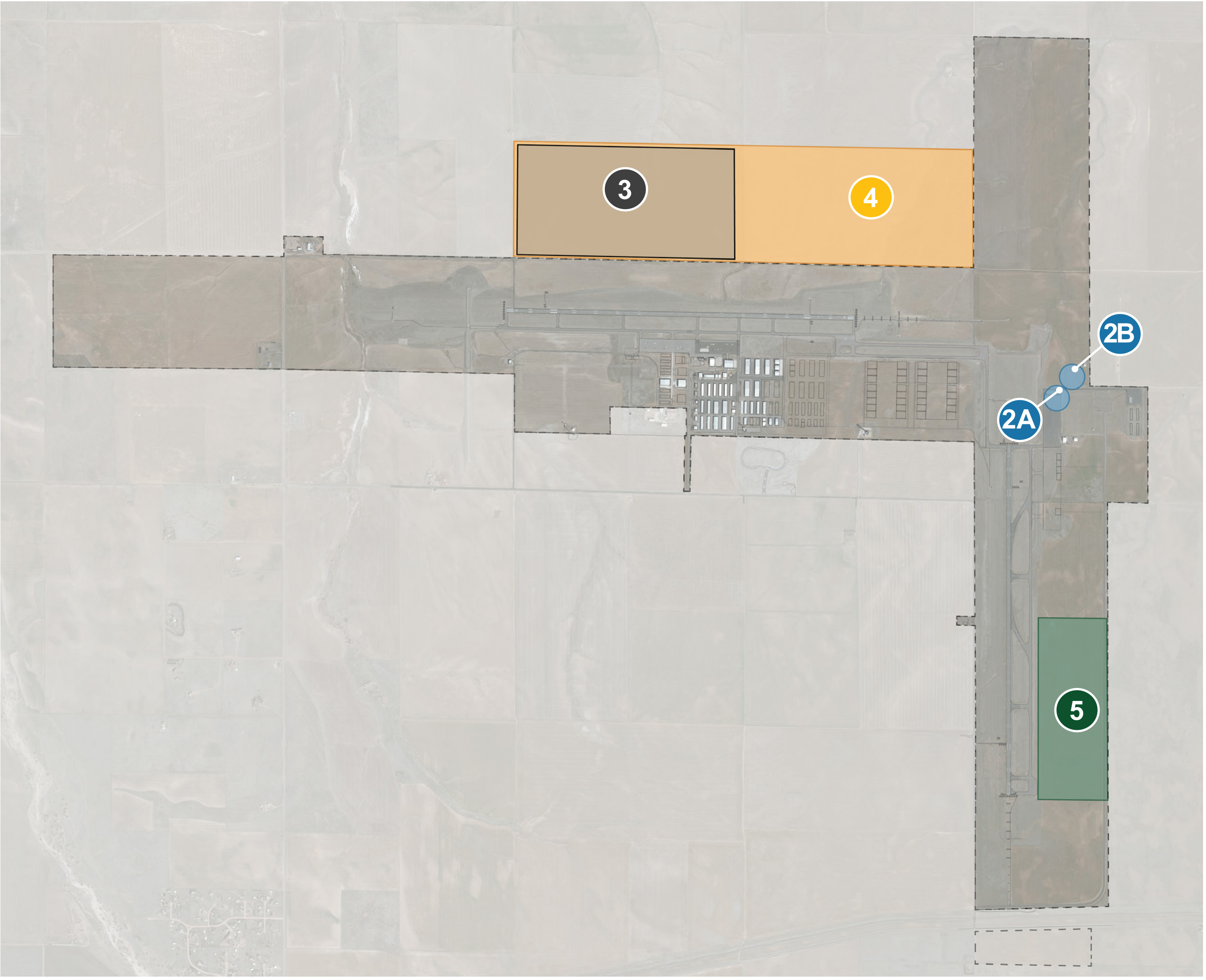
The area proposed is currently not within the air and space port boundary, so agreements would need to be made to acquire the land prior to designation. If agreements could be reached, basic land developments would be completed such that future users could more easily develop test sites. Basic land developments would include extension of utilities to proposed test site plots and a perimeter road providing basic access to the proposed test site plots.

Alternative 5 – Establish a 150-acre Test Area East of Runway 17/35

Alternative 5 would establish a 150-acre test area east of Runway 17/35 capable of supporting 2 small test sites. The proposed area is entirely contained within the current air and space port boundary. However, there is a possibility that the safety distances associated with testing could extend beyond the property boundary, impact operations on Runway 17/35, and intersect taxiways. Additionally, this location intersects both transitional Part 77 surfaces, so permanent infrastructure and testing altitudes would be height restricted. Under this alternative, CASP will need to work with future test operators to minimize the impact to surrounding infrastructure and ensure that access is controlled to all areas within the safety distances.

Basic land developments would be completed as part of this alternative. The land improvements would include extension of utilities to proposed test site plots and a perimeter road providing basic access to the proposed test site plots. Development of alternative 5 overlaps some aerospace development alternatives.

Figure 5-9. Test Facilities Alternatives

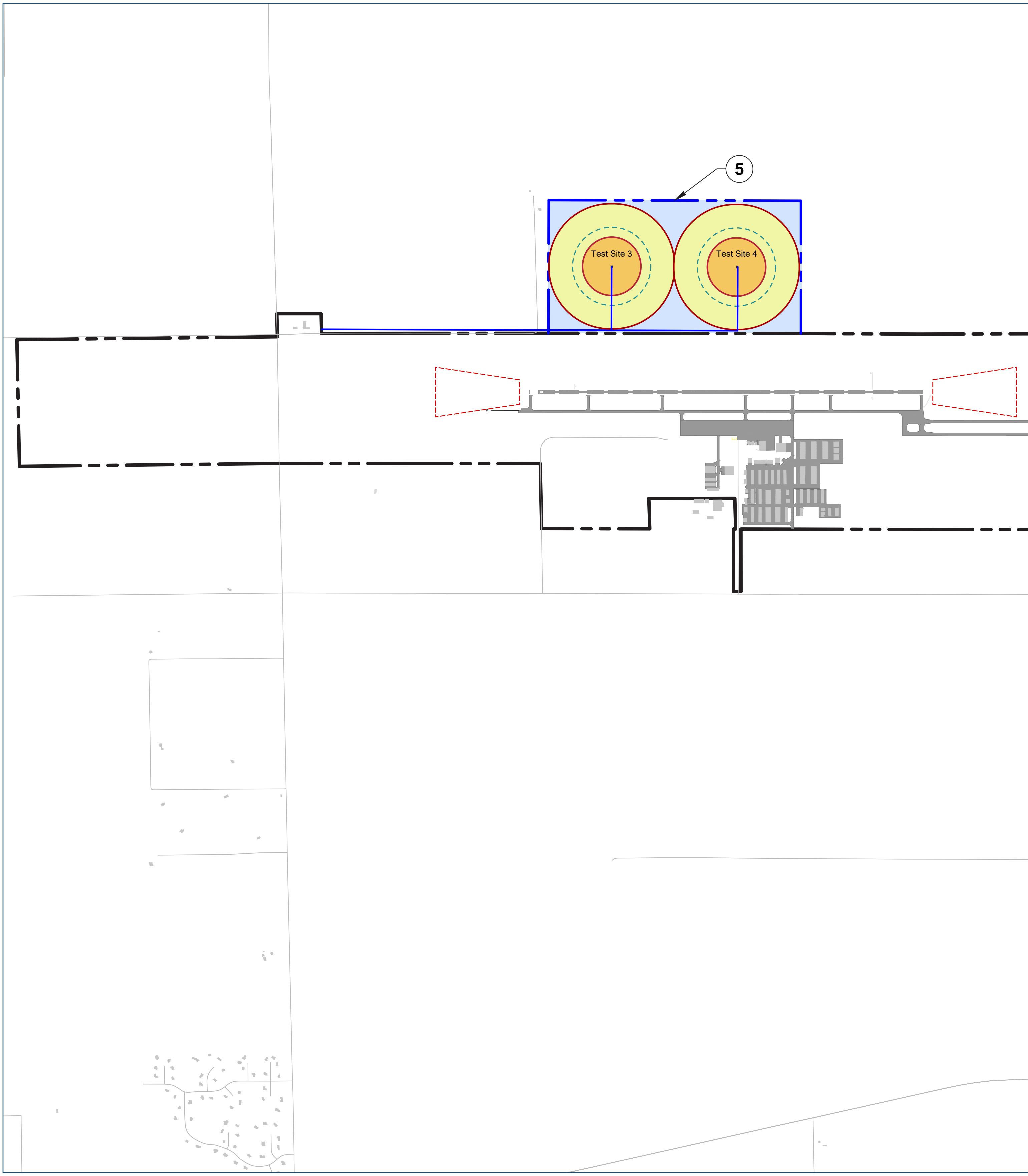


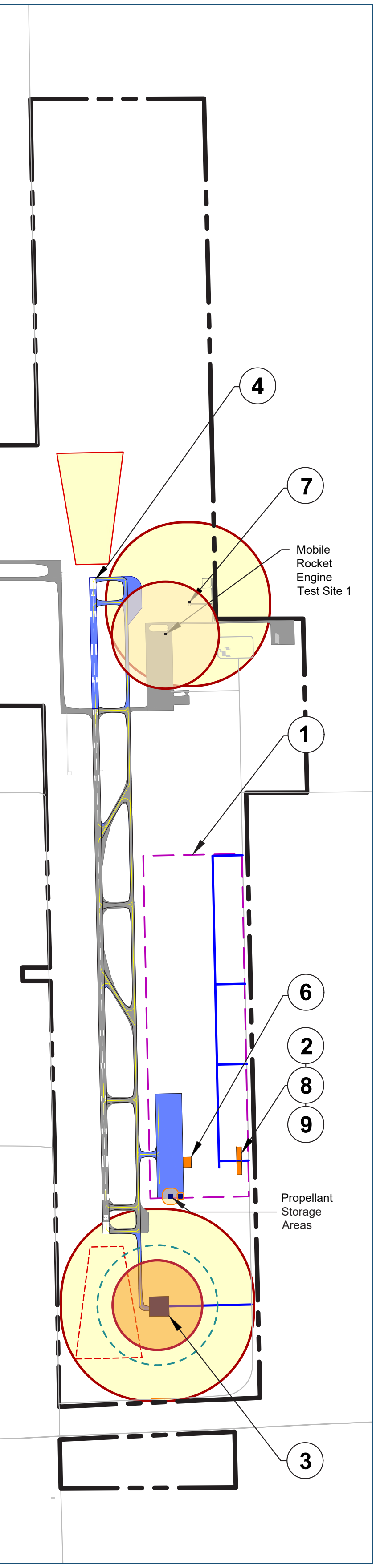
Source: Kimley-Horn

Recommended Development Plan and Summary of Preferred Alternatives

This section provides a summary of the preferred alternatives from the previous section and defines a plan for development. Refer to **Figure 5-10** for a map of recommended development. Areas of development and corresponding projects are depicted here with respect to the current airport diagram.

Figure 5-10. Recommended Development Plan and Summary of Preferred Alternatives





Legend		
Item	**Existing**	**Future**
Property Line		
Roadways		
Aerospace Development Area	N/A	
Public Area Distance	N/A	
Public Traffic Route Distance	N/A	
Incompatable Intraline Distance	N/A	
Test Area	N/A	
Runway Protection Zone (RPZ)		
Structure		
Airfield Pavement		
Concrete Pad	N/A	

Project List	
Number	**Project**
1	Aerospace Development Area (includes propellant storage areas)
2	Multi-use Facility
3	Mission Preparation Area #1
4	Runway 17/35 Extension and Taxiway D Improvements
5	Test Area (Outside Existing Airport Property)
6	Vehicle Processing and Integration Facility
7	Rocket Engine Test Site 2
8	Payload Processing Facility
9	Mission Control Center

Source: Kimley-Horn

Preferred Alternatives Summary

Table 5-14. Preferred Alternatives

	Near-Term	Mid-Term	Long-Term
Runway 8/26	Alternative 1 – No Action		
Runway 17/35	Alternative 1 – No Action	Alternative 2 – Intermediate Runway Extension	
Taxiways	Alternative 1 – No Action	Alternative 3 – Modify Taxiways to Support ADG III and TDG 3	
Aprons	Alternative 2 – Alternative 1 and New Apron within Support Aerospace Development Area		
Mission Preparation Area	Alternative 1 - No Action	Alternative 4 – Construct New Mission Preparation Area #1, Southeast of Runway 17/35	
Dedicated Aerospace Development Area	Alternative 5 – Develop 120-acre Aerospace Development Area East of Runway 17/35	Alternative 4 – Develop 180-acre Aerospace Development Area East of Runway 17/35	
Vehicle Processing and Integration Facility	Alternative 1 - No Action	Alternative 3 – Develop a 20,000- sqft hangar	
Payload Processing Facility	Alternative 1 – No Action	Alternative 2 – Acquire a Modular PPF	Alternative 5 – Develop a Cleanroom within a Multi-Use Facility
Mission Control Center	Alternative 1 – No Action	Alternative 2 – Incorporate MCC Infrastructure within a Multi-Use Facility	
Propellant Storage	Alternative 2 – Temporary Liquid Propellant Storage		Alternative 4 – Install Permanent Liquid Propellant Storage Tanks – User Provided
Multi-Use Facility	Alternative 2 – Develop a 15,000-sqft Multi-Use Facility	Alternative 3 – Develop a 30,000- sqft Multi-Use Facility	
Terminal Facility	Alternative 1 – No Action		
Test Facilities	Alternative 2 – Utilize existing testing areas	Alternative 3 – Establish a 320-acre Test Area North of Runway 8/26	

Source: Kimley-Horn

Ultimate Development Plan and Summary of Unconstrained Alternatives

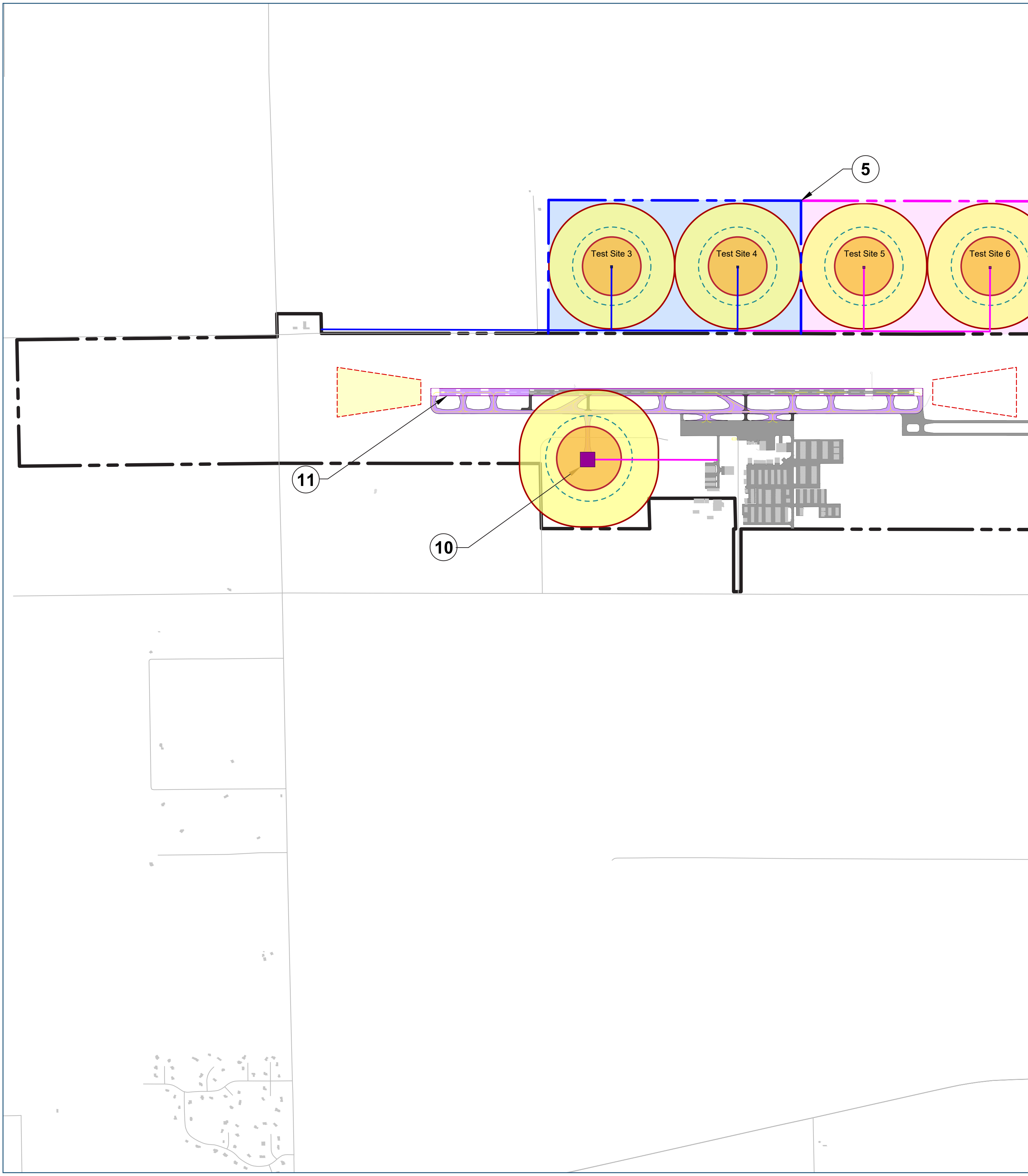
This section provides a summary of the ultimate development plan (UDP) from the alternatives analysis. In an unconstrained scenario, spaceport development at CASP would include additional infrastructure that would increase user compatibility and provide additional support to attract a larger user base. Due to large infrastructure cost and a lack of available FAA funding for spaceport infrastructure, this additional infrastructure was not included in the RDP. A UDP was developed to identify the infrastructure that would be beneficial to the overall development of the spaceport. The UDP provides an extension of the RDP that can be utilized in the event funding sources become available that can support this growth. A map of proposed alternatives to be included in the UDP are found in **Figure 5-11** and summarized in **Table 5-15**.

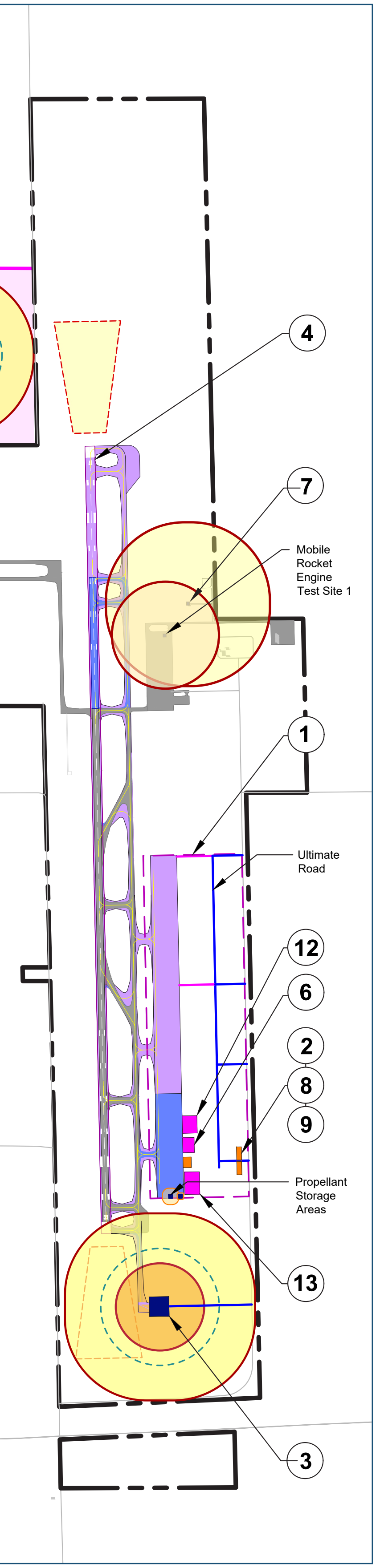
Table 5-15. Unconstrained Alternatives

	Ultimate
Runway 8/26	Alternative 2 – Ultimate Runway Extension, Runway Widening, and Pavement Strengthening
Runway 17/35	Alternative 4 – Ultimate Runway Extension, Runway Widening, and Pavement Strengthening
Taxiways	Alternative 4 – Modify Taxiways to Support ADG V and TDG 7
Aprons	Alternative 2 – Alternative 1 and New Apron within Aerospace Development Area
Dedicated Aerospace Development Area	Alternative 3 – Develop 180-acre Aerospace Development Area East of Runway 17/35
Vehicle Processing and Integration Facility	Alternative 3 – Develop a 20,000-sqft hangar Alternative 4 – Develop an additional 40,000-sqft hangar Alternative 5 – Develop an additional 60,000-sqft hangar
Payload Processing Facility	Alternative 5 – Develop a Cleanroom within a Multi- Use Facility
Mission Control Center	Alternative 2 – Incorporate MCC Infrastructure into Future Facility
Propellant Storage	Alternative 4 – Install Permanent Liquid Propellant Storage Tanks – User Provided
Multi-Use Facility (Incubator Space)	Alternative 3 – Develop a 30,000- sqft Multi-Use Facility
Test Facilities	Alternative 2 – Establish Testing Area on Existing Apron Alternative 4 – Establish a 640-acre Test Area North of Runway 8/26
Terminal Facility	Alternative 5 – Establish a standalone terminal within the Aerospace Development Area

Source: Kimley-Horn

Figure 5-11. Ultimate Development Plan and Summary of Unconstrained Alternatives





Legend			
Item	**Existing**	**Future**	**Ultimate**
Property Line			
Roadways			
Aerospace Development Area	N/A		No Change
Public Area Distance	N/A		No Change
Public Traffic Route Distance	N/A		No Change
Incompatable Intraline Distance	N/A		No Change
Test Area	N/A		
Runway Protection Zone (RPZ)		N/A	
Structure			
Airfield Pavement			
Concrete Pad	N/A		

Project List	
Number	**Project**
1	Aerospace Development Area (includes propellant storage areas)
2	Multi-use Facility
3	Mission Preparation Area #1
4	Runway 17/35 Extension and Taxiway D Improvements
5	Test Area (Outside Existing Airport Property)
6	Vehicle Processing and Integration Facility (1 hangar)
7	Rocket Engine Test Site 2
8	Payload Processing Facility
9	Mission Control Center
10	Mission Preparation Area #2
11	Runway 8/26 Extension and Taxiway A Improvements
12	Vehicle Processing and Integration Facility (2 hangars)
13	Terminal Facility

Source: Kimley-Horn

6

Chapter 6

Implementation Plan

IMPLEMENTATION PLAN

This chapter provides a strategy for CASP to implement the Recommended Development Plan (RDP) while taking into consideration numerous factors that influence the schedule of completion. Factors that must be taken into consideration are addressed through appropriate project phasing, environmental documentation, and analysis of project cost.

Recommended Development Plan

The RDP provides the Spaceport with phasing recommendations to complete projects in alignment with development goals and objectives. Some projects include sub-phasing to allow for further development or completion of a project in later RDP phases. Projects are divided into three (3) primary phases; near-term, mid-term, and long-term.

RDP Near-Term Improvements (2022-2026)

The following projects from the RDP are recommended to be implemented in the near-term (1- to 5-year timeframe, 2022-2026):

- **Aerospace Development Area (Phase I) –** Phase I of the Aerospace Development Area is a 120-acre site development that includes planning, design, and construction of roads, utilities, and site improvements. Planning and design of the Aerospace Apron will also take place during this phase with construction occurring in Phase II. The design and construction of the additional 60-acre site extension will occur in Phase II.

- **Multi-Use Facility (Phase I) –** Phase I of the Multi-Use Facility includes the planning, design, and construction of a 15,000 sqft facility. Planning, design, and construction of an additional 15,000 sqft facility will occur in Phase II. It should be noted that a future Payload Processing Facility, and the Mission Control Center could potentially be housed within the Multi-Use Facility.

- **Runway 17/35 Extension and Taxiway D Improvements (Phase I) –** Phase I of the Runway 17/35 extension and Taxiway D improvements include planning and environmental compliance on the north end of Runway 17 for a 2,000 ft extension. Design will be completed in Phase II with construction completed in Phase III.

- **Rocket Engine Test Site 2 (All Phases) –** Development of the Rocket Engine Test Site 2 includes planning, design, and construction of a 50-foot by 50-foot pad with a 350-foot long by 25-foot-wide access road.

- **Test Area (Phase I) –** Phase I of the Test Area includes the land acquisition of 320-acres north of Runway 8/26. Planning, design, and construction of the test area will take place in Phase II.

RDP Mid-Term Improvements (2027-2031)

The following projects are recommended to be implemented in the mid-term (6- to 10-year timeframe, 2027-2031):

- **Aerospace Development Area Expansion (Phase II) –** Phase II includes design and construction of an additional 60-acre site extension. The site extension includes construction of roads, utilities, and site improvements. This completes the recommended construction of the full 180-acre Aerospace Development Area.

- **Multi-Use Facility Expansion (Phase II) –** Phase II includes design and construction of an additional 15,000 sqft Multi-Use Facility. This completes the recommended construction of a total of 30,000 sqft of multi-use facilities.

- **Mission Preparation Area 1 (All Phases) –** All development of the Mission Preparation Area would be completed in this phase and includes planning, design, and construction of the proposed site southeast of Runway 17/35.

- **Runway 17/35 Extension and Taxiway D Improvements (Phase II) –** Phase II of the Runway 17/35 extension and Taxiway D improvements includes design of the 2,000-foot runway extension and respective taxiway improvements.

- **Test Area (Phase II) –** Phase II is the final phase of the Test Area and includes planning, design, and construction of test site 3 and 4 with the 320-acres acquired in phase I.

- **Vehicle Processing and Integration Facility (All Phases) –** All development for the vehicle processing and integration facility would be completed in this phase and includes planning, design, and construction of a 20,000 sqft hangar on the south end of the Aerospace Development Area.
- **Payload Processing Facility (Phase I) –** Phase I of the Payload Processing Facility (PPF) would consist of a 1,000 sqft modular cleanroom. The modular cleanroom would be installed into an existing facility, most likely a Vehicle Processing Facility or the Multi-Use Facility.
- **Mission Control Center (All Phases) –** All development for the Mission Control Center is completed place in this phase and includes 1,000 sqft to 2,500 sqft of dedicated space within an existing facility such as a Multi-Use Facility or Vehicle Processing Facility. The Mission Control Center should be able to accommodate 5 to 10 individuals for administration, engineering, and operations support.

RDP Long-Term Improvements (2032-2041)

The following projects are recommended to be implemented in the long-term (11- to 20-year timeframe, 2032-2041):

- **Runway 17/35 Extension and Taxiway D Improvements (Phase III) –** Phase III is the final phase of the Runway 17/35 extension and Taxiway D improvements and includes construction of a 2,000-foot runway extension and respective taxiway improvements. This project satisfies the recommended 10,000-foot total runway length. At this distance (without strengthening or widening) the runway can support approximately 50% to 55% of future aerospace users and provide an additional margin of safety.
- **Payload Processing Facility (Phase II) –** Phase II is the final phase of the Payload Processing Facility and includes design and construction of a 5,000 sqft cleanroom that is fully integrated into the Multi-Use Facility or a similar existing facility. The facility would include amenities such as small cranes and hoist to support the scale of operations needed by operators working with large payloads.

Summary of Project Phasing

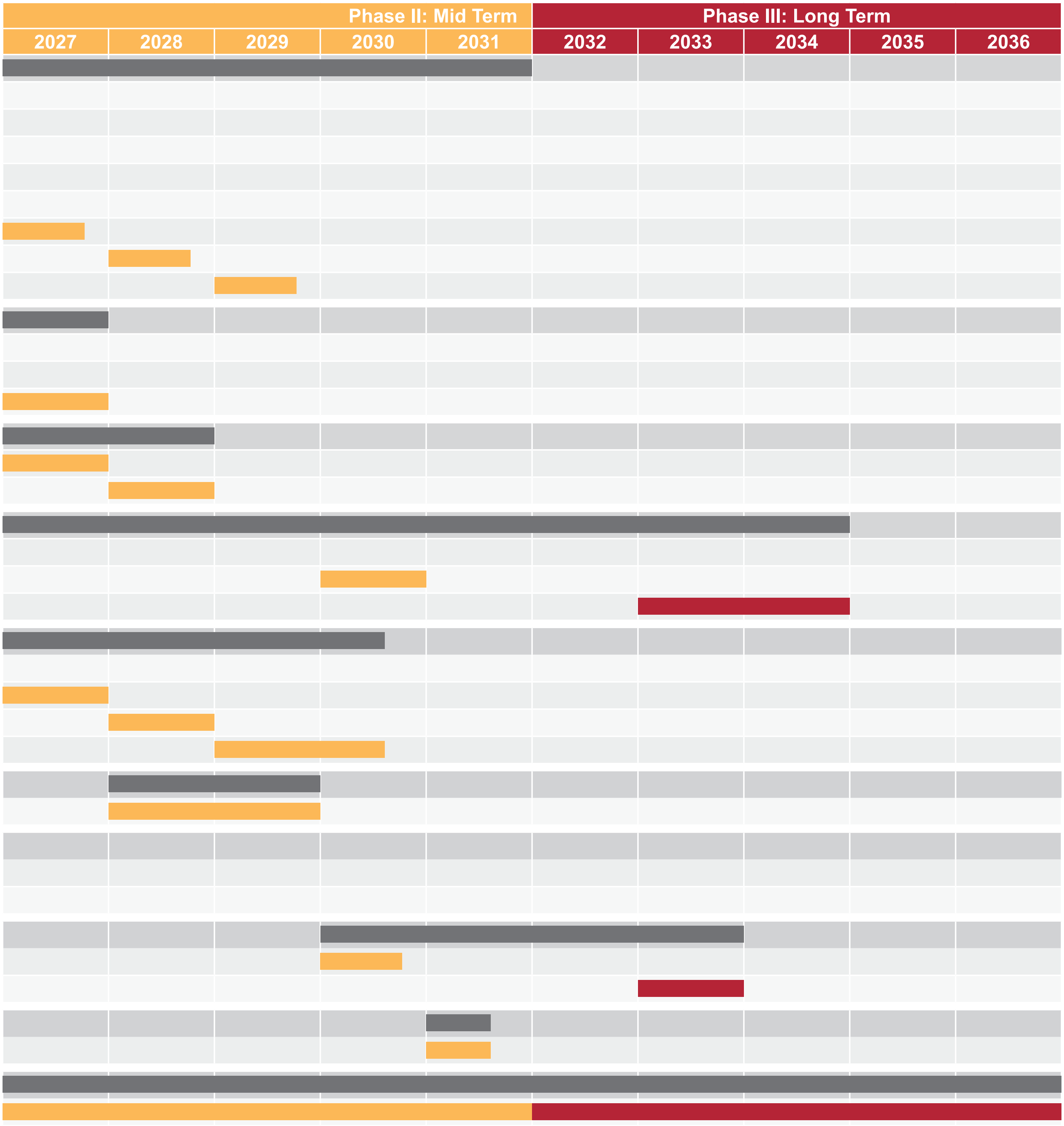
A summary of project phasing and duration can be found in **Table 6-1**. The table provides a high-level outlook of each project described in the previous section and includes a timeline for completion.

Near-Term projects were identified because of their ability to provide return on investment, meet the goals of providing a hub for aerospace startup companies, and fulfilling demand for aerospace testing activities for companies interested in operating at CASP. The combination of these three functions at CASP will likely spur additional growth and investment in the facility. The construction of the Rocket Engine Test Site 2 in 2023 is intended to provide additional testing capabilities in support of recent user requests for mobile, hover, and tethered testing activities. The completion of construction of the initial 120 acres for the Aerospace Development Area in 2025 is intended to attract users to invest at CASP and spur growth into the mid-term. In conjunction with these common use improvements in the Aerospace Development Area, the construction of the first Multi-Use Facility in 2025 is intended to lower the barrier to entry for new and existing aerospace companies to establish a presence at CASP.

Mid-term projects include construction of an additional Multi-Use Facility, addition of an apron at the Aerospace Development Area, expansion of the Aerospace Development Area to 180-acres, construction of a Mission Preparation Area, construction of a 320-acre rocket engine test area, and the addition of payload and mission preparation infrastructure. Expansion of the Aerospace Development Area and Multi-Use Facility would likely be triggered by continued growth and investment in the Spaceport and such demand should be monitored by CASP.

Table 6-1. Program Schedule

#	Task	Phase I: Near Term 2022	2023	2024	2025	2026
1	**Aerospace Development Area (ADA)**	■	■	■	■	■
1.1	ADA Planning (180-Acres)	■				
1.2	ADA Design (120-Acre)		■			
1.3	ADA Construction (120-Acres)			■	■	
1.4	ADA Apron Planning	■				
1.5	ADA Apron Design				■	
1.6	ADA Apron Construction					
1.7	ADA Design (60-Acres)					
1.8	ADA Construction (60-Acres)					
2	**Multi-Use Facility (MUF)**		■	■	■	■
2.1	MUF Planning (30,000 sqft)		■			
2.2	MUF Design and Construction (Phase I – 15,000 sqft)				■	■
2.3	MUF Design and Construction (Phase II – 15,000 sqft)					
3	**Mission Preparation Area (MPA) #1**					
3.1	MPA Planning					
3.2	MPA Design and Construction					
4	**Runway 17/35 Extension and Taxiway D Improvements**				■	■
4.1	RWY/TWY Planning				■	■
4.2	RWY/TWY Design					
4.3	RWY/TWY Construction					
5	**Test Area (Test Sites 3 & 4)**				■	■
5.1	Test Area Land Acquisition (320-Acres)				■	■
5.2	Test Area Planning					
5.3	Test Area Design					
5.4	Test Area Construction					
6	**Vehicle Processing and Integration Facility (VPIF)**					
6.1	VPIF Design and Construction (20,000 sqft)					
7	**Rocket Engine Test Site 2**	■	■			
7.1	Test Site 2 Planning and Design	■				
7.2	Test Site 2 Construction		■			
8	**Payload Processing Facility (PPF)**					
8.1	PPF Planning, Design, and Construction (Phase I - Modular)					
8.2	PPF Planning, Design, and Construction (Phase II - Integrated)					
9	**Mission Control Center (MCC)**					
9.1	MCC Design and Construction					
10	**Follow-on Planning Activities**	■	■	■	■	■
10.1	General Spaceport Planning and Consulting Support	■	■	■	■	■



Source: Kimley-Horn

Project Descriptions

1. Aerospace Development Area (ADA)

1.1 ADA Planning (180-Acres) – This project includes planning and environmental compliance for a 180-acre Aerospace Development site that includes, clearing, grubbing, mass grading, utility distribution for power, communications, natural gas, potable water, well system, sanitary sewer, paving for shared internal access roads, site security fencing, and preliminary planning for the ADA Apron. A sanitary sewer force main extension would be required and involves routing the force main and associated lift stations north then west towards the existing hangar area to connect to the existing system. It is assumed the existing CASP power distribution system has capacity for the proposed Aerospace Development Area infrastructure and would require extension of existing power/communications distribution from the north.

1.2 ADA Design (120-Acres) – This project includes the design of the initial 120-acre site with elements identified in 1.1.

1.3 ADA Construction (120-Arcres) – This project includes construction of the initial 120-acre site with elements identified in 1.1.

1.4 ADA Planning (Apron) – This project includes planning and environmental compliance for an aerospace apron within the Aerospace Development Area that includes an approximately 400-foot wide by 1,760-foot long apron comprised of 80% asphalt and 20% concrete, taxiway connectors, concrete pads for propellant storage, clearing, grubbing, and mass grading of the site.

1.5 ADA Design (Apron) – This project includes design of the apron with elements identified in 1.4.

1.6 ADA Construction (Apron) – This project includes design of the apron with elements identified in 1.4.

1.7 ADA Design (60-Acres) – This project includes design of the 60-acre site extension with elements identified in 1.1. It is assumed that utility connections completed in 1.3 are sufficiently sized to support the 60-acre development.

1.8 ADA Construction (60-Acres) – This project includes construction of the 60-acre site extension with elements identified in 1.1.

2. Multi-Use Facility (MUF)

2.1 MUF Planning (30,000 sqft) –This project includes planning and environmental compliance for a 30,000 sqft Multi-Use Facility within the ADA intended to be used as a flexible space for ultimate build out by aerospace users, including startup companies. The MUF uses include office space, research and development and future mission control functions.

2.2 MUF Design and Construction (Phase I – 15,000 sqft) – This project includes design and construction of the first 15,000 sqft MUF.

2.3 MUF Design and Construction (Phase II – 15,000 sqft) – This project includes design and construction of an additional 15,000 sqft MUF adjacent to the phase I development.

3. Mission Preparation Area (MPA) #1

3.1 MPA Planning – This project includes planning and environmental compliance for a Mission Preparation Area that would include a 300-foot wide by 300-foot long by 1-foot thick reinforced concrete pad for oxidizer loading, a 1,340 foot of taxiway connector, and an internal access roads to the area.

3.2 MPA Design and Construction – This project includes the design and construction of the reinforced concrete pad, taxiway connector, and additional internal access roadways for connectivity.

4. Runway 17/35 Extension and Taxiway D Improvements

4.1 RWY/TWY Planning – This project includes the planning and environmental compliance for a 2,000-foot extension to Runway 17/35 and Taxiway D to 10,000 feet that includes clearing, grubbing, mass grading, paving markings, and runway lighting extension.

4.2 RWY/TWY Design – This project includes design of the runway and taxiway extensions.

4.3 RWY/TWY Construction – This project includes construction of the runway and taxiway extensions.

5. Test Area (Test Sites 3 & 4)

5.1 Test Area Land Acquisition (320-Acres) – This project includes the land acquisition of 320-acres and associated parcels north of the existing CASP property line.

5.2 Test Area Planning – This project includes planning and environmental compliance for the common use infrastructure within the 320-acres to be used for Test Site 3 and Test Site 4.

5.3 Test Area Design – This project includes design of the test area common use infrastructure with elements that include clearing, grubbing, mass grading, utility distribution for power, communications, potable water, paving for shared internal access roads, and site security fencing.

5.4 Test Area Construction – This project includes construction of the test area common use infrastructure with elements identified in 5.3.

6. Vehicle Processing and Integration Facility (VPIF)

6.1 VPIF Planning, Design, and Construction (20,000 sqft) – This project includes planning, design, and construction of a 20,000 sqft hangar to be used as a vehicle processing and integration facility that includes clearing, grubbing, mass grading, utility distribution for power, communications, natural gas, potable water, sanitary sewer, paving, fire suppression systems, and compressed air distribution. Integrated office space is attached to the hangar.

7. Rocket Engine Test Site 2

7.1 Test Site 2 Planning and Design – This project includes planning, environmental compliance, and design of a rocket engine test site that includes a 50-foot by 50-foot by 1-foot thick concrete pad, a 350-foot long by 25-foot wide access road, clearing, grubbing, and mass grading of the site.

7.2 Test Site 2 Construction – This project includes construction of a rocket engine test pad and access road with elements identified in 7.1.

8. Payload Processing Facility (PPF)

8.1 PPF Planning, Design, and Construction (Phase I – Modular) – This project includes planning, design, and construction of a roughly 500 sqft modular payload processing facility within the MUF.

8.2 PPF Planning, Design and Construction (Phase II – Integrated) – This project includes planning, design, and construction of a 1,000 sqft fully integrated payload processing facility with ISO cleanroom designation within the MUF. Scope of this project involves retrofitting of a portion of a VPIF or MUF for the integration of the PPF and the installation of commodity ground support equipment on the building exterior.

9. Mission Control Center (MCC)

9.1 MCC Planning, Design, and Construction – This project includes planning design, and construction of a MCC within the MUF. Scope of this project involves retrofitting approximately 7,500 sqft of interior space within the MUF to function as a MCC for future use by multiple users for launch operations at CASP.

10. Follow-on Planning Activities

10.1 General Spaceport Planning and Consulting Support – This task represents general planning and consulting support for spaceport related activities. In addition to the larger capital projects identified within this Spaceport Master Plan, CASP should plan to budget for general consulting needs related to the Spaceport including:

- Unidentified feasibility and planning studies
- Facilitation of stakeholder engagement meetings
- Technical analyses
- Evaluation of prospective tenant / operator needs
- Spaceport license amendments and modifications
- Spaceport license renewal
- Environmental reviews

The following planning projects are recommended to be completed in the near-term:

1. Reentry Site Feasibility Study (2022)
2. Spaceport Stakeholder Engagement Meetings (2022)
3. Explosive Site Plan Update (2022)
4. Launch Site Operator License Renewal (2023)

It is recommended that Adams County budget between $50k to $200k per year for general spaceport consulting support.

Environmental Documentation Requirements

An environmental review for specific projects may be necessary to assess potential environmental impacts and comply with federal, state, and local environmental regulations. This section provides an overview of environmental reviews that may be required at CASP and identifies the types of review that may be required for each project in the RDP. The identification of the projects requiring environmental review will assist with project planning and design.

Projects Requiring Environmental Review:

Several projects included in the RDP require environmental documentation under the National Environmental Policy Act (NEPA) prior to construction. Most projects require some level of environmental review during the planning phase. The environmental review process will be important to CASP due to the nature of the development needed. Recommended projects include a large amount of land development, and in some cases potential storage of hazardous material. If development of projects within the UDP are pursued, additional environmental review may be required at that time. It is recommended to phase planning and environmental review in the near-term and mid-term to enable design and construction activities and facilitate "shovel ready" projects that may align with future funding opportunities.

There are three types of environmental documentation requirements typically associated with airport/spaceport improvement projects:

- **Environmental Assessment (EA) –** a public document prepared by an airport Sponsor providing sufficient evidence to determine whether a proposed action would result in significant impacts or a finding of no significant impact (FONSI) could be issued. The average completion timeframe for an EA is one to two years.
- **Environmental Impact Statement (EIS) –** a public document required for airport development actions that may "significantly affect the quality of the human environment." An EIS describes the impacts on the environment affected by a proposed action, the impacts of alternatives, and plans to mitigate impacts. The average completion timeframe for an EIS is two to three years.
- **Categorical Exclusion (CATEX) –** some actions do not individually or cumulatively have a significant effect on the human environment and therefore do not require either an EA or an EIS. If an action falls within one of the categorical exclusion groups and the FAA approves a CATEX, then the action can proceed without an EA and EIS. The typical timeframe to document a CATEX and receive FAA approval is two months to one year.

The projects included in the RDP that require an environmental review are shown in **Table 6-2**. Estimated costs for anticipated environmental review are bundled into the cost estimates provided with the Capital Improvement Plan.

Table 6-2. Environmental Documentation Requirements (RDP)

Project:	Anticipated Documentation	Environmental Review Phase
Rocket Engine Test Site 2	CATEX	Complete 2021
Aerospace Development Area (180 Acres)	EA	Near-Term
Aerospace Development Area Apron	EA	Near-Term
Multi-use Facility (Phase 1 & 2)	CATEX	Near-Term
Runway 17/35 Extension and Taxiway D Improvements (Phase 2)	EIS	Near-Term
Vehicle Processing and Integration Facility (All Phases)	CATEX	Mid-Term
Test Area (320 Acres)	EA	Mid-Term

Notes: **EA** = *Environmental Assessment* | **EIS** = *Environmental Impact Study* | **CATEX** = *Categorical Exclusion*
Required level of environmental review and documentation is subject to FAA concurrence.

Source: Kimley-Horn

Ultimate Development Plan

The Ultimate Development Plan (UDP) represents an unconstrained scenario where additional funding sources becomes available for spaceport infrastructure. Project phasing for the UDP would be determined based on infrastructure needs and funding availability and is outside of the scope of this master plan.

UDP Project Summary

A summary of the projects within the UDP are as follows:

- **Runway 8/26 Extension and Taxiway A Improvements –** This project includes planning, design, and construction for Runway 8/26, that includes a 2,000-foot runway extension, 150-foot runway widening, runway strengthening, and Taxiway A improvements. This satisfies the ultimate construction for 10,000-foot total runway length, a Runway Design Code (RDC) of C-IV-2400, and a runway strength of 90,000 pounds for single-wheel gear (SWG) and 250,000 pounds for dual-tandem-wheel gear (DTWG).
- **Additional Improvements to Runway 17/35 and Taxiway D –** This project includes planning, design, and construction of a proposed 4,000-foot runway extension, 150-foot runway widening, runway strengthening, and respective taxiway improvements. This satisfies the ultimate construction for 12,000-foot total runway length, a RDC of D-V-2400, and a runway strength of 90,000 pounds for SWG and 250,000 pounds for DTWG.
- **Mission Preparation Area #2 –** This project includes planning, design, and construction of Mission Preparation Area #2 south of Runway 8/26 and includes the construction of a landside access road to the site.
- **Test Area Expansion –** This project includes land acquisition, planning, design, and construction for the expansion of the Aerospace Test Area site to a total of 640-acres and adds Test Sites 5 and 6.
- **Aerospace Terminal –** This project includes planning, design, and construction of an 80,000 sqft standalone aerospace Terminal facility.
- **Additional Vehicle Processing and Integration Facilities –** This project includes planning, design, and construction of two additional hangars (40,000 sqft and 60,000 sqft).

Project Cost and Schedule

The ability to fund recommended projects depends on cost phasing ability and potential funding sources. A funding plan was developed to identify potential funding sources for projects included in the RDP and is provided in **Table 6-3**. In addition to the funding plan, a Capital Improvement Plan (CIP) was developed coincident with the RDP. The Spaceport Mater Plan CIP identifies spaceport projects unique to this master plan and is separate from the Airport CIP and County CIP, although there may be some overlap in projects. It should be noted that due to the large capital investment necessary for funding the UDP and the limited return on investment, the UDP was not included in the funding plan or CIP.

Capital Improvement Plan:

CASP’s updated 20-year CIP is summarized in **Table 6-3**, including near-term (2022–2026), mid-term (2027–2031), and long-term (2032–2041) projects. Estimated capital expenditures total approximately $150M (in escalated dollars) for all projects in the RDP.

Table 6-3. CASP Capital Improvement Plan

ID	Project Name	Estimate of Probable Cost
1	**Aerospace Development Area**	
1.1	ADA Planning (180-Acres)	$260,000
1.2	ADA Design (120-Acre)	$1,800,000
1.3	ADA Construction (120-Acres)	$26,000,000
1.4	ADA Apron Planning	$160,000
1.5	ADA Apron Design	$1,200,000
1.6	ADA Apron Construction	$32,000,000
1.7	ADA Design (60-Acres)	$350,000
1.8	ADA Construction (60-Acres)	$2,900,000
	Aerospace Development Area Totals	**$64,670,000**
2	**Multi-Use Facility (MUF)**	
2.1	MUF Planning (30,000 sqft)	$130,000
2.2	MUF Design and Construction (Phase I – 15,000 sqft)	$6,400,000
2.3	MUF Design and Construction (Phase II – 15,000 sqft)	$6,800,000
	Multi-Use Facility Totals	**$13,330,000**
3	**Mission Preparation Area (MPA) #1**	
3.1	MPA Planning	$100,000
3.2	MPA Design and Construction	$11,000,000
	Mission Preparation Area #1 Totals	**$11,100,000**
4	**Runway 17/35 Extension and Taxiway D Improvements**	
4.1	RWY/TWY Planning	$240,000
4.2	RWY/TWY Design	$1,500,000
4.3	RWY/TWY Construction	$14,000,000
	Runway 17/35 Extension Subtotals	**$15,740,000**
5	**Test Area (Test Sites 3 & 4)**	
5.1	Test Area Land Acquisition (320-Acres)	$5,200,000
5.2	Test Area Planning	$210,000
5.3	Test Area Design	$910,000
5.4	Test Area Construction	$31,000,000
	Test Area Totals	**$37,320,000**
6	**Vehicle Processing and Integration Facility (VPIF)**	
6.1	VPIF Planning, Design and Construction (20,000 sqft)	$13,000,000
	Vehicle Processing and Integration Facility Subtotals	**$13,000,000**
7	**Rocket Engine Test Site 2**	
7.1	Test Site 2 Planning and Design	$110,000
7.2	Test Site 2 Construction	$490,000
	Rocket Engine Test Site 2 Subtotals	
8	**Payload Processing Facility (PPF)**	
8.1	PPF Planning, Design and Construction (Phase I - Modular)	$200,000
8.2	PPF Planning, Design and Construction (Phase II - Integrated)	$2,200,000
	Payload Processing Facility Totals	**$2,400,000**
9	**Mission Control Center (MCC)**	
9.1	MCC Planning, Design & Construction	$1,700,000
	Mission Control Center Totals	**$1,700,000**
10	**Follow-on Planning Activities**	
10.1	General Spaceport Planning and Consulting Support	$4,750,000
	Follow-on Planning Activities Subtotals	**$4,750,000**
	Year Totals	

Near Term 1-5 Year CIP					Mid Term 6-10 Year	Long Term 11-20 Year
FY 2022	**FY 2023**	**FY 2024**	**FY 2025**	**FY 2026**	**FY 2027-2031**	**FY 2032-2041**
$260,000						
	$1,800,000					
		$26,000,000				
$160,000						
			$1,200,000			
					$32,000,000	
					$350,000	
					$2,900,000	
$420,000	**$1,800,000**	**$26,000,000**	**$1,200,000**	**$-**	**$35,250,000**	**$-**
	$130,000					
			$6,400,000			
					$6,800,000	
	$130,000		**$6,400,000**		**$6,800,000**	
					$100,000	
					$11,000,000	
$-	**$-**	**$-**	**$-**	**$-**	**$11,100,000**	**$-**
				$240,000		
					$1,500,000	
						$14,000,000
$-	**$-**	**$-**	**$240,000**	**$-**	**$1,500,000**	**$14,000,000**
			$5,200,000			
					$210,000	
					$910,000	
					$31,000,000	
$-	**$-**	**$-**	**$5,200,000**	**$-**	**$32,120,000**	**$-**
					$13,000,000	
$-	**$-**	**$-**	**$-**	**$-**	**$13,000,000**	**$-**
$110,000						
	$490,000					
$110,000	**$490,000**	**$-**	**$-**	**$-**	**$-**	**$-**
					$200,000	
0					$2,200,000	
$-	**$-**	**$-**	**$-**	**$-**	**$200,000**	**$-**
					$1,700,000	
$-	**$-**	**$-**	**$-**	**$-**	**$1,700,000**	**$-**
$150,000	$200,000	$200,000	$200,000	$200,000	$1,000,000	$2,800,000
$150,000	**$200,000**	**$200,000**	**$200,000**	**$200,000**	**$1,000,000**	**$2,800,000**
$680,000	**$2,620,000**	**$26,200,000**	**$13,240,000**	**$200,000**	**$102,670,000**	**$16,800,000**

Source: BRPH, Kimley-Horn

Funding Plan

A funding plan is provided in **Table 6-4** and was developed using planning level information and assumptions.

The funding plan is preliminary in nature and is not intended to be used to support the sale of bonds or to obtain any other forms of financing. More detailed cost estimates and financial analyses are required to implement individual projects as project estimates are not a result of detailed engineering analysis. It is also important to note that some projects in the RDP could be postponed if changes occur, including if forecast aerospace activity is not realized, construction costs rise significantly, or projected funding is not available.

Assumed funding sources are described in detail below. The funding sources available to CASP have unique availability, eligibility, and timing constraints. While funding availability is discussed, it should not be assumed that all funds projected to be available would be allocated to projects in the RDP. Internal revenue sources at air and space ports seldom satisfy funding needs for capital improvement projects and are typically reliant on funding provided by Federal, state, local or private entities. The following sub-sections outline the existing Federal, State, and local funding mechanisms in place and whether they may or may not be compatible with CASP CIP projects for the spaceport.

Potential funding sources identified here include:

- FAA Airport Improvement Program (AIP) Grants
- FAA Office of Commercial Space Transportation STIM Grants
- FAA State Apportionments
- Other Federal Initiatives
- US Economic Development Administration (EDA) Grants
- Colorado Department of Transportation (CDOT) Grants
- State Infrastructure Bank (SIB) Loans
- Public Private Partnerships (P3)

Source: Kimley-Horn

Table 6-4. Funding Source Compatibility

		Federal			State	
		FAA AIP+	FAA AST‡	US EDA Grant	CDOT Aviation Grant Program	SIB Program
1	**Aerospace Development Area (ADA)**					
1.1	ADA Planning (180-Acres)	X	🟢	🔴	🟠	🟢
1.2	ADA Design (120-Acre)	X	🟢	🟢	🟠	🟢
1.3	ADA Construction (120-Acres)	X	🟢	🟢	🟠	🟢
1.4	ADA Apron Planning	X	🟢	🔴	🟠	🟢
1.5	ADA Apron Design	X	🟢	🟠	🟠	🟢
1.6	ADA Apron Construction	X	🟢	🟠	🟠	🟢
1.7	ADA Design (60-Acres)	X	🟢	🟢	🟠	🟢
1.8	ADA Construction (60-Acres)	X	🟢	🟢	🟠	🟢
2	**Multi-Use Facility (MUF)**					
2.1	MUF Planning (30,000 sqft)	X	🔴	🔴	X	X
2.2	MUF Design and Construction (Phase I – 15,000 sqft)	X	🔴	🟠	X	X
2.3	MUF Design and Construction (Phase II – 15,000 sqft)	X	🔴	🟠	X	X
3	**Mission Preparation Area (MPA) #1**					
3.1	MPA Planning	X	🟢	🔴	🔴	🔴
3.2	MPA Design and Construction	X	🟢	🔴	🔴	🔴
4	**Runway 17/35 Extension and Taxiway D Improvements**					
4.1	RWY/TWY Planning	X	🟢	🔴	🟠	🟠
4.2	RWY/TWY Design	X	🟢	🟠	🟠	🟠
4.3	RWY/TWY Construction	X	🟢	🟠	🟠	🟠
5	**Test Area (Test Sites 3 & 4)**					
5.1	Test Area Land Acquisition (320-Acres)	X	🟢	X	🔴	🟠
5.2	Test Area Planning	X	🟢	🔴	🔴	🟠
5.3	Test Area Design	X	🟢	🟢	🔴	🟠
5.4	Test Area Construction	X	🟢	🟢	🔴	🟠
6	**Vehicle Processing and Integration Facility (VPIF)**					
6.1	VPIF Planning, Design and Construction (20,000 sqft)	X	🟢	🟢	🔴	🔴
7	**Rocket Engine Test Site 2**					
7.1	Test Site 2 Planning and Design	X	🟢	🟠	🔴	🔴
7.2	Test Site 2 Construction	X	🟢	🟠	🔴	🔴
8	**Payload Processing Facility (PPF)**					
8.1	PPF Planning, Design and Construction	X	🟢	🔴	X	X
9	**Mission Control Center (MCC)**					
9.1	MCC Planning, Design & Construction	X	🟢	🔴	X	X

X Project is ineligible for funding under existing program

🔴 Project is unlikely to be eligible for funding under existing program

🟠 Project is potentially eligible for funding under existing program

🟢 Project is likely eligible for funding under existing program

+ And State Apportionment

‡ Program unfunded since 2012

Source: BRPH, Kimley-Horn

FAA Airport Improvement Program (AIP) Grants

The FAA has historically been the largest contributor of funding in the form of grants to general aviation airports. FAA grants have predominantly been sourced through the Airport Improvement Program (AIP) for planning, development, or noise compatibility projects at public-use airports. To be considered as eligible for AIP funding, projects must be related to the following types of improvements:

- Airport safety
- Airport capacity
- Airport security
- Environmental concerns

The most recent congressional reauthorization of the AIP occurred under the Federal Aviation Administration (FAA) Reauthorization Act of 2018 (HR 302). This bill funded the FAA for five years (FY 2019-2023) providing $3.35 billion towards the AIP over those five years. AIP funds are typically applied towards airfield capital improvement projects and preservation efforts. However, these funds can also be applied towards hangars, aprons, terminals, and other non-aviation type development given certain criteria are met. Regardless, documentation of an airport's demand for capital improvements must be provided and the project is required to be identified on an approved Airport Layout Plan.

AIP grants are categorized as either entitlements or discretionary. Entitlement Grants are funds provided by the FAA to NPIAS airports and distributed through a formula based on passenger enplanements, landed cargo weights, and types of operations. The amount of funding a given airport can receive through entitlement grants is based on whether it is a primary or non-primary airport. Discretionary grants are for capital projects that exceed the limitations of entitlement grants and are established annually by the FAA. Typically, certain portions of discretionary grants are reserved for special interest projects. With regard to construction of hangars, and in accordance with FAA Order 5100.38D Change 1 Airport Improvement Program Handbook, FAA AIP grant funding eligibility towards these types of projects is typically met if:

- It has been determined that the construction of the hangar will increase the revenue producing ability of the airport.
- The airport must be a nonprimary airport.
- Only nonprimary entitlements funding can be used.
- The use of the building must only be for aeronautical purposes only.

Apron projects eligible for AIP funding generally need to be able to service/park the "flying public" and not for "exclusive use". FAA Order 5100.38D states the follow eligibility criteria for apron funding under the AIP:

- The project must exclude auto parking or other non-aeronautical uses.
- The project cannot include pavement for exclusive use.
- Cargo apron are limited use, and the public is not allowed to freely use the apron.

Similarly, runway projects eligible for AIP funding must meet the below criteria:

- Where a study is required to demonstrate need, the FAA must have accepted the study and concurred with the need.
- The length, width, and strength of the pavement work must be based on critical aircraft justification.
- Runways must be planned, designed, and constructed in accordance with current FAA standards.

FAA Office of Commercial Space Transportation STIM Grants

The FAA has spaceport-specific funding avenues available through its Commercial Space Transportation Infrastructure Matching (STIM) grants program. The STIM grants program authorizes appropriation of Federal funds towards space transportation infrastructure. Projects eligible for funding under this program include technical and environmental studies; construction, improvement, design, and engineering of space transportation infrastructure; and real property to meet the needs of the United States commercial space transportation industry. Colorado Air and Space Port was the recipient of a STIM grant in 2012 to fund environmental documentation in support of the FAA LSOL Application. Since 2012, the STIM grants program has been unfunded. However, there are ongoing efforts within the aerospace industry to encourage the FAA to resume funding and expand the STIM grants program.

FAA State Apportionment

Annual funds are given to each state by the FAA based on an area-population formula. These funds are typically distributed at the discretion of each state. In fiscal-year 2021, Colorado's state apportionment was approximately $5.3 million.

https://www.faa.gov/airports/aip/grantapportion_data/media/FY-2021-State-Apportionments.pdf

Other Federal Initiatives

As part of the FAA Reauthorization Act of 2018, the Department of Transportation was required to submit a report to Congress on how the Federal government could support increased investment in space transportation infrastructure. The Government Accountability Office (GAO) was tasked with evaluating and providing recommendations towards this effort. In response to the 2018 Act, the FAA had identified two existing funding programs that could potentially meet this goal: the STIM grants program and AIP. In a December 2020 report to Congressional committees, the GAO concluded that the FAA had not comprehensively examined existing funding mechanisms, nor evaluated other potential solutions for increasing Federal investment into space transportation infrastructure. The GAO recommended the FAA AST report to Congress:

"the results of an examination of a range of options – including funding and financing tools, as well as alternatives to making funding available – to support space transportation infrastructure."

The implications of the GAO recommendation to the FAA are not yet known at the time of the study. However, the GAO recommendations can potentially lead to new or amended legislation that open avenues of funding targeted towards for space transportation infrastructure.

U.S. Economic Development Administration (EDA) Grants

The EDA is the Federal government's sole agency tasked with guiding economic development across the United States. Specifically, the agency puts an emphasis on facilitating sustainable job growth and establishing durable regional economies by promoting innovation and regional collaboration. The EDA is evaluated based on two primary performance goals:

- Providing infrastructure investments that promote private enterprise and job creation in economically distressed communities and regions.
- Providing non-infrastructure investments that build community capacity to achieve and sustain regional competitiveness and economic growth.

The agency meets these goals by providing economic assistance through the following programs:

- American Rescue Plan
- Public Works
- Economic Adjustment
- Planning
- Build to Scale
- Trade Adjustment Assistance for Firms
- University Centers
- Research and National Technical Assistance
- Local Technical Assistance
- Economic Development Integration

The type of grant funding and funding eligibility is dependent on the specific funding programs available at the time, which are subject to expiration based on the amount of funds expended and creation of new programs. Among the current active programs under the EDA is the Fiscal Year 2020 Public Works and Economic Adjustment Assistance Programs. With a focus towards economically distressed communities, projects provided financial assistance under this program by resulting in job creation and the retention of jobs, increased private investment, advancing innovation, improve regional manufacturing capabilities, and creating workforce development opportunities.

Colorado Department of Transportation (CDOT)

The CDOT's Division of Aeronautics leverages Colorado Aviation Fund monies by distributing discretionary grants to individual airports on an annual basis, chiefly through its Colorado Discretionary Aviation Grant (CDAG) program. These funds are intended to leverage FAA AIP grants by providing matching funds. Generally, CDAG funds are targeted towards non-revenue generating projects with priority given to runway/taxiway projects ahead of others.

Funding eligibility under the CDAG program is in accordance with Colorado Revised Statues (CRS), specifically CRS 43-10-103(4), CRS 43-10-108.5 and CRS 43-10-110. Pursuant to these codes, funds from the Colorado Aviation Fund "shall be used exclusively for aviation purposes". The term aviation purposes is defined as applying to projects that provide "direct and indirect benefits to the state aviation system". As it relates to the spaceport CIP projects at CASP, projects may be eligible for CDAG funding under the following sub-definitions of aviation purposes:

> CRS 43-10-102(3)(a)(I)
>
> Any work involved in constructing, planning, or repairing a public airport or portion thereof and may include any work involved in constructing or maintaining access roads;
>
> CRS 43-10-102(3)(a)(V)
>
> Any research study, proposal, or plan for the expansion, location, or distribution of aviation facilities or resources that are directly related to the state aviation system;
>
> CRS 43-10-102(3)(a)(VI)
>
> The promotion of economic development which is related to the promotion of development, operation, or maintenance of the state aviation system;

Discussions with CDOT should take place to verify the applicability of the above CRS definitions as it relates to potential eligibility of CASP's spaceport CIP projects.

State Infrastructure Bank (SIB) Loan Program:

The SIB program offers low-interest revolving loans to fund transportation projects, administered by the Colorado Transportation Commission. To-date, loans from the SIB program have been allocated to projects including airport capital improvements, air traffic control towers, snow removal equipment, pavement reconstruction and land acquisitions protecting airports from adjacent incompatible uses.

Public Private Partnerships (P3)

In some cases, commercial developers and/or other private entities may desire to build facilities and lease the space to potential tenants. This approach is common for hangars, aviation museums, office buildings, and payload processing facilities. Options for public private partnerships may need to be evaluated as a tool for increasing infrastructure capabilities in the near-term when other funding sources may not be readily available.

Financial Feasibility Plan

This section reviews the financial feasibility of implementation of projects identified in the CIP and assesses the County's ability to fund these projects. While an implementation schedule is identified, the actual execution of specific projects and the resulting financial requirements may change based on local economic conditions, actual aerospace/aviation-related activity, or other factors.

Adams County is CASP's Sponsor and is therefore responsible for management and budgeting of all generated revenues and expenditures. This includes providing local match for federal and state grants.

The following sections provide a summary of CASP's projected revenues and expenditures, as well as a comparison of anticipated cash flow and local grant matching.

CASP Revenues

As with the majority of airports, CASP operating revenues are largely contingent upon hangar/building leases, land leases and fuel sales. Other operating revenue sources at CASP include tiedown/ramp fees, restaurant leases, rental car commissions and direct financial contributions made by Adams County.

An overview of the economic potential the aerospace development area creates is provided in **Table 6-5** and summarizes the projected operating revenues for the spaceport at CASP. Projected revenues were developed and organized into the time horizons defined in this study. Spaceport revenue projections are based on assumed revenue rates for each CIP project. The projected spaceport-specific operating revenues are driven by the following proposed facilities, in order of magnitude of annual revenue (largest to smallest):

- **Aerospace Development Area –** Projected to incur lease revenues.
- **Vehicle Processing and Integration Facility –** Projected to incur hangar lease revenue in line with current hangar lease rates at CASP.
- **Test Area –** Projected to incur land lease revenue based on land lease rates provided by CASP.
- **Multi-Use Facility –** Projected to incur office lease revenue in line with office lease rates provided by CASP.
- **Aerospace Development Area Apron –** Projected to incur staging and tie down fee revenues assuming weekly uses.
- **Rocket Engine Test Site –** Projected to incur land lease revenue based on land lease rates provided by CASP in conjunction with assumed annual testing cadences included in the CASP CATEX.

Table 6-5. Aerospace Development Area Indirect Benefits

CIP Project	Indirect Benefit	Potential Future Revenue*
1.3 ADA Construction (120-Acres)	Creation of 75 acres of development-ready land for both office/administration and apron-adjacent uses	$4.7M – $8.1M Annually
1.8 ADA Construction (60-Acres)	Creation of 28 acres of development-ready land for both office/administration and apron-adjacent uses	$1.7M - $3.0M Annually
Values are based on assumed $3k - $12k revenue per acre for office/administration and $36.8k revenue per acre for apron-adjacent uses (hangars). Actual revenues will vary depending on factors including density of development and market conditions.		

Source: BRPH, Kimley-Horn

The spaceport operating revenues presented in **Table 6-6** can be referred to as direct and indirect benefits that the spaceport CIP projects can realize. The indirect benefits that certain spaceport CIP projects foster for both CASP and the community at large include the following:

- Creating a hub for aerospace startup companies as it relates to research, development, and testing.
- Encouraging further economic growth by providing common use infrastructure in the form of roads, utilities and compatible air and landside land uses.

Table 6-6. Projected Spaceport Operating Revenues

	Near-Term[A/B/C]					Mid-Term[A/B/C]	Long-Term[A/B/C]
	2022	2023	2024	2025	2026	(2027-2031)	(2032 - 2041)
Total Annual Spaceport Revenues	-	-	-	$360,000	$720,000	$19,800,000	$91,900,000

Source: BRPH, Kimley-Horn

CASP is uniquely positioned in a region with a significant aerospace workforce including both aerospace start-up companies and the broader aerospace and defense industry. The spaceport CIP projects have been strategically selected to accommodate this workforce with the goal of providing an incubator/business park as well as testing, training and research and development venues for such aerospace users. The near-term projects including the Aerospace Development Area, Multi-Use Facility and Rocket Engine Test Pad offer particular value towards increasing the economic viability of the surrounding area. Aerospace companies who conduct testing, like what would occur at the Rocket Engine Test Pad, often want to establish support operations nearby. Providing space available for companies to set up business operations like the Multi-Use Facility and additional development-ready acres in the form of the Aerospace Development Area, creates fiscal opportunities as well as services various demands imposed by commercial and defense users alike.

The direct benefits associated with the CIP projects include revenue generation and job creation. Excluding capital expenditures, the array of spaceport CIP projects are projected to result in net revenues of approximately $11M for CASP over the 20-year planning horizon. The near-term Multi-Use Facility and 120-acre Aerospace Development Area projects have the potential of creating approximately 1,500 permanent direct jobs which can in turn lead to approximately 4,300 indirect/induced jobs in the region. This does not include the hundreds of temporary construction jobs that would be created to implement these projects at CASP.

The practice of developing common use infrastructure for space port business park and testing venues to boost regional economies is being exemplified at other space ports across the country. At Houston Spaceport, 1,400-1,500 jobs are projected to be created by similar development efforts initiated by two aerospace companies across approximately 22 acres. Similarly, 2,100 high wage jobs are projected to be created in Brevard County, Florida by a proposed satellite manufacturing facility for Terran Orbital Corp. This project was incentivized by recent efforts to bring common use infrastructure including power, water and communications utilities to what was vacant land with the intent to serve as a foundation for a space hub environment targeted towards companies like Terran Orbital Corp.

The proposed spaceport CIP projects also introduce added value to adjacent development efforts. Projects like the Multi-Use Facility and Aerospace Development Area would complement existing plans to develop land adjacent to CASP such as the Rocky Mountain Railroad development. Furthermore, investment in spaceport infrastructure including proposed hangars, runway/taxiway improvements, common use utilities and roadways and aprons can also bolster the general aviation operations at CASP. The spaceport CIP projects should be evaluated for potential gains in cargo and/or corporate air traffic operations providing additional revenue generation.

The aerospace development area CIP projects in particular present an array of indirect benefits for future development that can lead to the creation of employment and revenue generating opportunities.

CASP Expenditures

Expenses at CASP are classified as either capital costs or operating expenses. Capital costs are defined in the spaceport CIP for each recommended project. The bulk of operating expenses at CASP have historically been attributed to personnel services, airport supplies, aviation fuel, equipment maintenance and utilities, as documented in the 2019 Airport Master Plan.

A summary of projected operating expenses at CASP are identified in **Table 6-7**. The expenses shown represent projected operations and maintenance expenses for each spaceport CIP project which are calculated relative to their projected annual revenue. It is not anticipated that the spaceport CIP projects would lead to significant increases in annual personnel expenses thus the **Table 6-7** figures primarily represent costs attributable to infrastructure O&M. Expenses are assumed to begin the year following completion of project construction.

Table 6-7. Projected Spaceport Operating Expenses

	Near Term					Mid Term	Long Term
	2022	2023	2024	2025	2026	(2027-2031)	(2032 - 2041)
Spaceport Operating Expenses	-	-	-	($5,000)	($5,000)	($250,000)	($8,000,000)

Source: BRPH, Kimley-Horn

Cash Flow Analysis

In order to project the financial outlook of spaceport improvements at CASP, a comparison of both the operating and capital cash flow is provided in **Table 6-8** below. The operating cash flow indicates a net annual profit from 2028 onwards once the projects are achieving full revenue-generating capacity. These annual revenues would supplement future airport revenues which are projected in the 2019 Airport Master Plan.

Table 6-8. Spaceport Cash Flow

	Near Term					Mid Term	Long Term
	2022	2023	2024	2025	2026	(2027-2031)	(2032 - 2041)
Operating Cash Flow							
Spaceport Operating Revenues	-	-	-	$360,000	$720,000	$19,800,000	$91,900,000
Spaceport Operating Expenses	-	-	-	($5,000)	($5,000)	($250,000)	($8,000,000)
Net Operating Cash Flow	-	-	-	**$355,000**	**$715,000**	**$19,550,000**	**$83,900,000**
Capital Cash Flow							
Potential Capital Funding Grants*	-	-	$5,000,000	-	-	$10,000,000	$7,000,000
Spaceport Capital Expenditures	($680,000)	($2,620,000)	($26,200,000)	($13,240,000)	($200,000)	($102,670,000)	($16,800,000)
Unidentified Funding Required for Spaceport Capital Expenditures	**($680,000)**	**($2,620,000)**	**($21,200,000)**	**($13,240,000)**	**($200,000)**	**($92,670,000)**	**($9,800,000)**

Source: BRPH, Kimley-Horn

The capital cash flow analysis shows the annual CIP expenditures in contrast with available funding sources from federal, state, or local entities. The largest increase in capital expenditures occur in 2024, 2027, 2028, and 2029 which are attributable to the Aerospace Development Area, Vehicle Processing Facility, and Test Area projects. While there are no existing funding programs slated to offer dedicated financial support to space transportation infrastructure, this study assumes FAA grant funding will become available within the next decade. While state funding programs are not incorporated in **Table 6-8** projections, it is possible certain projects may be eligible for such funding, specifically from the Colorado Aviation Grant Program or State Infrastructure Bank.

After the completion of CIP projects, with the last project ending in mid-2023, average annual net revenues for the spaceport are estimated at $608,000 through the end of the planning period.

Conclusions

With regard to operating revenues and expenses, it is estimated that net operating revenues will increase throughout the planning period with the implementation of spaceport CIP projects. Primary increases in net revenues are shown to occur between the years 2027 – 2029 and in 2032 with the realization of revenues from the Vehicle Processing and Integration Facility, Multi-Use Facility and Test Area projects.

However, these positive cash flows will not balance the capital expenditures required to fully fund the spaceport development plan within the planning horizon. As is typical with airports, capital funding will be reliant on external sponsors in the form of Federal, state, local or private investment. General aviation airports have the advantage of benefitting from FAA AIP grant funding where they can anticipate receiving financial relief for up to 90 percent of eligible costs for their CIP projects. Additional state cost sharing is often provided, contingent and in concert with the FAA funds. Such Federal financial mechanisms are not currently available for space transportation infrastructure projects under existing legislation and FAA regulations. Further dialogue with CDOT should take place as to the eligibility of grant funding towards spaceport CIP projects, particularly for the Aerospace Development Area and Runway 17/35 Extension and Taxiway D Improvements projects. It is likely like CIP capital expenditures will require significant private investment, especially for projects slated to occur in the near to mid-term. Private investment and/or cost sharing for spaceport development at CASP may be feasible given recent interest and agreements with various aerospace companies including Reaction Engines, PD Aerospace, Dawn Aerospace and NFA.

Investments into airport infrastructure for spaceport use provides an added benefit to traditional aviation users. Alternatively, potential improvements to aviation infrastructure for aeronautical use can benefit spaceport users. For example, if CASP were to received FAA funding for infrastructure improvements in support of cargo service then the spaceport users could benefit from additional capabilities. Despite the need for capital expenditures to construct the proposed spaceport facilities, the additional indirect benefits the spaceport CIP projects provide for CASP and the Colorado community at large should not be overlooked. CASP is uniquely positioned in a region with a significant aerospace workforce including both aerospace start-up companies and the Federal aerospace and defense industry. The spaceport CIP projects have been strategically selected to accommodate this workforce with the goal of providing an incubator/business park as well as testing, training and research and development venues for such aerospace users. Advancement of spaceport development will likely attract users which will in turn incur more investment in spaceport development projects.

Source: Kimley-Horn

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Appendices

APPENDIX A: ACRONYMS

A-1	Agricultural District 1
A-2	Agricultural District 2
A-3	Agricultural District 3
AAC	Aircraft Approach Category
AC	Advisory Circular
AD	Airport District
ADA	Aerospace Development Area
ADG	Airplane Design Group
AIZ	Airport Influence Zone
ALP	Airport Layout Plan
AM	Additive Manufacturing
ARFF	Aircraft Rescue and Firefighting
ARTCC	Air Route Traffic Control Center
AST	Office of Commercial Space Transportation
ATC	Air Traffic Control
ATCT	Air Traffic Control Tower
AV	Aviation District
BEA	Bureau of Economic Analysis
Bryce	Bryce Space and Technology
CAD	Computer Aided Design
CASP	Colorado Air and Space Port
CATEX	Categorical Exclusion
CDLA	Colorado Department of Local Affairs
CDOT	Colorado Department of Transportation
CFO	Colorado Air and Space Port
CFR	Code of Federal Regulations
CIP	Capital Improvement Plan
CO	Carbon Monixide
DEN	Denver International Airport
DTWG	Dual Tandem Wheel Gear
DW	Dual Wheel
EA	Environmental Assessment
EDA	U.S. Economic Development Administration
EIS	Environmental Impact Study
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FBO	Fixed Base Operator
FONSI	Finding of No Significant Impact
FSA	Fuel Storage Area
FTG	Front Range Airport
GA	General Aviation
GDP	Gross Domestic Product
GIS	Geographic Information System
GSE	Ground Support Equipment
HD	Hazard Division
HMA	Hot Mix Asphalt
HNWI	High-Net-Worth Individuals
HTHL	Horizontal Takeoff Horizontal Landing
I-2	Industrial District 2
ILD	Intraline Distance
ISS	International Space Station
KSC	Kennedy Space Center
lbf	Pound Force
LOA	Letter of Agreement
LOX	Liquid Oxidizer
LSOL	Launch Site Operator License
MCC	Mission Control Center
MGW	Main Gear Width
MOA	Military Operating Area
MPA	Mission Preparation Area
MPPF	Multi-Payload Processing Facility
MSA	Metropolitan Statistical Area
MUF	Multi-Use Facility
NAAQS	National Ambient Air Quality Standards
NASA	National Aeronautics and Space Administration
NASTAR	National Aerospace Training and Research
NEW	Net Explosive Weight
NFA	New Frontier Aerospace
NO2	Nitrogen Dioxide
NOTAM	Notice to Airman
NPIAS	National Plan of Integrated Airport Systems
ORBITEC	Orbital Technologies Corporation
OSA	Oxidizer Loading Area
OTV	Orbital Test Vehicle
P3	Public Private Partnership
PAD	Public Area Distance

Pb	Lead
PCC	Portland Cement Concrete
PEA	Programmatic EA
PM10	Particulate Matter of 10 micrometers or smaller
PM2.5	Particulate Matter of 2.5 micrometers or smaller
PPF	Payload Processing Facility
PTRD	Public Traffic Route Distance
PUD	Planned Unit Development
QD	Quantity Distance
R&D	Research and Development
RASP	Regional Airport System Plan
RDC	Runway Design Code
RDP	Recommended Development Plan
RLV	Reusable Launch Vehicle
RP-1	Rocket Propellant 1
SABRE	Synthetic Air Breating Rocket Engine
SIB	State Infrastructure Bank
SID	Standard Instrument Departures
SNC	Sierra Nevada Corporation
SO2	Sulfur Dioxide
SSTC	Supersonic Transportation Corridor
STAR	Standard Terminal Arrival Route
STIM	Space Transportation Infrastructure Meeting
SW	Single Wheel
SWG	Single Wheel Gear
TDG	Taxiway Design Group
TF2	Reaction Engines Test Facility 2
UAM	Urban Air Mobility
UAS	Unmanned Aerial System
UDP	Ultimate Development Plan
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Services
VPIF	Vehicle Processing and Integration Facility
VTVL	Vertical Takeoff Vertical Landing

APPENDIX B: REFERENCE

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APPENDIX C: FORECAST AND MARKET ANALYSIS

Forecast and Market Analysis of Horizontal Space Launch and Reentry at Colorado Air and Space Port (CASP)

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1 Introduction

In 2018, Adams County was granted a license by the Federal Aviation Administration (FAA) Office of Commercial Space Transportation (AST) to operate the Colorado Air and Space Port (CASP) as a site servicing dual propulsion Concept X vehicles (vehicles that fly horizontally under jet power until reaching a designated area to engage a rocket engine designed to enable access to suborbital space, whereupon they return on jet power). While CASP is not currently authorized to support commercially licensed launches of orbital vehicles or vertically launched orbital and suborbital vehicles, it may support low-altitude testing of some systems under an experimental permit.

Adams County contracted with Kimley-Horn to develop a Spaceport Master Plan for CASP. To support this effort, Kimley-Horn subcontracted with Bryce Space and Technology to:

- Develop a 20-year forecast of suborbital horizontal launch and reentry activity;
- Identify and characterize factors that will influence relevant markets;
- Review roles and capabilities of peer U.S. spaceports;
- Describe CASP's critical suborbital vehicle(s);
- Project potential orbital spacecraft reentry candidates; and
- Characterize manufacturing, infrastructure, and transportation modes supporting suborbital vehicles

In addition, this report describes the means, methods, assumptions, and results of the forecasting effort.

1.1 What is a Suborbital Reusable Launch Vehicle (RLV)?

Suborbital RLVs are reusable space vehicles that carry humans, cargo, and/or experiments. The companies developing these vehicles typically target high flight rates and relatively low costs. A suborbital RLV launches or lands either horizontally (as an airplane) or vertically (as a rocket). The suborbital RLV typically follows a four-part ballistic trajectory. The first part consists of the launch phase, the second part the apogee or peak of the trajectory where a period of weightlessness will be experienced, a third part called reentry, and a fourth part, landing (which can be via parachute). For horizontal takeoff-horizontal landing (HTHL) suborbital RLVs, the FAA provides the following classifications:

- Concept X: Vehicles that take off from and land on a runway under jet power, but also carry a rocket engine which is used to propel the vehicle into suborbital space.
- Concept Y: Vehicles that use a rocket engine for take off from a runway and glide to a landing following completion of the mission.
- Concept Z: Vehicles composed of two stages; one is a jet-powered carrier aircraft that releases a rocket-powered spacecraft capable of suborbital flight, which then glides to a landing on a runway.[1]

There is one suborbital RLV currently in service, a vertical launch system: UP Aerospace's single-stage SpaceLoft XL vehicle has been in service since 2006. It is essentially a reusable sounding rocket capable of carrying 79 pounds (36 kilograms) to an altitude just above 62 miles (100 kilometers). Launched from Spaceport America, it has been flown 13 times with a reliability of 85%. After it has reached apogee, the vehicle returns to Earth via parachute.

[1] https://www.faa.gov/about/office_org/headquarters_offices/ast/media/20060505%20Oklahoma%20EA%20FONSI%20FR.pdf.

There are two large suborbital RLVs undergoing flight tests. Both are licensed by the FAA to provide commercial flights.[2]

Virgin Galactic's system, composed of the WhiteKnightTwo carrier aircraft and SpaceShipTwo spacecraft, makes use of a runway. Once operational in 2021, this RLV will operate from Spaceport America in New Mexico. The other system, Blue Origin's New Shepard, is launched and landed vertically. New Shepard is operated from an inland site owned by Blue Origin in sparsely populated western Texas.

Other suborbital RLVs are in varying stages of development around the world. Some are technology demonstrators that may lead to government-owned and -operated systems, while others are in a planning phase as companies seek financing to advance system development. A list of suborbital RLVs, broadly described to include stratospheric balloons in operation, under development, or in planning stages, is included in Table 1.

System	Provider	Country/ Region	Type	Remarks	First Flight
Intermediate eXperimental Vehicle (IEV)	ESA	Europe	VTOL	Uncrewed reusable demonstrator has flown. Development of full-scale vehicle under way.	2015 2025 for commercial service
GOLauncher 1	Generation Orbit	USA	HTHL	Crewed reusable aircraft, uncrewed rocket	TBD
HyperDrone	New Frontier Aerospace	USA	VTOL	Details limited; jet powered vertical take off and rocket powered cruise phase	TBD
New Shepard	Blue Origin	USA	VTOL	Reusable, carries 6 people	2015
RLV-TD	ISRO	India	VTO/HL	Uncrewed testbed	2016
SpacePlane	Airbus	France	HTHL	Reusable, carries 4 people. No published investment and status unclear.	TBD
SpaceLiner	DLR	Germany	VTO/HL	Passenger or cargo P2P vehicle in planning stages. No funding.	2040s
SpaceLoft XL	UP Aerospace	USA	VTOL	Reusable sounding rocket, lands with parachute, uncrewed	2006
Spaceship Neptune	Space Perspective	USA	VTOL	Stratospheric balloon, carries 9 people	2021
SpaceShipTwo	Virgin Galactic	USA	HTHL	Crewed, carries 6 spaceflight participants	2018
Stratolaunch	Stratolaunch Systems	USA	HTHL	Reusable airplane can carry an orbital or suborbital stage.	2019
Unnamed Vehicle	PD Aerospace	Japan	HTHL	Planned crewed vehicle with capacity to carry 6 spaceflight participants	2020-2021

Table 1. Suborbital RLVs in operation, under development, or planned. *HTHL – horizontal takeoff/horizontal landing, VTOL – vertical take off and landing, HL – horizontal landing.*

[2] https://www.faa.gov/data_research/commercial_space_data/licenses/.

2 Review of Existing Forecasts

Bryce conducted a thorough review of relevant published forecasts and selected those considered useful for this study. This review yielded the following findings:

- One forecast provides a realistic projection with significant methodological detail supported by evidence. It was published in 2012 by The Tauri Group and jointly funded by the FAA and Space Florida (updated in 2019).
- At least five forecasts or market assessments provide some evidence or insight into their forecasting approach with defensible growth rates. These were conducted within the past several years.
- Several other potentially useful sources were identified that generally lack any methodological detail or evidence (e.g., corporate commitment or expenditure). These were published over a decade ago, and/or show unprecedented or unrealistic growth rates.

2.1 Suborbital Reusable Vehicles: A 10-Year Forecast of Market Demand *(with 2019 update)*

This study forecasts 10-year demand for suborbital RLVs. The goal of this study was to provide information for government and industry decision makers on the emerging suborbital RLV market by analyzing dynamics, trends, and areas of uncertainty in eight distinct markets these vehicles could address. This study was produced by The Tauri Group and was jointly funded by the FAA and Space Florida.

2.1.1 Projections

Total projected demand for suborbital RLVs, across all eight markets, grows from around 370 seat/cargo equivalents in Year 1 to over 500 seat/cargo equivalents in the 10th year of the baseline case. (Year 1 represents the first year of regular suborbital RLV operations.) Demand under the growth scenario, which reflects increases due to factors such as marketing, research successes, and flight operations, grows from about 1,100 to more than 1,500 seat/cargo equivalents over 10 years. The constrained scenario, which reflects significantly reduced consumer spending and government budgets, shows demand from about 200 to 250 seat/cargo equivalents per year. See Table 2.

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Baseline Scenario	373	390	405	421	438	451	489	501	517	533
Growth Scenario	1,096	1,127	1,169	1,223	1,260	1,299	1,394	1,445	1,529	1,592
Constrained Scenario	213	226	232	229	239	243	241	247	252	255

Table 2. Number of seat/cargo equivalents beginning in Year 1 of commercial operations.
Source: Suborbital Reusable Vehicles: A 10-Year Forecast of Market Demand (with 2019 update).

The Tauri Group found that demand for suborbital RLVs is dominated by the commercial human spaceflight market. The company's analysis indicated that about 8,000 high-net-worth individuals from across the globe are sufficiently interested and have spending patterns likely to result in the purchase of a suborbital flight—one-third from the United States (based on global wealth distribution). The interested population will grow at the same rate as the high net worth population (about 2% annually). The Tauri Group estimated that about 40% of the interested, high-net-worth population, or 3,600 individuals, will fly within the 10-year forecast period.

The forecast shows a total of $600M in demand for suborbital RLV flights over 10 years in the baseline case. The growth scenario totals $1.6B, and the constrained scenario totals $300M.

2.1.2 Methodology

The Tauri Group combined primary research (more than 120 interviews, a survey of high-net-worth individuals, and a poll of suborbital researchers) and open source materials (such as market studies and data on analog markets, government budgets, and performance information on competing platforms) to build a full and objective picture of suborbital RLV market dynamics. The forecast results are in seat/cargo equivalents based on average capacity of suborbital RLVs.

Demand in each market was forecast for three scenarios:

- **Baseline scenario:** Suborbital RLVs operate in a predictable political and economic environment that is relatively similar to that of today. In this scenario, existing trends generate demand for these vehicles.
- **Growth scenario:** This forecast reflects new dynamics emerging from marketing, branding, and research successes. Commercial Human Spaceflight has a transformative effect on consumer behavior, and more customers purchase suborbital RLV flights. Research results are highly productive and attract significant new government, international, and commercial interest for future experiments.
- **Constrained scenario:** Suborbital RLVs operate in an environment of dramatic reduction in spending compared to today, due, for example, to worsened global economy

2.1.3 Report Highlight

"Total projected demand for SRVs, across all eight markets, grows from around 370 seat/cargo equivalents in Year 1 to over 500 seat/cargo equivalents in the tenth year of the baseline case."[3]

2.1.4 Factors Affecting Forecast Confidence

Suborbital Reusable Vehicles: A 10-Year Forecast of Market Demand provides a detailed forecast across 10 years supported by a methodology described in

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[3] Year 1 represents the first year of regular suborbital RLV operations.

sufficient detail. Bryce used this 8-year-old forecast as a baseline to develop an updated forecast described later in this report. Taken together, these factors inform a high level of confidence in the forecast.

2.2 Space Tourism Market Study: Orbital Space Travel & Destinations with Suborbital Space Travel *(and 2006 update)*

Published in October 2002 by the analytics firm Futron Corporation, this forecast was the first of its kind containing sufficient detail about the emerging market of space tourism. It was inspired by the plethora of orbital and suborbital launch vehicles being developed at the time to tap, among other things, the anticipated extreme growth in the demand for launches of low Earth orbit (LEO) communication satellite constellations.

The report is divided into two parts. The first part describes the nature of demand. Analysis of demand was supported by the use of a survey, developed in partnership with Zogby, designed to obtain statistical information on the demographics of potential customers and their willingness to purchase tickets. The second part provided forecasts, supported by descriptions of the methodologies employed, of orbital and suborbital tourism.

2.2.1 Projections

Table 3 shows projections provided in the study.

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Baseline Suborbital Forecast (Passengers)	503	642	820	1,045	1,330	1,692	2,150	2,726	3,448	4,350	5,468	6,842	8,517	10,532	12,923	15,712
Baseline Orbital Forecast (Passengers)	3	4	4	4	10	14	16	20	24	28	34	42	46	48	54	60
Dedicated Orbital Flights	-	-	-	-	1	3	4	6	8	10	13	17	19	20	23	26
Soyuz ISS Flights	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4

Table 3. Number of passengers, dedicated orbital flights, and Soyuz flights to ISS*. Source: Space Tourism Market Study: Orbital Space Travel & Destinations with Suborbital Space Travel (and 2006 update).*

2.2.2 Methodology

The survey conducted in partnership with Zogby focused on wealthy individuals and asked a series of questions to determine their interest in suborbital tourism. This information was then applied to demographic statistics to calculate a total number of interested individuals. To determine how many fly in a given year, Futron modeled market diffusion by applying a Fisher-Pry curve with a 40-year maturity period to the potential demand. This study was updated in 2006 in three ways: 1) moving the date of the first flight from 2006 to 2008; 2) increasing the initial ticket price from $100,000 to $250,000; 3) updating population demographics with best available information

2.2.3 Report Highlight

"Demand for sub-orbital tourism will be strong for the period after the service is introduced, but will depend largely on emerging, unpredictable factors."

2.2.4 Factors Affecting Forecast Confidence

Space Tourism Market Study: Orbital Space Travel & Destinations with Suborbital Space Travel provides a good forecast with a methodology that is described in sufficient detail. While this study was updated in 2006, it is still outdated and does not reflect developments since its publication. In total, these factors instill moderate confidence in this forecast.

2.3 Commercial Viability Evaluation of the Suborbital Space Tourism Industry (2019)

Published in the journal *New Space* in 2019, this study attempts to capture the uncertainty in many aspects of human suborbital flight to analyze the viability of the market. The study's goal was to determine a set of possible economic outcomes based on the performance of different types of vehicles, a model of costs associated with those vehicles, and the uncertain demand for suborbital flights. Additionally, this study includes a sensitivity analysis of the impact of these factors on the economic result. The study was authored by a trio of researchers at the Massachusetts Institute of Technology (MIT).

2.3.1 Projections

This paper does not provide a forecast or make projections. It instead assesses market dynamics using a model that incorporates previous Futron and Tauri forecasts. It does indicate that aggressive fleet expansion of large vehicles and less aggressive expansion with medium vehicles were dominant strategies.

2.3.2 Methodology

The authors combined multiple inter-linked models of technical capability, vehicle cost, and market demand to create inputs for a Monte-Carlo simulation. They did this for a range of fleet expansion strategies to generate a distribution of possible economic results.

The elements of the fleet expansion strategies included the number of vehicles developed and the number of seats per vehicle. The number of seats represented an input for a model of the mass of the vehicles, which informed a cost model. The cost model included development cost and marginal cost per flight. The total cost was an input in the Monte-Carlo simulation while the marginal cost informed the pricing in the market model. The market model included pricing and demand, with demand as an input into the Monte-Carlo simulation. The Monte-Carlo simulation was evaluated based on the net present value of the probable results.

2.3.3 Report Highlight

"Aggressive fleet expansion with a large vehicle (16 participants) and neutral (less aggressive) fleet expansion with a medium vehicle (4 participants) are the two dominant strategies a company can take given our model and uncertainty assumptions."

2.3.4 Factors Affecting Forecast Confidence

This paper is not intended to be a forecast. It does provide estimates of the sensitivity of the suborbital human spaceflight market, but only for a limited number of individual factors. These factors instill moderate confidence in this study.

2.4 Great Expectations: An Assessment of the Potential for Suborbital Transportation (2008)

Authored by a group of graduate students at the International Space University in 2008, this report makes a series of recommendations to enable point-to-point suborbital travel for both people and cargo.

2.4.1 Projections

This report calculated that there could be anywhere from 17 to 150 daily passengers on suborbital point-to-point flights depending on the specific route. The report also determined that under the same conditions, cargo flights would not be beneficial unless the price were to significantly drop or there were substantial gains to be made by reducing the travel time.

2.4.2 Methodology

The potential traffic volume for suborbital point-to-point transportation was estimated by first examining the most traveled long-haul international flights to determine possible routes. The number of people who fly these routes annually was calculated based on data from the International Air Transport Association and population growth estimates. To arrive at the addressable market for point-to-point suborbital flights, as well as its elasticity, price and quantity data for the New York–Paris route for premium and economy tickets as well as the Concorde were analyzed was used to estimate elasticity. This elasticity was then applied to the estimated traffic population to arrive at a final estimate for each suborbital point-to-point route.

2.4.3 Report Highlight

"Initial analysis shows that at USD 50,000 per ticket, a future market of about 50 passengers per day could exist in the major routes between New York, London, and Tokyo."

2.4.4 *Factors Affecting Forecast Confidence*

This estimate is part of a much larger analysis of a specific type of suborbital flight and relies heavily on comparisons to conventional air travel. This study also predicated its numbers on the first flight occurring in 2020, which will not occur. These factors instill low confidence in this analysis.

2.5 Other Potentially Useful Forecasts and Market Assessments

Commercial U.S. spaceports require a launch site operator's license issued by AST. Because the AST decision to license a commercial spaceport is considered a major federal action under the National Environmental Policy Act (NEPA) of 1969, AST is responsible for analyzing the environmental impacts associated with licensing proposed commercial launch sites. This activity is embodied in an environmental review during the license application process, and requires the applicant to describe the type of activity expected to occur at the spaceport during the period covered by the 5-year license, should it be issued. These launch and reentry forecasts were reviewed and, while most are obsolete, still proved very useful in identifying the type of activity anticipated by various suborbital RLVs. The following spaceport and launch site EAs were reviewed:

- Blue Origin's Van Horn launch site
- Cape Canaveral Spaceport (Launch and Landing Facility)
- Cecil Spaceport
- Colorado Air and Space Port
- Houston Spaceport
- Midland International Air and Space Port
- Mojave Air and Space Port
- Oklahoma Air and Space Port
- Spaceport America

Market Demand Methodology for U.S. Suborbital Reusable Launch Vehicle Industry (2014) described the technological capability needed to sustain a commercial sub-orbital reusable launch vehicle market. It was authored by six researchers both from The Aerospace Corporation and NASA's Armstrong Flight Research Center and presented at AIAA Space 2014. This study utilized economic physics to evaluate developing suborbital vehicles by comparing them to other modes of transportation across eight parameters.[4] This study's methodology considers the market from the vehicle development direction and develops a system for estimating the cost of supplying suborbital flights. It finds that the cost estimates track closely to published prices for both suborbital tourism and science and technology missions.

Feasibility Study and Future Projections of Suborbital Space Tourism at [sic] the Example of Virgin Galactic (2008) is a senior thesis by Matthias Otto at the Cologne

[4] Economic physics, or econophysics, is an interdisciplinary research field applying theories and methods originally developed by physicists in order to solve problems in economics.

Business School Köln. It is an overview analysis of the sub-orbital tourism market and its commercial viability. The methodology centers on a case study of Virgin Galactic and includes some original data from interviews.

Next Generation Suborbital Activities: Assessment of a Commercial Stepping Stone (2010) is a Next-Generation Suborbital Researchers Conference presentation. It discusses publically available business plans for suborbital tourism companies and how additional suborbital research flights could expand the number of competitors and funding available in the market. It was authored by D. I. Lackner and O.M. Al-Midani from ALPS Ventures, a business valuation and corporate finance firm.

3 An Evaluation of Trends and Factors Impacting Commercial Suborbital Launch and Reentry Demand

Section III has two parts. Subsection one describes suborbital industry trends and the second subsection covers industry barriers to entry. Industry trends include a description of suborbital markets and competing markets, a discussion of peer spaceport support with potential competitive influence, and suborbital RLV manufacturing techniques designed to reduce costs. The second subsection covers barriers to market entry.

3.1 Industry Trends

3.1.1 Markets

Eight suborbital markets were assessed for this study:[5] 1) Suborbital tourism, 2) basic and applied research, 3) aerospace technology test and demonstration, 4) media and public relations, 5) education and training, 6) satellite deployment, 7) remote sensing, and 8) point-to-point transportation.

Both suborbital tourism and suborbital research and technology demonstration have relatively high projections for the number of flights and revenue. The remaining six markets are considered comparatively minor in terms of revenue and number of flights, nascent (substantial growth not expected before 2040), or likely to be unsustainable because of competing alternatives.

Suborbital Tourism

Suborbital tourism is the use of suborbital RLVs by individuals who have purchased tickets to fly aboard these vehicles for pleasure. As this market matures,

[5] The most comprehensive study conducted on suborbital markets is *Suborbital Reusable Vehicles: A 10-Year Forecast of Market Demand*, produced by The Tauri Group and jointly funded by the Federal Aviation Administration Office of Commercial Space Transportation and Space Florida (2012). This study identified eight suborbital markets: Commercial Human Spaceflight, Basic and Applied Research, Aerospace Technology Test and Demonstration, Media and Public Relations, Education, Remote Sensing, Satellite Deployment, and Point-to-Point Transportation.

differentiation may take place in the types of individuals that pay for a flight aboard this type of vehicle. These types include firms using seats as incentives or rewards, organizations offering seats in contests and promotions, and space agencies or other space-related organizations using suborbital RLVs for in-space training. Individuals using their own funds can purchase tickets for a flight aboard a suborbital RLV to experience microgravity and a view from space combined with the rare opportunity to cross the threshold into space. The advertised price per seat is in the low six figures (and expected to rise to mid six figures in 2020), much more expensive than a parabolic flight and double the price to climb Mount Everest or sail on a luxury six-month global cruise. However, a ticket aboard a suborbital RLV is far less expensive than a seat aboard a commercial orbital spacecraft, which is estimated to be about $60M.

There are two companies with planned commercial service for flights aboard suborbital RLVs: Virgin Galactic and Blue Origin. Virgin Galactic tickets went on sale in 2004 for a price of about $200,000. In 2013, the price increased to $250,000. In 2014, Virgin Galactic halted ticket sales following the fatal accident of SpaceShipTwo *VSS Enterpris*e during a test flight. Virgin Galactic has sold just over 600 tickets since 2004 (with some sources saying "nearly 700 tickets"), and in February 2020 the company announced it would re-open ticket sales by the end of 2020, accepting a fully refundable $1,000 deposit to secure a reservation.[6] The company has conducted two rocket-powered test flights of its SpaceShipTwo *VSS Unity* since 2018 and may start commercial services in 2021. Blue Origin expects to start selling tickets for flights aboard its New Shepard vehicle in 2020. While details on pricing were not released, company CEO Bob Smith said the first tickets would cost "hundreds of thousands of dollars."[7]

Market Drivers: Target Market

The target market is composed of high-net-worth individuals (HNWI), with a net worth of at least $5M, and enthusiasts with net worth below $5M. There are an estimated 5.7 million individuals with a net worth of over $5M.[8] Table 4 shows the 5-year trend for this group.

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[6] Ticket sales were suspended in 2014 following loss of SpaceShipTwo VSS Enterprise during a test flight accident that killed the pilot and injured another. Ciao, Sissi, "Virgin Galactic's Top Priority Is to Fly Richard Branson to Space This Year," *Observer.com* (January 15, 2020). See also Sheetz, Michael, "Virgin Galactic will begin accepting $1,000 deposits toward space flight tickets for tourists," *CNBC* (February 25, 2020).

[7] Boyle, Alan, "NASA gets set to put astronauts on Blue Origin and Virgin Galactic suborbital flights," *GeekWire* (June 19, 2020).

[8] *Credit Suisse Global Wealth Report 2019*. About 5.4 million people have a net worth of between $5M and $50M. About 168,000 people have a net worth over $50M (called ultra-high net worth individuals).

	2015	2016	2017	2018	2019
$5M to $10M	2.5M	2.5M	3M	3.3M	3.7M
$10M to $50M	1.3M	1.5M	1.6M	1.6M	1.8M
$50M+	123,800	140,900	148,200	149,890	168,030

Table 4. Estimated number of high net worth individuals (HNWI) and ultra high net worth individuals (UHNW) worldwide (2015-2019). Source: Credit Suisse.

Historically, a very small number of HNWIs have expressed strong interest in flying on a suborbital tourist flight. This group includes people who engage other activities considered extreme or high-risk, such as auto racing and other motorsports, spelunking, high stakes gambling, hang gliding, hot air ballooning, mountain climbing, private aviation, scuba diving, sky diving, skiing, and snowboarding. Others have explored the oceanic trenches, climbed Mount Everest, and visited the South Pole.

In addition, there are people with a net worth below $5M who have expressed a strong interest in participating in a suborbital spaceflight. These enthusiasts are willing to spend a large portion of their income or borrow on credit to experience spaceflight.

Taken together, HNWIs with a predilection for adventure and a tiny pool of space enthusiasts are motivated to spend about $250,000 to experience spaceflight. The number doubles if the ticket price drops to about $100,000, indicating that demand is somewhat elastic.

Market Drivers: U.S. Government Policy

The FAA is the regulatory authority for commercial suborbital RLV operations. Historically, the FAA has taken a "light approach" to the regulation of commercial suborbital RLV activity to ensure that regulations are not so over burdensome that they inhibit the emerging commercial suborbital RLV industry.

In order to conduct revenue-generating suborbital RLV flights, operators must obtain FAA licenses for themselves and their vehicles. Unpowered test flights are conducted under a Special Airworthiness Certificate and powered test flights under an Experimental Permit (though powered test flights can and do take place under a license). This relatively lenient approach is used in place of certification, which is required for aircraft and informed by extensive flight experience, as this would be cost prohibitive for the relatively new commercial space transportation industry, especially suborbital RLVs. Instead of imposing a prescriptive and limited set of design criteria, FAA sets performance-based requirements to ensure safe operations of commercial space vehicles. This approach has enabled greater industry innovation at a much lower cost, along with the ability to test designs and methods before entering the market.[9]

In addition, under current regulations, commercial suborbital RLVs operate under a regime known as "informed consent," which requires crew and spaceflight participants to be informed, in writing, of mission hazards and risks, vehicle safety record, and the overall safety record of all launch and reentry vehicles. Prior to flight, crew and spaceflight participants must provide their written consent to participate.[10]

This "light approach" by FAA is expected to continue as the office plans to issue reformed regulations later in 2020 designed to streamline the license application process.[11] Regulatory reform was directed by the White House in the form of Space Policy Directive 2 (SPD-2), "Streamlining Regulations on Commercial Use of Space," signed by the president on May 24, 2018.[12] SPD-2 involves consolidating and simplifying regulations relevant to commercial space transportation and commercial remote sensing satellites. FAA AST, the licensing authority for commercial launches and reentries, was subsequently reorganized, a process completed in April 2020.[13] As part of the reorganization, a new Office of Spaceports was established to handle licensing and issues for commercial spaceports.[14] However, regulatory reform is not expected to be complete until late 2020.[15] Some expect this reform to automate license applications to alleviate AST workload and provide more efficient services to applicants, and enable remote presence of AST at launch sites when supporting commercial launches. FAA Associate Administrator Wayne Monteith, who heads the AST, is planning for an increase in budget and workforce as the office anticipates an increase in license applications and its oversight responsibilities.[16]

Beyond regulatory concerns, the NASA Flight Opportunities Program will continue to drive the market for suborbital RLVs. Begun more than a decade ago as the Commercial Reusable Suborbital Research program, Flight Opportunities has flown science payloads on traditional suborbital RLVs, high-altitude balloons, and commercial microgravity aircraft flights. Both Virgin Galactic and Blue Origin have flown Flight Opportunity payloads with their SpaceShipTwo and New Shepard

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[9] Nield, George et al, "Certification Versus Licensing for Human Space Flight in Commercial Space Transportation," 63rd International Astronautical Congress, Naples, Italy (2012).
[10] Fact Sheet – Commercial Space Transportation Activities (June 19, 2020).
[11] Foust, Jeff, "White House official recommends slow approach to high-speed suborbital transportation," *SpaceNews* (June 23, 2020).
[12] SPD-1 is focused on human exploration of the Moon, SPD-3 is focused on the development of space traffic management, and SPD-4 on the establishment of a U.S. Space Force.
[13] Foust, Jeff, "FAA commercial space office completes reorganization," *SpaceNews* (April 19, 2020).
[14] The Office of Spaceports was a requirement made by Congress in its 2018 FAA reauthorization bill.
[15] Ibid. See also Foust, Jeff, "FAA expects revised launch regulations to be completed next fall," *SpaceNews* (October 10, 2019).
[16] Foust, Jeff, "FAA commercial space office completes reorganization, *SpaceNews* (April 19, 2020).

vehicles, respectively.[17] Both NASA personnel and external researchers can compete for funding for their payloads through the agency's Space Technology Mission Directorate (STMD). The Flight Opportunities Program budget is below $20M.

In June 2020, two events took place designed to enable NASA to support development of a program for training astronauts and potentially procuring and system qualifying suborbital RLVs. NASA is seeking opportunities to fly its personnel for three reasons: training of astronauts, testing space hardware, and human-tended microgravity research. On June 22, NASA signed a Space Act Agreement with Virgin Galactic for the company to provide training flights for agency astronauts as they prepare for missions to the International Space Station (ISS).[18] On June 23, NASA issued a Request for Information (RFI) to begin the qualification process for suborbital RLVs to carry NASA employees. This effort is purposefully different from the FAA licensing process, because FAA is restricted from regulating safety of spaceflight participants on commercial vehicles until 2023. Despite receiving the authority to do so in 2004, the FAA was concurrently instructed to follow what is sometimes called a learning period, or "moratorium" to avoid establishing regulatory hurdles that could preclude the commercial human spaceflight industry from being able to grow.[19]

Market Drivers: Demand

Demand for space tourism is driven by interest in spaceflight or the experience of a unique adventure, affordability, prestige due to the small number of people who have been in space, and availability of service.

Those interested in participating in a suborbital spaceflight share a common interest in experiencing something unique and perhaps life changing. Yet, there are subtle differences that account for separate treatment. While HNWIs are keen to add spaceflight to their varied list of adventures, space enthusiasts, as the name suggests, are more emotionally invested in the idea of spaceflight. This emotional attachment means a space enthusiast is willing to spend outside their means to experience the drama of spaceflight.

For the HNWI market for space tourism, the level of exclusivity and luxury associated with the experience will drive demand. As expected, many HNWIs are well-known celebrities. Among the ranks of celebrities who have purchased or were gifted a ticket to fly aboard a suborbital RLV are Justin Bieber, Russell Brand, Leonardo DiCaprio, Angelina Jolie, Ashton Kutcher, Lady Gaga, and Katy Perry. Even after the fatal accident of *VSS Enterprise* in 2014, few of these high-profile people

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[17] Foust, Jeff, "Bridenstine supports increased funding for NASA's Flight Opportunities program," *SpaceNews* (August 28, 2018).

[18] Sheetz, Michael, "Shares of Virgin Galactic surge after announcement that it will train astronauts for NASA," *CNBC* (June 22, 2020).

[19] Bellamy, Woodrow, "US Commercial Space Regulation on Path to FAA Policy Inflection Point," *Aviation Today* (July 13, 2020).

canceled their tickets.[20] Virgin Galactic, in particular, has focused on this segment with the early purchasers of tickets treated as members of an exclusive club with offers and opportunities not available to others.

Jim Clash, an adventure journalist and member of The Explorers Club, is an example of a space enthusiast who bought a ticket with Virgin Galactic with a down payment of $20,000.[21] Commenting nine years after purchasing his ticket and waiting for his ride, he remains excited: "Weightlessness is one thing, but I'm really going to focus on the view, trying to relax and take it all in. I understand that it is a life-changing experience."[22] He has said he will likely need to take out a loan against his 401K retirement account to finance the trip.[23] Business school professor Ketty Maisonrouge is a space enthusiast who purchased her ticket in 2005. Fourteen years later, she tried on her spacesuit and flew aboard a Zero-G Corporation airplane for a parabolic flight. Regarding her preparation in November 2019, she said, "For me, it was like the realization that this is really going to happen soon. When you've been waiting for 15 years, when you've been dreaming about it for as long as you can remember, you wonder until it happens if it will really happen."[24]

Virgin Galactic has published a description of the experience that can be expected for those who have purchased a ticket. First, up to six ticket holders (the company uses the term "Future Astronauts" to describe customers about to embark on their flight) will undergo three days of training at the launch and landing site, Spaceport America in south central New Mexico. Wearing their custom-fitted flight suits, the Future Astronauts will board SpaceShipTwo, slung under the WhiteKnightTwo carrier aircraft, in the early morning. The vehicle combination will take off like a conventional airplane, reaching the spacecraft release altitude of 50,000 feet (15,240 meters) in about one hour. Seconds after being released, SpaceShipTwo will engage its single engine to take it up beyond an altitude of 100 km (62 miles), also called the von Kármán line, recognized as the point beyond which one is in outer space. After the passengers experience almost four times the force of gravity during the powered portion of the flight, the crew will shut off the engine. The vehicle will coast along its ballistic trajectory, enabling all aboard, no longer strapped to their seats, to experience microgravity for up to five minutes. After this, the spaceflight participants have become astronauts. Strapping back into their seats, they prepare for reentry and landing as a conventional airplane. A ceremony will be held following landing in which the astronauts receive their private astronaut wings.

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[20] Green, Dennis, "Celebrities Aren't Bailing On Virgin Galactic After Crash," *Business Insider* (November 4, 2014).
[21] The Explorers Club is an American-based international multidisciplinary professional society with the goal of promoting scientific exploration and field study.
[22] O'Callaghan, Jonathan, "2019 is the year that space tourism finally becomes a reality. No, really," *Wired* (January 24, 2019).
[23] Garre, Taylor, "Adventurer Jim Clash Preps for Dream Ride on Virgin Galactic Spacecraft," *Cheddar.com* (October 17, 2019).
[24] Thomas, Zoe, "The woman who paid $250,000 to go into space," *BBC News* (January 12,2020).

Virgin Galactic has teamed with Land Rover and Microsoft to enhance the experience for customers, with the former making available the Astronaut Edition Land Rover created exclusively to those who have flown aboard SpaceShipTwo and the latter providing a virtual experience via WebVR designed to "democratize" the experience worldwide.[25]

The Blue Origin experience will be markedly different than that offered by Virgin Galactic, since the New Shepard vehicle is launched like a rocket instead of an airplane, potentially enhancing the appeal of the suborbital spaceflight experience. Though details about the experience have not been published, enough has been provided to understand the flight profile, which will last about 11 minutes. New Shepard, capable of carrying six spaceflight participants (the vehicle does not require a crew) will launch from the company's West Texas site near the town of Van Horn. Passengers, wearing flight suits, will enter the capsule via a launch gantry while New Shepard is vertical. The booster will propel the capsule until both units separate; the reusable booster will land under its own power back at the same spot it launched from. The capsule will follow its ballistic trajectory past the Von Kármán line, allowing passengers to experience a few minutes of microgravity. Following reentry, the capsule will deploy parachutes for a soft landing near the launch site.[26]

Though these experiences are compelling, they are nevertheless not affordable to most people or may be perceived as too risky. Terrestrial competition for suborbital space tourism includes experiences that deliver key elements of the space experience, such as a view of the curvature of the Earth against the blackness of space or short periods of microgravity, using planes and balloons. For a price of between $5,400 and $6,700 per person, U.S.-based Zero-G Corporation (owned by Space Adventures), France-based Novespace, and Switzerland-based MigFlug offer parabolic flights that create microgravity conditions.[27] Space Adventures, MigFlug, and others also offer flights in high performance jets that reach altitudes of 13.7 miles (22 kilometers), far below what is considered space, but nevertheless a unique experience. Beginning in 2024 and for a ticket price of around $125,000, at least two companies (zero2infinity and Space Perspective) will offer the capability to send tourists and researchers aloft aboard large capsules carried by balloon to altitudes of about 18.6 miles (30 kilometers).[28] This altitude enables people to easily see the curvature of the Earth. Space Perspective anticipates 500 flights per year, carrying eight people each time,

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[25] https://www.virgingalactic.com/learn/.
[26] https://www.blueorigin.com/new-shepard/.
[27] Foust, Jeff. "Zero-G plans international expansion," *SpaceNews* (March 6, 2020). (https://spacenews.com/zero-g-plans-international-expansion/). For pricing data, see https://www.gozerog.com/, https://www.airzerog.com/reservation/, https://migflug.com/flights-prices/zero-gravity-in-russia/.
[28] Mosher, Dave. "A new spaceship-on-a-balloon startup wants to float you high enough to see Earth's curvature and the darkness of space for roughly $125,000 per ticket, *Business Insider* (June 18, 2020). Note that a U.S. company operating such a capsule, and the capsule itself, must be licensed by the FAA's Office of Commercial Space Transportation.

within a few years of beginning operations.[29] On the ground, the National Aerospace Training and Research (NASTAR) Center in Pennsylvania offers suborbital flight training and has trained over 700 future spaceflight participants.[30]

Suborbital Research and Technology Demonstration

Suborbital research and technology demonstration refer to the use of crewed and uncrewed suborbital RLVs by organizations requiring low-cost, rapid, and repeated access to the space environment to support scientific research and the development and testing of technologies. Suborbital RLVs provide up to seven minutes of microgravity, exposure to a near vacuum environment above the Earth's atmosphere, and the ability to immediately retrieve payloads following a flight. In addition, suborbital RLV operators represent a one-stop-shop for administration, processing, and management of payloads, contrasting with more complex options involving space agencies when securing missions aboard orbital platforms and sounding rockets.

Market Drivers: Target Market

Governments, companies, and academics conducting space-related scientific research and technology test and demonstration missions represent the target market for suborbital research and technology demonstration.

Among governments, organizations with an existing or potential interest in using suborbital RLVs are NASA, National Science Foundation (NSF), National Oceanic and Atmospheric Administration (NOAA), and their international equivalents around the world. National security organizations may also represent part of the target market, though often their missions may be classified, making that market difficult to address.[31] The number of potential customers in the private sector is probably quite large, with the majority seeking to support applied research across diverse disciplines (from pharmaceuticals to additive manufacturing) and some keen to conduct technology demonstrations (to space qualify new capabilities). Finally, a good deal of the target market consists of academic researchers from across the globe, with a similar diversity of work evident among researchers in the private sector.

In terms of the target market local to CASP, Colorado is one of the largest centers of space-related activity among the 50 U.S. states, representing a large pool of potential suborbital RLV users. The state is home to nearly 500 aerospace companies providing 191,000 space-related jobs, almost all located in the Boulder-Denver-Colorado Springs corridor.[32] Among these are long-established companies like Ball Aerospace, Boeing, Lockheed Martin, Maxar, Northrop Grumman, and United

[29] Ibid. The company plans at least one test flight from KSC's former Shuttle Landing Facility, but plans to use Pacific Spaceport Complex – Alaska as a base for commercial operations.
[30] Interview, July 10, 2020.
[31] If such missions prove addressable, suborbital RLVs would likely need to be certified to carry national security payloads.
[32] See http://www.spacecolorado.org/.

Launch Alliance (ULA); and relative newcomers making significant strides like Blue Canyon Technologies and Oakman Aerospace. In addition, there are several universities and research institutions that have played a significant role in space projects. These include the Colorado School of Mines, Metropolitan State University, University of Colorado Boulder (with its newly completed Aerospace Engineering Complex), National Center for Atmospheric Research (NCAR, sponsored by the National Science Foundation), Southwest Research Institute (SwRI) Boulder Office, University Corporation for Atmospheric Research (UCAR), and the U.S. Air Force Academy. Finally, the area includes 10 economic development organizations and three local space industry associations. These organizations, all within a two-hour drive of CASP, represent a significant nexus of space-related research and technology development supported by a robust higher education pipeline.

Market Drivers: Government Policy

In the U.S., government policy and regulation of suborbital RLVs used for research and technology demonstration missions are essentially the same as for their use in suborbital tourism.

Market Drivers: Demand

Demand for suborbital research and technology demonstration is driven by the speed of access to results (and control over experiments) as compared to orbital options, the need for continuous microgravity for a period of up to seven minutes as compared to non-orbital options, affordability, and repeatability—the capability to fly an experiment several times in one day.

Researchers have expressed a desire for a means to deploy experiments in space quickly, from getting scheduled for a launch to rapidly obtaining the experiment and data after the mission. Many researchers have been seeking opportunities to access a sustained period of microgravity (up to seven minutes) within a relatively short schedule encompassing acquisition of launch services, the necessary number of flights, and access to results. Some researchers have pointed out that repeated and low-cost access to space provided by suborbital RLVs can increase the tolerance for risk in evolving an experiment; failure can be tolerated and learned from, promoting innovation.

Orbital platforms like the ISS and free-flying spacecraft like SpaceX's Dragon, Boeing's CST-100 Starliner, and Northrop Grumman's Cygnus represent potentially excellent opportunities for research missions, since the experiment can be exposed for longer durations in the environment of space. However, access is both relatively expensive and difficult to schedule—with the scheduling process often extending for several years. Sounding rockets present a better opportunity, but the lead times are often more than a year and the cost is still high. On the opposite end of the spectrum, though much less expensive, parabolic flights and drop towers only provide a few seconds to under two minutes of microgravity.

The types of basic and applied research generating demand for suborbital RLVs include:

- Atmospheric research – Suborbital RLVs will allow researchers regular access to poorly understood upper reaches of the atmosphere to understand the dynamics that drive Earth's weather and climate. Demand for this need would come from NOAA and similar organizations.
- Suborbital astronomy – Suborbital RLVs will allow researchers to conduct high-quality infrared (IR) and ultraviolet (UV) observations outside the atmosphere. Demand for this capability would come from NASA and other civil space agencies.
- Longitudinal human research – Suborbital RLVs will enable studies of a diverse and large population of space travelers on frequent flights to understand the effects of microgravity and acceleration on the human body. Demand for this capability would come from NASA, other civil space agencies, and possibly private industry and publicly funded institutions (like the National Institutes of Health) conducting biomedical research.
- Microgravity research – Suborbital RLVs will offer a unique combination of attributes, including meaningful duration in high-quality microgravity, human tending, and lower cost. Demand for microgravity research is significant, with interests across government, commercial, and academic disciplines.

In terms of technology test and demonstration missions, NASA and other civil space agencies will likely be the major users of suborbital RLVs. Over time, NASA will likely transition to suborbital RLVs for some (not all) suitable test and demonstration payloads. As previously noted, NASA has shown initial support for suborbital RLVs through the agency's Flight Opportunities program.

In addition to demand identified in historical trends, significant additional growth could occur if NASA and international partners target suborbital RLVs as a steppingstone for most applicable exploration technologies before demonstration on the ISS. However, barriers to this access have been identified (described in the subsection on industry barriers).

Other Suborbital Markets

The following markets were assessed and considered negligible in terms of their potential during the forecast period.

Media and Public Relations

The market for media, public relations, and novelties includes activities that use space to promote products, increase brand awareness, or film space-related content, typically to leverage associations with space. Submarkets include activities in film and television; media, advertising, and sponsorship; public relations and outreach; and space novelties and memorabilia. While space-themed advertising and memorabilia are ubiquitous, relatively little related activity has historically occurred in space or using space analogs (such as parabolic flights). In the latter case, parabolic flights were used in the filming of *Apollo 13* and some television commercials, while documentary and educational material has been filmed on the ISS. NASA recently disclosed discussions on a future commercial feature film to include active production on ISS. Suborbital flight provides a middle ground in the cost and duration between these two for potential media applications.

Demand for media and public relations use of suborbital flights will be influenced by the amount of media coverage and public interest surrounding initial commercial suborbital flights on Virgin Galactic and Blue Origin vehicles.

Education and Training

Suborbital RLVs could provide opportunities to K-12 schools, colleges, and universities to increase access to and awareness of space, especially through the flight and return of student-built payloads and teacher-in-space programs. There also might be opportunities for astronautical engineering students to learn first hand how to develop a space mission from start to finish. Colorado in particular has a vibrant and diverse education infrastructure, with over 1,800 schools and several institutions actively engaged in space-related curricula.

Key attributes for schools are frequent flights that would align with school schedules and affordable costs for small payloads. If frequent flights of suborbital RLVs occur from CASP, the potential for ride-share of small student experiments may be possible. Through an educational outreach program, Blue Origin's New Shepard, for example, carried a 2U CubeSat for a Colorado school into space for less than $10,000.

Existing space-related education build projects use small and large rockets (as rideshare payloads or CubeSats delivered to ISS for later deployment), balloons, parabolic flights, amateur rockets, and potentially suborbital RLVs. Student-built payloads are typically small, from ping-pong-ball-sized experiments to soda can-sized and CubeSat (a 10 cm cube) form factors. The cost to launch CubeSats and other small satellites can be prohibitive, although universities are often able to take advantage of government-sponsored complimentary rides to orbit as secondary payloads.[33] Some education payloads have already begun launching on suborbital RLVs. In May 2019, Blue Origin launched 38 payloads, one of which tested a standardized set of hardware for classroom-developed space experiments. The hardware, developed by a non-profit group called Teachers in Space, previously flew on high-altitude balloons and a stratospheric glider.[34] It is likely that the launch was provided for free or at low cost for demonstration purposes.

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[33] NASA's CubeSat Launch initiative (CSLI) provides access to space for small satellites, CubeSats, developed by NASA Centers and programs, educational institutions, and non-profit organizations. These are launched as CSLI Educational Launch of Nanosatellites (ELaNa) missions via ISS deployment opportunities or ride-share launches.

[34] Boyle, Alan, "Watch Jeff Bezos' Blue Origin venture launch suborbital science extravaganza," *Geek Wire* (May 1, 2019).

Private and public education funding, often sponsored through technology companies and STEM organizations, will provide resources and opportunities for education and training programs to be conducted on suborbital vehicles.

Remote Sensing

The suborbital RLV remote sensing market is the potential use of suborbital RLVs for the acquisition of imagery of the Earth and Earth systems for commercial, civil government, or military applications (imagery intelligence, or IMINT). Suborbital RLVs are unlikely to compete effectively with aerial platforms with loiter capability and Earth observation constellations operated by companies like Planet, Maxar, Spire Global, and others.

Satellite Deployment

Early suborbital RLV concepts, like XCOR Aerospace's Lynx III, have involved the addition of a small upper stage to expand service options for customers. With the emergence of dedicated smallsat launch vehicles (those with a capacity of 1,102 pounds—500 kilograms—to low Earth orbit or less) and competitive ride share options, the already limited interest in a suborbital RLV with this capability has effectively disappeared.

Deployment of smallsats is expected to increase during the forecast period, with the majority of these providing commercial service and having a mass toward the higher end of the scale due to greater payload capability and power needs. To address this anticipated increase, over one hundred launch service companies have been established around the world to develop dedicated smallsat launch vehicles.[35] Additionally, operators of large rockets have made more capability for smallsat rideshare missions available on their vehicles. These developments will likely hinder any investment in satellite deployments from suborbital vehicles. CASP is not likely to support launches of satellite due to its geographical location and airspace constraints. Some horizontal orbital air launch platforms, however, may operate with sufficient range that they could conduct satellite launches from either the Gulf of Mexico or Pacific Ocean for missions originating from CASP.

Point-to-Point Transportation

Suborbital point-to-point transportation (PTP) involves the use of a suborbital RLV for transporting people or cargo between locations on Earth through the space environment, achieving significant improvements to today's travel time between distant hubs. Using such a system, a trip from Washington, DC, to Tokyo, normally 14 hours in the air, could theoretically be accomplished in two hours. While there is significant interest and effort in researching and developing the technologies necessary for PTP, this transportation approach, particularly for long-distance travel, is unlikely to be operational within the study period of 20 years.

[35] From Bryce Space and Technology launch vehicle database.

The largest barrier to PTP is developing, maturing, and integrating technologies into operational systems. These activities combine to produce high research and development costs measured in billions of dollars, which would then need to be recovered over time through ticket sales and service contracts. While there are no PTP passenger or cargo suborbital RLV programs under way, some have been rendered as concepts that may lead to the development of hardware and test articles, like the Skylon single-stage-to-orbit concept being explored by UK-based Reaction Engines.[36] At least one system is being developed that may be used for PTP services, SpaceX's Starship. Starship is designed primarily as a reusable launch vehicle, but the company has indicated that as the system matures it may be employed for PTP services as well.[37]

Several hypersonic research programs, mostly focused on missile development, are active in the U.S., Russia, China and other countries that may inform development of such a transport system.[38] In addition, several supersonic passenger aircraft are in conceptual stage, including systems proposed by companies like Aerion Corporation, Boom Technology, Spike Aerospace, and Virgin Galactic. Further, a 2010 FAA report concluded that "[w]hile the vehicles themselves may qualify for commercial transport, they will have to be licensed for flight using regulations like those for jet aircraft or ones specifically crafted for suborbital PTP [vehicles]."[39] Licensing such a vehicle, its integration into the air traffic management system, and the need to gain public confidence in PTP systems are challenges that make the introduction of PTP services unlikely during the forecast period. However, it is possible that PTP prototype systems may be introduced during the forecast period and these would require testing sites. For example, CASP could partner with similar commercial spaceports to support PTP testing of flight corridors considered necessary to support the unique flight profile of future operational PTP vehicles.

Competing Markets

Other Space-Related Human Spaceflight Options

As described on Page 17, terrestrial competition for space-related tourism include experiences that deliver key elements of the space experience, such as a view of the curvature of the Earth against the blackness of space or short periods of

[36] Skylon emerged from studies of a similar vehicle from the 1980s called HOTOL (for horizontal take off and landing). The system is planned as an orbital launch vehicle, but could be used for PTP services.

[37] Ralph, Eric, "SpaceX CEO Elon Musk wants to use Starships as Earth-to-Earth transports," *Teslarati.com* (May 30, 2019).

[38] Morganteen, Jeff and Andrea Miller, "Hypersonic weapons are the center of a new arms race between China, the US and Russia," *CNBC* (September 26, 2019); Isachenkov, Vladimir, "Putin crows as he oversees Russian hypersonic weapons test," *ABC News* (December 26, 2018); PTI, "China successfully tests first hypersonic aircraft that can carry nuclear warheads," *The Times of India* (August 6, 2018).

[39] *Point-to-Point Commercial Space Transportation in National Aviation System Final Report*, prepared by Volpe National Transportation Systems Center, U.S. DOT for FAA AST (2010).

microgravity, using planes and balloons. These types of services could be supported at CASP, but challenges due to proximity to Denver International Airport and the shelf of Class B airspace directly above.

Less challenging from a launch and airspace perspective is the complementary capability to support astronaut and space participant training on site. It could be modeled after the National Aerospace Training and Research (NASTAR) Center in Pennsylvania, which offers suborbital flight training and has trained over 700 future spaceflight participants.[40]

The influence of orbital human spaceflight on suborbital space tourism will likely be significant. Recent developments, like the SpaceX Demo-2 mission to the ISS, a flurry of contracts related to commercial human spaceflight, and NASA's Artemis Program to send astronauts to the Moon are examples of this potential influence.

As of the publication of this report, 562 individuals have entered orbit 1,333 times since Yuri Gagarin's historic spaceflight in 1961. In comparison, only 17 individuals have flown missions aboard suborbital vehicles.[41] Less than 2% of the 579 total individuals that have flown into space did so without government funding..[42] The last private spaceflight participant to visit the ISS was Guy Laliberté, who was delivered by a Russian Soyuz spacecraft in 2009, two years prior to the retirement of the Space Shuttle. All Soyuz missions to ISS since then have been for transporting essential personnel only. A resurgence in interest regarding the potential for orbital space tourism has emerged as development of commercial human spacecraft take place under NASA's Commercial Crew Program. The first of these vehicles to launch into orbit with a crew was the SpaceX Crew Dragon on May 30, 2020. Boeing's CST-100 *Starliner* is expected to follow suit with its first crewed flight 2021.

U.S.-based Axiom Space aims to develop a commercial space station that can be accessed using vehicles like the Crew Dragon and CST-100 *Starliner*.[43] The first step in this process will be a Crew Dragon mission to ISS purchased by Axiom Space in

[40] Interview, July 10, 2020.
[41] Based on an altitude of 100 km, the so-called Kármán line. Alan Shepard and Gus Grissom on Mercury-Redstone missions (1961); Robert White (1962), Joseph Walker (1963), Robert Rushworth (1963), Joe Engle (1965), John McKay (1965), William Dana (1966), William Knight (1967), and Michael Adams (1967) on X-15 missions; Mike Melvill and Brian Binnie on SpaceShipOne test flights (2004); and Mark Stucky (2018), Frederick Sturckow (2018), Dave Mackay (2019), Michael Masucci (2019), and Beth Moses (2019) on SpaceShipTwo test flights. The Soviet Union/Russia and China, the only other countries besides the United States capable of human spaceflight, never launched humans into suborbital trajectories.
[42] Those individuals are Anousheh Ansari, Brian Binnie, Richard Garriott, Guy Laliberté, Dave Mackay, Michael Masucci, Mike Melvill, Beth Moses, Gregory Olsen, Mark Shuttleworth, Charles Simonyi, Mark Stucky, Frederick Sturckow, and Dennis Tito.
[43] The Sierra Nevada Corp. is developing a cargo version of the Dream Chaser, leveraging a long development history for a crewed system, it is unclear if and when a crewed Dream Chaser will be produced and flown during the forecast period.

March 2020 for a flight in 2021.[44] Axiom, which was established in 2016, plans to develop a commercial module for installation on ISS. In 2020, NASA awarded Axiom a $140M contract to provide at least one habitable module that will attach to the *Harmony* module.[45] Meanwhile, Space Adventures, the company that brokered eight space tourist flights to ISS from 2001 to 2009, signed a contract with SpaceX in 2020 for a Crew Dragon mission carrying four spaceflight participants during the next two years.[46] Space Adventures also signed two contracts with RSC Energia for tourist flights to ISS in 2021 and 2022, with the latter flight including the first commercial spacewalk.[47] In March 2013, Space Adventures brokered the first contract for a commercial flight around the Moon, though the $150M deal was ultimately canceled. The individual who would have made the flight, Australian Harold McPike, had undertaken expeditions to the North and South poles and scaled many mountain peaks including Mt. Kilimanjaro. He had wanted to add space travel to his list of adventures before backing out of the deal with Space Adventures, believing the company did not have the capacity to fulfill its obligations under terms of the contract.[48]

Finally, NASA has been developing the Artemis Program, consisting of the Space Launch System (SLS), the Orion crew spacecraft it will carry, and a plan to land astronauts on the Moon by 2024. Within a very tight timeline, NASA has teamed with a variety of companies, including Boeing, Lockheed Martin, SpaceX, Blue Origin, and many others, to develop the necessary hardware not just to land on the Moon, but establish a permanent presence there.[49]

Space-Related Terrestrial Research Platforms

Space-related research is conducted using airplanes or uncrewed aerial systems with attached sensors and instruments, parabolic flights, balloons, sounding rockets, and orbital platforms like the ISS (Table 5). Suborbital RLVs can provide the benefits of most of these existing platforms, with the advantage that they bring together the microgravity duration of a sounding rocket, the potential to include a principle investigator on the flight, the repeated flight campaigns characteristic of airplanes, and a competitive price as the market matures.

[44] O'Callaghan, Jonathan, "Axiom Space Signs Deal With SpaceX To Launch Private Astronauts To The ISS In 2021," *Forbes* (June 17, 2020).
[45] Northon, Karen, "NASA Selects First Commercial Destination Module for International Space Station," NASA press release (June 12, 2020).
[46] Sheetz, Michael, "SpaceX signs deal to fly 4 space tourists around Earth in about two years," *CNBC* (February 18, 2020).
[47] Foust, Jeff, "Space Adventures signs contract for Soyuz flight with spacewalk option," *SpaceNews* (June 25, 2020).
[48] https://www.casemine.com/judgement/us/5a1e85f8add7b05e8ebd9014.
[49] NASA's Plan for Sustained Lunar Exploration and Development, NASA document (2020). https://www.nasa.gov/sites/default/files/atoms/files/a_sustained_lunar_presence_nspc_report4220final.pdf.

Alternative Platform	Research Flights	Parabolic Flights	Balloons	Suborbital RLVs	Sounding Rockets	Orbital Platforms
Description	Airplanes with attached sensors and scientific instruments	Flying passenger jets in arcs to simulate microgravity	Large balloon that flies ~3-4 times as high as a commercial airplane	Jet- or rocket-powered vehicle enters space for brief period, capable of multiple flights per day	Rocket takes experiments tens to hundreds of km above Earth	Experiments conducted aboard ISS or other orbital platform
Microgravity experience	No microgravity	Short bursts of microgravity (~30 seconds) during the flight; ~10 minutes total	A few hours to 60+ days in upper atmosphere; can simulate microgravity only on descent	4-5 minutes	5-20 minutes	Days to years in microgravity
Cost per experiment	$5,000+	$5,000+	$1,500+	$100,000+	~$1M+ per vehicle	$15,000+ (governments subsidize cost of flight to ISS)

Table 5. Comparison of alternative space-related experiment platforms. *Source: Bryce Space and Technology.*

For atmospheric research, suborbital astronomy, and human research, suborbital RLVs provide unique capabilities that are better than existing platforms and enable specific research activities that cannot be conducted using (or that perform poorly on) current platforms. For microgravity research, suborbital RLVs provide a unique combination of capabilities with the potential to energize the research community and enable new research by attracting new organizations to microgravity research. For example, a doctoral thesis requiring microgravity research is more likely to be pursued with suborbital RLVs available because the timeline is shorter and the costs are much lower compared to using the ISS or some other orbital platform.

3.1.2 Spaceport Support and Infrastructure for Suborbital RLVs

This section is divided into two parts: 1) a description of peer spaceports, and 2) an overview of support services offered by spaceports. For the purposes of this section, launch complexes such as Kennedy Space Center and Vandenberg Air Force Base are not considered. Similarly, private spaceports, such as Blue Origin's Corn Ranch launch and landing site for New Shepard, are omitted.

Description of Peer Spaceports

The following is a review of the roles and capabilities of peer U.S. spaceports. For purposes of this report, a peer U.S. spaceport has the capability to support horizontal launch and landing of Concept X, Y, or Z vehicles and is licensed by the FAA to conduct commercial operations.

There are 12 commercial spaceports in the United States, two of which are co-located with federal launch sites. Of these, nine are licensed by the FAA to support horizontal launch, reentry, and landing of suborbital RLVs. These are listed in Table 6 below:

Operator	Site	Co-located with Federal Site	State	License Expiration	Licensed Horizontal Takeoff/Horizontal Landing (HTHL) Capability	CASP Peer Spaceport
Space Florida	Cape Canaveral Air Force Station	Y	FL	July 1, 2025	N	N
Houston Airport System	Ellington Airport	N	TX	June 26, 2025	Y	Y
Titusville-Cocoa Airport Authority (TCAA)	Space Coast Regional Airport	N	FL	May 5, 2025	Y	Y
Jacksonville Aviation Authority	Cecil Spaceport	N	FL	Jan 10, 2025	Y	Y
Midland International Airport	Midland International Air and Space Port	N	TX	Sep 14, 2024	Y	Y
Mojave Air & Space Port	Mojave Air & Space Port	N	CA	Jun 16, 2024	Y	Y
New Mexico Spaceflight Authority	Spaceport America	N	NM	Dec 14, 2023	Y	Y
Space Florida	Cape Canaveral Spaceport/Launch and Landing Facility	Y	FL	Nov 7, 2023	Y	Y
Alaska Aerospace Development Corporation	Pacific Spaceport Complex – Alaska	N	AK	Sep 23, 2023	N	N
Adams County	Colorado Air and Space Port	N	CO	Aug 16, 2023	Y	--
Virginia Commercial Space Flight Authority	Mid-Atlantic Regional Spaceport/Wallops Flight Facility	Y	VA	Dec 18, 2022	N	N
Oklahoma Space Industry Development Authority	Oklahoma Air and Space Port	N	OK	June 11, 2021	Y	Y

Table 6. FAA-licensed spaceports. *Source: FAA AST.*

This section will focus on the roles and capabilities of peer spaceports: those that complement or compete with CASP. Cape Canaveral Air Force Station (CCAFS), Pacific Spaceport Complex - Alaska, and Wallops Flight Facility (WFF) are omitted due to their focus on vertical launch and government customers.

Cape Canaveral Spaceport/Launch and Landing Facility, FL

Co-located with CCAFS and Kennedy Space Center (KSC), the Cape Canaveral Spaceport includes a horizontal launch facility at the former Shuttle Landing Facility (SLF). Space Florida holds a license to operate a launch site and manages and operates the facility under a 30-year lease from KSC, enabling private companies to use the 15,000-foot (4,572-meter) runway.[50]

Since its spaceport license was awarded in December 2018,[51] the designated Launch and Landing Facility (LLF) has yet to support commercial space operations. Space Florida is mainly targeting Concept Z vehicles and air-launched suborbital systems; however, the site has also been designated a preferred reentry site for (SNC's) Nevada Corporation's Dream Chaser Cargo System. The runway has had some commercial customers, however, with revenue going to Space Florida. For example, Zero Gravity Corporation, which offers parabolic microgravity gravity flights, flies out of the LLF.[52] FedEx planes also use the facility, as a close partner of Space Florida.[53] The Air Force's X-37B vehicle lands at LLF following its long-term orbital missions. It is then transported to a dedicated orbiter processing facility located nearby.

Cecil Spaceport, FL

Located 20 miles inland from Jacksonville, Cecil Spaceport is a former military airport that is today used primarily for cargo and other non-passenger flights. Since their FAA spaceport license was issued more than a decade ago, local development groups led by the Jacksonville Aviation Authority have aimed to attract suborbital and orbital launches.[54] Due to Cecil Spaceport's suburban and inland location, it is only licensed to support horizontal launch.

As Cecil Spaceport is co-located with Cecil Airport, it has the capability to support a wide variety of services. The longest runway is 12,503 feet (3,811 meters) long, and

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[50] The agreement for the more than 3-mile long runway was signed in 2015, expiring 2045. It was motivated in part by the end of the Space Shuttle program in 2011, leaving NASA with little use for the Shuttle Landing Facility. https://www.nasa.gov/press-release/nasa-signs-agreement-with-space-florida-to-operate-historic-landing-facility-1/.

[51] License can be found here: https://www.faa.gov/about/office_org/headquarters_offices/ast/licenses_permits/media/SF%20SLF%20License%20LSO%2018-018_Nov_08_2018.pdf.

[52] This agreement predates the Space Florida lease on the SLF, but has continued. https://www.nasa.gov/centers/kennedy/news/releases/2005/release-20051031.html.

[53] https://www.nasa.gov/centers/kennedy/news/nascartesting.html.

[54] License can be found here: https://www.faa.gov/about/office_org/headquarters_offices/ast/licenses_permits/media/JAA%20License%20LSO%2009-012%20renewal_01_09_2020.pdf

there are numerous hangers and outbuildings available for rent. More than half of the air traffic at Cecil is military, but many commercial transportation companies operate through the airport as well.[55]

Cecil Spaceport is still waiting to host its first launch. One of its customers, Generation Orbit, had scheduled the first launch of its Concept Z hypersonic testbed rocket for "early 2020".[56] Another customer, Aevum, anticipated launching its orbital Concept X vehicle from Cecil in the third quarter of 2021.[57]

Houston Spaceport, TX

While the aerospace industry has ties to Houston that predate NASA, the spaceport at Ellington Airport is a much more recent development. The spaceport obtained its launch site operator license in 2015 and has since embarked a series of infrastructure development activities.

Located in the southeast of Houston, Ellington Airport does not support passenger flights, and has only limited commercial cargo flights. NASA's administrative, cargo, and training aircraft are based at the facility, including their T-38 Talon jets and parabolic-flight aircraft. The airport's longest runway is 9,001 feet (2,744 meters) long, and there are numerous hangers and outbuildings available for rent.

Houston Spaceport has not, so far, focused on finding clients interested in launching from its facility. Rather, spaceport officials have focused on building a "space business park", which has involved improving existing infrastructure and installing new roads, fiber optics, and ground equipment. Phase 1 of the space business park's construction broke ground in June 2019.[58] Houston purchased a dormant Boeing facility (Houston Product Support Center), renaming it the Houston Aerospace Support Center (HASC), and completed construction of a new air traffic control

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[55] All information on runway length, aircraft operations, and airspace usage is publicly available through FAA Form 5010.

[56] Generation Orbit has targeted their first launch for late 2019 and January 2020; there is no public indication of a newly scheduled launch date. Generation Orbit has a wide range of potential launch options, including hypersonic, suborbital, and orbital vehicles. They have also tested extensively at Cecil, and plan to continue testing there after their first launch. https://generationorbit.com/generation-orbit-completes-hot-fire-test-of-go1-hypersonic-testbed-prototype-at-cecil-spaceport/ https://news.wjct.org/post/following-delays-generation-orbit-expected-be-first-cecil-spaceport-launch-customer.

[57] Aevum's launch architecture is not publicly available, although they have won numerous launch contracts for small satellites, including from government customers. Their architecture does involve an aerojet first stage. https://www.bizjournals.com/jacksonville/news/2019/09/18/cecil-spaceport-moves-one-step-closer-to-space.html.

[58] The scope of Phase 1 includes "streets, water, wastewater, electrical power and distribution, fiber optics and communications facilities" and "the construction of 53,000 square feet of lab and office space". The license can be found here: https://www.faa.gov/about/office_org/headquarters_offices/ast/licenses_permits/media/HAS_LSOL_June2020.pdf https://www.bizjournals.com/houston/news/2019/06/27/houston-airport-system-to-break-ground-on.html.

tower with an aerospace mission control room. The first aerospace company to sign on as a tenant was Houston-based Intuitive Machines (setting up in the HASC), which is developing a lunar lander as well as high-altitude autonomous drones. While no launch companies are scheduled to launch at Houston Spaceport, some orbital vehicles, including SNC's Dream Chaser, could use its runways to land.[59]

Midland International Air and Space Port, TX

In September 2014, the FAA issued Midland International Airport its spaceport license, a first for an airport with regular commercial air service.[60] Midland is closely connected to parts of the aerospace industry, as well as nearby universities with active aerospace projects. Relative to other licensed spaceports, Midland is an active commercial airport, with a daily average of 26 commercial passenger flights on major airlines. Its longest runway is 9,501 feet (2,896 meters) long, and there is a nearby Space Port Business Park with office and manufacturing space available.

Midland's first space tenants were XCOR Aerospace, a propulsion and spaceflight company developing the Lynx suborbital RLV, and Orbital Outfitters, a spacesuit maker. While Lynx was being developed at Mojave Air and Space Port and all future flights were going to remain there, the company planned to move its development and manufacturing division to Midland. XCOR in 2016 laid off much of its staff, and in 2017 filed for Chapter 7 bankruptcy.[61] In addition, Midland developed the Midland Altitude Chamber Complex for Orbital Outfitters, but the company ultimately shut down shortly thereafter. Today, Midland Air and Space Port's only aerospace companies are satellite manufacturers. The largest is Avellan Space Technology & Science, a microsatellite manufacturer, which announced its intention to invest more than $30M in a new 85,000-square-foot (7,897-square-meter) manufacturing facility at the spaceport business park.[62]

Mojave Air and Space Port, CA

Located north of Los Angeles, Mojave Air and Space Port is the most active horizontal launch spaceport in the U.S. Due to its proximity to Edwards Air Force Base, Mojave is a popular destination for air racing and flight testing. There is a substantial area of unrestricted airspace and a large supersonic corridor.

Mojave is tailored for many aerospace activities. Its longest runway is 12,503 feet (3,811 meters) long, able to accommodate the largest cargo planes. Mojave also has dozens of hangars, test sites, and office/storage facilities available for rent.[63] The

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[59] A list of tenants and partners is available on Houston Spaceport's website: https://www.fly2houston.com/spaceport/community/

[60] License is available here: https://www.faa.gov/about/office_org/headquarters_offices/ast/licenses_permits/media/Midland%20License%20LSO%2014-015%20renewal_09_12_2019.pdf.

[61] https://spacenews.com/xcor-aerospace-files-for-bankruptcy/.

[62] https://spacenews.com/astscience-midland/.

[63] Details on available real estate are available from Mojave's website https://www.mojaveairport.com/business--leasing.html.

test sites include engine test stands and environmental testing. Due to Mojave's use as an aircraft boneyard, there are substantial scrap and manufacturing facilities available. While today only licensed for horizontal launch, Mojave has supported suborbital vertical launch in the past, including vertical takeoff-vertical landing vehicle testing.

Many launch companies have taken advantage of these accommodations. Mojave was a popular test site for several teams participating in the Ansari X Prize, most famously Scaled Composite's Concept Z SpaceShipOne, which successfully conducted the first privately funded suborbital spaceflight in June 2004 (just days after Mojave was licensed as a spaceport by the FAA).[64] Virgin Galactic's descendent vehicle, SpaceShipTwo, is being tested at Mojave prior to full operations at Spaceport America (see below). Virgin Galactic's sister company, Virgin Orbit, also tests at Mojave and plans at least the first four launches of its air-launched, orbital LauncherOne from there. Other horizontal launchers that have tested or operated out of Mojave include Stratolaunch, XCOR (bankrupt in 2017), and Orbital Sciences Corporation (purchased by Northrop Grumman in 2018).[65] Mojave also hosts non-horizontal launch companies: several vertical launch companies have tested at the site, including Masten Space Systems and InterOrbital Systems.[66]

Oklahoma Air and Space Port, OK

Operated by the Oklahoma Space Industry Development Authority (OSIDA), Oklahoma Air and Space Port is largely inactive as a spaceport today. Located at the Clinton-Sherman Airport, a former military base, the facility has one of the longest runways in the U.S. at 13,504 feet (4,116 meters). Airlines and large-body aerospace manufacturers use this runway due to its size and lack of obstructions at either end: Boeing is testing its 777 model and recertifying its 737-MAX at Clinton-Sherman. OSIDA's revenue comes almost entirely from a multi-million-dollar contract with the Department of Defense that allows military use of the runway; more than 95% of the traffic through the airfield is military.

The last space-related operations at the spaceport were more than a decade ago.[67] Rocketplane Kistler, and later Rocketplane Global, tested and operated from

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[64] License can be found here: https://www.faa.gov/about/office_org/headquarters_offices/ast/licenses_permits/media/Mojave%20Air%20&%20Space%20Port%20LSO%2004-009%20(Rev6).pdf.

[65] https://www.airspacemag.com/space/the-mojave-launch-lab-442836/.

[66] https://web.archive.org/web/20150218055359/http://www.kerngoldenempire.com/specialreports/story/d/story/kget-special-report-mojave-air-and-spaceport/84740/3hrM3k6tfEyhH0EWMVkSIw.

[67] OSIDA was founded in 2006. They argue that the Oklahoma Air and Space Port is particularly important as it is the only licensed space corridor that lies outside military-controlled airspace. https://okcfox.com/news/fox-25-investigates/twenty-years-in-was-oklahomas-space-investment-worth-it.

Oklahoma until its bankruptcy in 2010.[68] Armadillo Aerospace tested both vertical and horizontal launch systems, including efforts aimed at the Ansari X Prize.[69] Today, OSIDA is negotiating with at least two undisclosed aerospace tenants to operate at the Oklahoma Air and Space Port.

Spaceport America, NM

Self-advertised as "the world's first purpose-built commercial spaceport," Spaceport America (SA) has a wide range of operations and tenants, due in large part to the effective advocacy of the New Mexico Spaceport Authority. Since receiving its spaceport license in December 2008, SA has become a premier destination for amateur, early stage, and mature launch testing and operations, despite its remote location.

Much of the facility is used by Virgin Galactic: while it continues to test its Concept Z SpaceShipTwo operations from Mojave in California, Virgin Galactic will operate its commercial passenger suborbital flights from Spaceport America. Virgin Galactic has invested substantial amounts in facilities at SA, most famously its Gateway to Space hangar and customer building. Other operators from Spaceport America include:

- UP Aerospace – Vertical takeoff sounding rockets
- Armadillo Aerospace – Vertical takeoff suborbital rockets
- Exos Aerospace – Vertical takeoff suborbital rockets
- SpinLaunch – centrifugally accelerated orbital launch
- Boeing – CST-100 *Starliner* crewed vehicle testing
- TMD Defense and Space – propulsion testing

Past operators have included:

- SpaceX – reusable vehicle development; SpaceX retains rights to operate from SA in the future
- Google – high-altitude solar powered drones and Internet balloons
- X Prize Foundation – Early in development, SA was expected to hold frequent suborbital launch competitions

SA has a single runway with a length of 12,001 feet (3,658 meters), numerous terminals, hangars, and manufacturing facilities. Many tenants bring temporary structures or build their own facilities upon arrival for testing or operations. As SA is adjacent to White Sands Missile Range, there is substantial unrestricted airspace in the area, although launches at SA have been postponed due to conflicts with White Sands activities.

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[68] Kistler also planned a vertical takeoff, vertical landing vehicle called the K-1 which would have required a coastal launch site. https://web.archive.org/web/20060212231745/http://kistleraerospace.com/newsinfo/publications/vehiclestatus083104.pdfhttp://www.newspacejournal.com/2010/07/07/farewell-rocketplane/.

[69] https://www.flightglobal.com/armadillo-aerospace-rocket-engine-flies/82596.article http://commercialspace.pbworks.com/f/Armadillo.pdf.

Space Coast Regional Airport, FL

The closest commercial airport to Kennedy Space Center, Space Coast Regional Airport, received its FAA spaceport license in May 2020. The application was proposed by the Titusville-Cocoa Airport Authority (TCAA), and sought to launch Concept X, Y, and Z vehicles.[70] Its runway is 7,320 feet (2,231 meters) long, less than half the length of the LLF, which is just eight miles away. TCAA proposed to build a large manufacturing facility and hangar, along with fueling and other infrastructure, specifically for suborbital RLVs.[71]

Although the airport is located close to a large and thriving aerospace industry, including Boeing's space headquarters, it is unclear what benefits it would offer over alternative spaceport options in Florida beyond being "outside the fence" of federal launch sites.[72]

Overview of Support Services Offered by Spaceports

As detailed above, the level of support services differs greatly between spaceports and between spaceport tenants. This is due in part to what the FAA requires from spaceport operators, and in part due to customer preferences.

The process for procuring a spaceport license from FAA AST focuses on safety to the uninvolved public, environmental impacts, safe handling of propellants, and spaceport security.[73] Most crucially, spaceports, like airports, are responsible for safe operations within their airspace. In most cases, U.S. spaceports are co-located with airports or landing strips. Flight control operations for aircraft and spacecraft are handled by the airport operator, as licensed by the FAA, or by the appropriate government agency (for example, the Air Force in the case of CCAFS). Tenants are expected to inform the spaceport operator well in advance of any tests and airborne operations, and spaceport officials contribute to launch control, particularly range operations.[74]

On top of these required services, as part of their business models, spaceports offer tiers of support services to customers. The less active spaceports, such as Houston

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[70] License is available here: https://www.faa.gov/about/office_org/headquarters_offices/ast/licenses_permits/media/Final_TIX%20License_Apr%202020.pdf

[71] https://spacenews.com/florida-airport-seeks-spaceport-license/

[72] https://spacenews.com/faa-establishes-spaceport-office-to-support-growing-number-of-launch-sites/ https://www.thespacereview.com/article/3846/1

[73] For details on the requirements to obtain a launch site operator license, see 14 CFR 420. For details on the requirements to obtain a reentry site operator license, see 14 CFR 433. https://www.ecfr.gov/cgi-bin/text-idx?SID=51287235c5ccd353a97ac56f8a8e023f&mc=true&node=pt14.4.420&rgn=div5 https://www.ecfr.gov/cgi-bin/text-idx?SID=51287235c5ccd353a97ac56f8a8e023f&mc=true&node=pt14.4.433&rgn=div5

[74] Some spaceport tenants at Mojave and Spaceport America have attempted to minimize spaceport involvement in mission control due to intellectual property concerns. This is rare, however, due to close relationships between spaceport operators and their tenants.

Spaceport and Oklahoma Air and Space Port, operate as business parks.[75] The stated goal is to incentivize aerospace companies to move to and conduct business in the areas surrounding the spaceport. Many of the services offered at these spaceports are focused on infrastructure, including aircraft rescue and firefighting, office space, hangar infrastructure, access control, utilities, government liaison services, and public transportation.[76]

Other spaceports see substantially more launch activity and offer different services to different customers. At Spaceport America, for instance, some tenants choose to outsource more services to spaceport itself, such as facility maintenance, marketing, and engineering support. Other tenants prefer spaceport staff to remain distant from their operations, signing strict non-disclosure agreements and only interfacing with spaceport authorities for safety reviews and launch permits. For these clients, spaceports only provide runway access, land, and occasionally empty real estate. In almost all cases, spaceport tenants operate their own vehicle integration facilities, payload processing facilities, and propellant handling.

While some of the peer spaceports have supported occasional vertical launches in the past (notably Mojave and Spaceport America), all have focused on horizontal launch in their business development and marketing. It is common for these spaceports to advertise their runway lengths, as some suborbital RLVs require long runways for takeoff and landing. Nationally, this focus on horizontal launch has been motivated by a) substantial pre-existing horizontal launch infrastructure (i.e., runways), and b) the anticipated lower marginal cost of horizontal launch because suborbital RLVs are operationally similar to conventional aircraft. This is well-illustrated by the geographic distribution of commercial spaceports: while some have opted for remote locations, almost all peer spaceports are located near populated areas, making vertical orbital launch difficult.[77]

[75] These spaceports have chosen not to build their business cases around operations, but focus on attracting early-stage aerospace companies to their areas. Houston Spaceport especially has focused on not just launch companies, also bringing in UAV and satellite manufacturers, as well as building aviation training facilities. https://spacenews.com/commercial-spaceports-increase-focus-on-economic-development/
[76] Utility and infrastructure expansion is particularly relevant for local and state government authorities. As the above spaceport authorities are operated by governments agencies, they are often able to compete by making their spaceports more attractive through governmental programs.
[77] The exceptions are Cape Canaveral and Kodiak Launch Complex, both of which predate the Ansari X Prize-inspired push for horizontally launched SRVs.

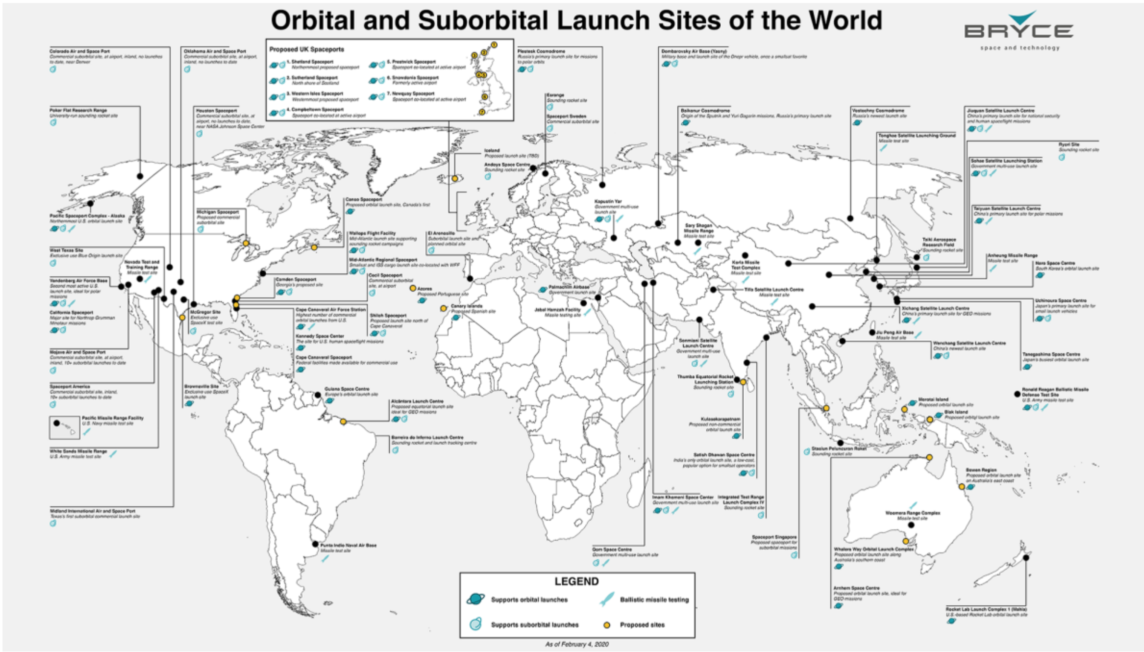

Figure 1. Orbital and suborbital launch sites of the world, including major ballistic missile sites. *Source: Bryce Space and Technology.*

3.1.3 Suborbital RLV Manufacturing Techniques Designed to Reduce Costs

Simplicity of Design

Reducing the number of parts is an obvious means to reducing the cost of a flight system. It translates into less hardware costs, but also facilitates more efficient maintenance for a reusable system and reduces the number of potential failure points.

The Spaceship Company, owned by Virgin Galactic, reduced the complexity of its launch system by using the same crew cabin and cockpit in both WhiteKnightTwo (the carrier aircraft) and SpaceShipTwo (the spacecraft). This approach allowed crew to simplify the manufacturing process, streamline maintenance, and provide a potential training platform for both spacecraft pilots and passengers.

Composites

Composites were introduced into aircraft manufacturing since shortly after the invention of the airplane, with birch impregnated with phenolic resin and fiberglass in the 1960s. Carbon composites have been used in aircraft manufacturing since the mid-1970s with aircraft like the F-14. The use of composites in rockets also dates back to the mid-1970s, with reinforced carbon-carbon being employed in rocket nozzles and the thermal protective system of the Space Shuttle.

Simplicity, resistance to corrosion, ability to be formed into complex shapes, low weight, and incredible strength made composites attractive for use in aircraft and spacecraft. Drawbacks are difficulty in using composites to contain cryogenic propellants, susceptibility to moisture penetration, and cost of raw materials compared to common metal alloys.

Founded in 1982 by Burt Rutan, California-based Scaled Composites, now owned by Northrop Grumman, became known for its innovative use of composite materials in the manufacture of unique aircraft and spacecraft. While Scaled Composites was not the first to employ composites in aerospace, it popularized the practice. It built the White Knight and SpaceShipOne combination that won the Ansari X Prize in 2004 and became the basis for WhiteKnightTwo-SpaceShipTwo development during the nearly two decades since. The company started as a kit plane manufacturer notable for the composite *VariEze* aircraft conceived by Rutan in 1975. That characteristic carried through in the DNA of vehicles that followed like *Long-EZ*, *Voyager*, the first aircraft to fly around the world non-stop in 1986, and *Global Flier*, which made the first solo non-stop, non-refueled flight around the world, and SpaceShipOne and SpaceShipTwo, both spacecraft with structures entirely made of composite materials.

Rocket makers Rocket Lab and Orbex use composites as the primary material for structures. Rocket Lab uses composites for all of the structures on its Electron vehicle, a choice in part driven by a desire to speed up manufacturing in order to keep pace with anticipated manufacturing throughput of 50 vehicles per year.[78] Orbex's Prime vehicle, which carries 331 pounds (150 kilograms) to a Sun-synchronous orbit and is expected to launch for the first time in 2022, has a mass of 3,307 pounds (1,500 kilograms), about 30% less than if the vehicle were made of conventional metal alloys typically used.[79] SNC's *Dream Chaser* features a composite high-temperature pressurized airframe that will be covered in a thermal protection system. SNC is using composites because the material decreases the amount of thermal protection required compared to an aluminum primary structure and is less expensive. The woven construction also minimizes damage to the hot lower aeroshell during reentry.[80] The first *Dream Chaser* is scheduled to launch atop an Atlas V on a cargo mission to ISS in 2021.

Additive Manufacturing

Additive manufacturing (AM) is the fabrication of three-dimensional objects using a computer aided design (CAD) model fed into a printer or printers. The printing process involves fusing either liquid or powder feedstock using deposition or lasers. As material is added with precision layer by layer, any shape can be produced, including extremely complex forms. AM simplifies the design and manufacture of parts, allows for rapid prototyping, and reduces the need to outsource to other suppliers. This approach, in turn, reduces manufacturing and warehousing costs,

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[78] Greenaway, Slade, "Exclusive Inside Look at Rocket Lab's Previously Secret New Mega Factory," *Everyday Astronaut* (October 11, 2018).
[79] Hoodin, Kimberly, "Commercial Orbital Rocket Relying on Carbon Fiber and Aluminum Composites to Soar," *Composites Manufacturing* (February 21, 2020).
[80] "Dream Chaser Spacecraft Primary Structure Arrives in Colorado," SNC press release (October 15, 2019).

safeguards intellectual property, allows for stricter quality control, and reduces lead times. AM contrasts with traditional subtractive manufacturing, or machining, in which tools are used to carve out a part from a block of metal or other material. Along with molding and casting, many parts may be necessary to produce the whole component or subsystem in traditional manufacturing. AM components can be fabricated with little to no required assembly, reducing the number of parts needed and associated costs, while also enabling new assemblies and optimized designs. In addition, AM can be used to generate replacement parts on demand and on location, reducing maintenance costs and down time.

Originally used for rapid prototyping of parts not destined for use in operational hardware, AM was embraced by the space industry once it became clear the approach could produce aerospace quality parts. AM does not appear to be a major aspect to the production of suborbital RLVs, a situation that may change in the future. For example, Blue Origin's New Shepard is powered by the BE-3, a conventionally manufactured engine that may feature some AM parts in the future; whereas the BE-4, which will power the company's large New Glenn orbital launcher, will feature several critical AM parts. Virgin Galactic largely uses conventional manufacturing techniques for SpaceShipTwo and its carrier aircraft, while its sister company, Virgin Orbit, employs some AM in the production of the LauncherOne orbital launch vehicle.[81] As these companies evolve, AM techniques developed for orbital vehicles may transfer to the manufacturing and maintenance of these suborbital RLVs.

Relativity Space is perhaps the leader in the space industry when it comes to applying AM. Relativity builds its Terran-1 vehicle using the company's proprietary Stargate factory, an all-in-one platform that automates manufacturing by vertically integrating intelligent robotics, software, and data-driven AM technology. The company expects to be able to print 95% of the Terran-1 within 60 days using Stargate by the end of 2020, with first launch of the vehicle planned for 2021.[82]

Rocket Lab employs AM in the fabrication of the Rutherford engines that power its Electron vehicle. Each Electron uses 9 Rutherford engines for the first stage and a single Rutherford for the second stage. The 35-kg engine features a combustion chamber, injectors, pumps, and main propellant valves built using electron-beam melting. By the end of July, the company had launched 13 Electron vehicles, translating to 128 operational burns (the Electron's first stage uses 9 engines and one for the second stage; because 2 of the 13 launches ended in failure, two second stages were lost).[83]

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[81] Werner, Debra, "A peak inside Virgin Orbit's factory," *Aerospace America* (May 31, 2017).
[82] https://www.relativityspace.com/stargate.
[83] The Electron suffered two failures, both of which meant the second stage, powered by one Rutherford, didn't have a chance to burn.

Blue Origin appears to be investing in AM capabilities. As of August 2020, Blue Origin was recruiting for multiple AM-related positions based at its Kent, Wash., headquarters. This includes both engineers and a director of AM production. The position description lists the projects as "launch and space vehicle systems," which suggests this work is focused on the New Glenn orbital vehicle. AM techniques could be deployed at the New Glenn production and refurbishment facility near KSC, the vehicle's launch site. The ability to produce parts on location to meet refurbishment needs would reduce warehousing and logistics costs. While suborbital vehicles do not need the same rigorous refurbishment, Blue Origin might seek to develop similar capacities for New Shepherd to reduce costs and increase launch cadence.

Other manufacturers of spacecraft and space components have included use of AM. In 2019, ArianeGroup and the European Space Agency (ESA) conducted a successful hot fire test of the BERTA (Biergoler Raumttransportaengine) as part of the Ariane 6 launcher development effort. The engine was produced using a form of AM called selective laser melting (SLM), using a nickel-based alloy (for the engine injection head) and stainless steel (for the engine combustion chamber). BERTA is a means to demonstrate AM for engine manufacturing and will be the basis for scaling up to larger liquid rocket engines.[84]

SLM Solutions, a German AM company, fabricated a large liquid rocket engine as one piece for UK-based Orbex, though it has not yet been hot fire tested. Orbex is developing a dedicated smallsat launch vehicle called Prime that will be built using SLM, a process that is expected to produce a flight structure 30% lighter and 20% more efficient than a typical launch vehicle of its scale.[85]

In 2017, the Defense Advanced Research Projects Agency (DARPA) awarded Florida-based start-up Rocket Crafters a $542,600 research contract to develop its hybrid 3D printed rocket engine.[86] Using the company's proprietary Direct-Digital Advanced Rocket Technology (D-DART), Rocket Crafters developed AM-produced solid motor fuel grains and liquid propellants designed to power an engine capable of 22 kiloNewtons of thrust. The company completed 49 hot fire tests of its Comet solid motor in May 2020.[87]

AM is likely to play a very significant role in the space industry in the years ahead. This has implications for the space supply chain and represents a quality control

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[84] Jackson, Beau, "ESA Completes First Test Fire of ArianeGroup 3D Printed Rocket Engine," *3D Printing Industry* (February 25, 2019).
[85] "Orbex Builds World's Largest Single-Piece Rocket Engine 3D Printed on the SLV®800 Selective Laser Melting Machine," SLM Solutions press release (February 11, 2019).
[86] "DARPA Awards Rocket Crafters Contract to Design, Develop and Test Large-Scale Hybrid Rocket Engine," Rocket Crafters press release (July 25, 2017).
[87] Hanaphy, Paul, "Rocket Crafters Completes Testing of 3D Printed Comet Engine," *3D Printing Industry* (May 18, 2020).

challenge as inspection criteria and standards are developed for AM-produced aerospace hardware.

3.2 Industry Barriers

This subsection addresses barriers to entry to the suborbital tourism market and the suborbital research and technology demonstration market.

The barriers to entry into the suborbital tourism market are high. These include capital investment and economies of scale. To a lesser extent, other barriers are intellectual property, distribution channels, government policy, product differentiation, and customer demographics.

3.2.1 Technology

Development of a crewed suborbital RLV capable of carrying spaceflight participants is technically challenging, especially for companies without access to the substantial resources available to the U.S. government. This is evidenced by the fact that it has taken 17 years for Scaled Composites, then Virgin Galactic, to develop the Tier 1b system (SpaceShipTwo and its carrier aircraft), which is expected to become operational in 2021.[88] Blue Origin's New Shepard, derived from the New Goddard test vehicle (2006-2007), has taken about 13 years to develop and is also expected to become operational in 2021.

It is nevertheless unfair to compare these commercial systems with similar programs undertaken by the U.S. government during the late 1940s through the 1970s, when a variety of so-called X-planes frequently took to the sky. These programs were often supported by substantial budgets and infrastructure. Another aspect that challenges comparison with early X-planes is the unique mission being undertaken by Virgin Galactic and Blue Origin, which is to provide a unique but safe flight experience to paying customers. X-planes, in contrast, were designed to explore the limits of aeronautics and astronautics with test pilots in the cockpit. Because the systems were used in a flight regime involving significant unknowns, many X-planes presented dangers to the pilots, and indeed many were killed as a result.

A key challenge in spaceflight is the development of a reusable system that can be routinely flown and maintained in safe manner. This is because of stresses imparted on the vehicle during high-speed flight and the resulting heating of its surface areas. Based on published information, Virgin Galactic, Blue Origin, and others seem to have sufficiently addressed these challenges.

[88] Tier 1 consists of SpaceShipOne and its carrier aircraft, White Knight. SpaceShipOne was the vehicle used to win the Ansari X Prize in 2004. Tier 1b consists of SpaceShipTwo and its carrier aircraft, WhiteKnightTwo. At one point there was a Tier 2 involving an orbital launch and reentry system, but the status of this effort is unclear.

Another challenge is propulsion, since the high energies required involve risks associated with propellants. In 2007, Scaled Composites, then working on SpaceShipTwo, suffered a ground test accident when propellant exploded, killing three people.[89] Fortunately, no industrial accidents relating to suborbital RLV propulsion have apparently taken place since then.

SpaceShipTwo employs a unique flight configuration for the reentry phase of flight, leveraging experience with the successful SpaceShipOne test program. Called a "feather reentry system," the variable geometry allows a vehicle to increase drag and glide to a landing, a configuration only possible with the relatively low speeds involved. The National Advisory Committee for Aeronautics (NACA) proposed this approach for the first time in 1958, and it was subsequently used for the X-15. The tragic loss of Virgin Galactic's *VSS Enterprise* during a flight test in 2014 revealed how unforgiving spaceflight can be. In that incident, copilot Michael Alsbury was killed and pilot Peter Siebold was seriously injured following premature activation of the feather reentry system, resulting in loss of the vehicle. The National Transportation Safety Board (NTSB) identified lack of training, inadequate safety measures, and insufficient oversight by FAA as contributing factors.[90]

3.2.2 Capital Investment

The most significant barrier to entry is high capital investment. Suborbital RLVs require substantial investments in sophisticated hardware and software, significant testing, and a highly skilled workforce with specialized experience. By 2016, Virgin Galactic had spent an estimated $600M on development of SpaceShipTwo and its support infrastructure.[91] In July 2019, Virgin Galactic initiated a merger with Social Capital Hedosophia (SCH), an investment vehicle, raising several hundred million dollars of capital and allowing Virgin Galactic to become a publicly traded entity. SCH took on a 49% stake in Virgin Galactic at a valuation of $1.5B, with the CEO of SCH, Chamath Palihapitiya, investing an additional $100M.[92] Investors have continued to provide funding for start-up space ventures, including companies building suborbital and orbital launch vehicles; start-up space ventures attracted $5.7B in financing of all types in 2019 alone, a record year.[93]

3.2.3 Economies of Scale

At least in the near-term, economies of scale represent a barrier to suborbital tourism. The target market is expected to be relatively small initially, with modest growth in the years that follow. As the number of tickets and thus flights increase, the increased

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89 Whitcomb, Dan, "Three killed in blast at rocket site in Calif," *Reuters* (July 26, 2007).
90 https://www.ntsb.gov/investigations/AccidentReports/Reports/AAR1502.pdf.
91 Messier, Doug, "How Richard Branson Has Been Funding Virgin Galactic," *Parabolic Arc* (January 26, 2015).
92 Foust, Jeff, "Virgin Galactic to merge with investment company, go public," *SpaceNews* (July 9, 2020).
93 *Start-up Space: Update on Investment in Commercial Space Ventures*, Bryce Space and Technology (2020).

cadence may require the construction and maintenance of additional vehicles and attract further competition. This scenario should lead to a reduction in operating costs that translate into lower ticket prices. In 2019, Virgin Galactic CEO George Whitesides mentioned that the ticket price is likely to go up before ultimately dropping to $60,000 "in a few years" following the start of commercial services.[94]

A related barrier involves customer demographics and the distribution of high-net-worth individuals throughout the world who might want to fly aboard a suborbital RLV. It is unclear, for example, if Chinese citizens will be able to fly aboard U.S.-regulated spacecraft. In 2019, 10% of HNWI individuals hailed from China, placing it second to U.S. (40%) in the number of millionaires in the world, overtaking Japan's position. China's share of UHNW individuals is also substantial and growing, with 18,130 to the United States' 80,150.[95]

3.2.4 Government Policy

For research and technology demonstration missions aboard suborbital RLVs, U.S. government policy and regulation could impede growth of this market because there is no approval process from NASA or NSF regarding human tended research flights.[96] The opposite is true of suborbital tourism, as a moratorium exists regarding the regulation of commercial human spaceflight by the FAA until at least 2023 to allow for the market to accumulate data that can then be applied to the development of appropriate regulations.[97]

There is an apparent demand for suborbital RLV capabilities in Europe, but access to U.S. providers like Blue Origin and Virgin Galactic appears problematic. It is very difficult for European researchers to obtain direct funding because of push in France to use parabolic flights by a French provider and in the UK because all funds have historically gone to the ESA (a situation true of other ESA members with smaller space budgets). NASA's Research Opportunities in Space and Earth Science (ROSES) program has been successfully used by European researchers, typically in collaboration with U.S. academic institutions. In this program, the U.S. side provides space access and the European side brings the underlying science funding. This apparent need to secure two separate funding lines has been identified in interviews as a block to market growth.

3.2.5 Environmental Review

The environmental impacts for commercial spaceport development at airports mirrors the environmental impacts associated with traditional aviation operations and generally are related to on construction, noise, air quality, and propellant

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[94] Weitering, Hanneke, "Virgin Galactic May Raise the Ticket Price for SpaceShipTwo Again," *Space.com* (October 16, 2019).
[95] *Credit Suisse Global Wealth Report 2019*.
[96] Interview, March 28, 2019.
[97] Sheetz, Michael, "Shares of Virgin Galactic surge after announcement that it will train astronauts for NASA," *CNBC* (June 22, 2020).

handling. The barriers are generally a result of the review process and not so much a result of expected environmental impacts. The review process typically results in significant delays in spaceport development. Environmental reviews are designed to address categories identified in FAA Order 1050.1 and are based on detailed plans provided by the applicant. Other issues may emerge as activity grows and these must be addressed in turn.

Spaceflight is particularly notable for the noise it creates, from launch events to sonic booms during and following reentry to engine testing. Typically, spaceports and test centers are located an adequate distance to ameliorate acoustic disturbances that would otherwise impact population centers. Of course, changes in industrial activity can cause an increase in noise level. For example, Merlin liquid rocket engine testing conducted by SpaceX at its McGregor, Texas, site has produced noise levels disruptive to the community. Instead of potentially relocating or entering into a challenging legal battle, SpaceX has worked with the community to schedule tests during hours considered acceptable to those living relatively nearby.[98] Recognizing an opportunity to leverage existing federal assets, NASA's Stennis Space Center (SSC) is actively seeking tenants by advertising its acoustic buffer zone, among other attributes. The SSC buffer zone consists of 506 square kilometers of marsh and woodland once used to test the Saturn V's massive F-1 engines, including full hot fire tests of all five first-stage engines simulating a launch. For some companies, this buffer zone also provides adequate seclusion to conduct proprietary activity, an added benefit that emerged as NASA sought private sector and government tenants.

4 20-Year Commercial Suborbital Launch and Reentry Forecasts

4.1 Summary Forecast of Commercial Suborbital Launch and Orbital Reentry Activity

4.1.1 Methodology and Assumptions

Bryce used a research- and analysis-based approach to forecast 20-year demand for suborbital RLVs, using primary research and publicly available data to identify two markets likely to have appreciable growth over the forecast period: 1) suborbital tourism and 2) research and technology demonstration on suborbital flight.

Bryce established two ticket prices to execute the model: $250,000, which is the ticket price established for the first round of sales on commercially available Virgin Galactic flights; and $100,000, an aspirational target for the market within the

98 Copeland, Mike, "McGregor sets new limits on SpaceX rocket noise," *Waco Tribune-Herald* (May 11, 2016).

forecast period. Two scenarios, baseline and growth, for each ticket price were modeled, for a total of four forecasts. The baseline forecasts for both markets show a projection of demand for seats and seat equivalents for research and development payloads. For suborbital tourism, the growth forecast includes a larger and faster-growing population of HNWI who may be interested in suborbital flight. For suborbital research and technology demonstration, the growth forecast incorporates a larger and faster growth of demand for suborbital research payloads across all sectors.

For the suborbital tourism market, the size of two populations of individuals who would be willing to purchase tickets on suborbital flights are estimated: HNWI and space enthusiasts. The total population of HNWI consists of individuals having a net worth of more than $5M. This population was selected because, for them, the six-figure price tag currently on suborbital flights is not prohibitive. An estimate of price elasticity was applied to this population using data collected in a representative survey of HNWI preferences. Data collected through this multi-year survey include self-reported willingness-to-pay to participate in suborbital flight, highly ranking suborbital flight compared to other once-in-a-lifetime experiences, and stated likelihood of purchasing a seat on a suborbital flight. This estimate of price elasticity was used to estimate the number of HNWI interested in suborbital tourism and arrive at the total addressable HNWI population for the model.

A fly-out rate is applied to the addressable population to arrive at the number of individuals flying in a given year. This rate changes over time and resembles a technology adoption S-curve. The fly-out rate captures both the hesitancy to fly on unproven vehicles as well as some aspects of the limited supply of seats as vehicles first fly commercially during the early years of the forecast period. The result is that not all individuals who might want to fly in a given year take the opportunity to do so. It is also assumed that no individual would fly more than once over the 20-year period due to the high price tag and low level of supply.

In addition to the population of HNWI, there is a small population of "space enthusiasts." These individuals have a very high willingness to pay and would spend a larger share of their net worth than the average person to purchase a seat on a suborbital flight. Because of their strong desire to fly on suborbital RLVs, Bryce assumes that space enthusiasts are not as hesitant to fly on new vehicles as HNWIs, so all space enthusiasts projected to fly in a given year are expected to fly during that year.

Given the severity of the global economic and health crises caused by the COVID-19 pandemic, its impact is reflected generally in this forecast. The high degree of uncertainty regarding the ongoing situation makes it difficult to quantify the total impact on demand for suborbital tourism. The forecast includes a one-time reduction in the number of HNWI followed by a period of depressed growth for several years. Specific impacts of the pandemic on spending behaviors of HNWI, the population of space enthusiasts, and the development of suborbital RLVs were not evaluated in this forecast.

For the research and technology development market, Bryce estimated the number of experiments or technology demonstration missions that might take advantage of suborbital RLVs. The number of projected experiments was converted into the equivalent number of seats on a suborbital flight they would occupy as cargo lockers. This allows the estimates of the two markets to be combined and compared with similar units. Dedicated research flights requiring a unique flight path are considered to occupy the equivalent seats of an entire vehicle, regardless of how much volume the experiment itself might occupy. This market does not include test flights of vehicles as part of the development process; however, this report provides a perspective on test flights from CASP in the conclusion section (Page 63).

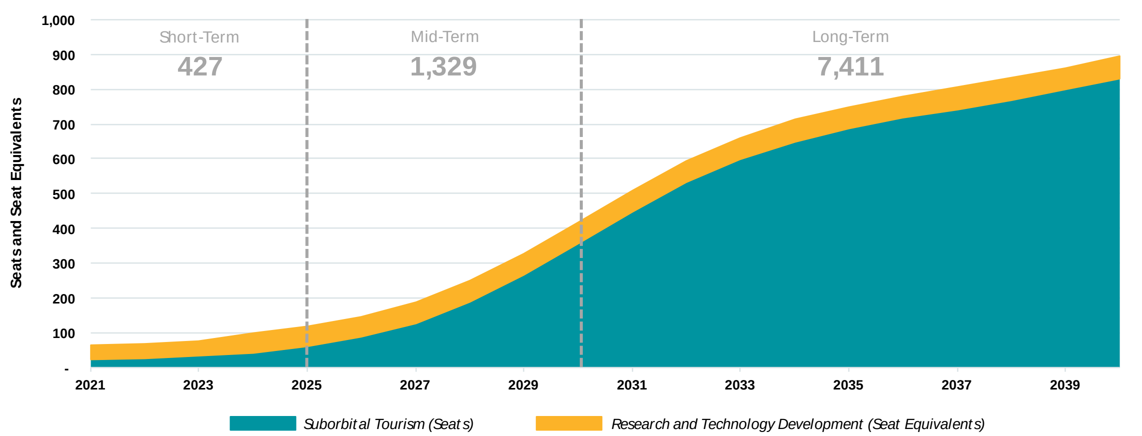
4.1.2 Results

The forecast results show that suborbital tourism is a much larger market than the suborbital research and technology market. There are differences in magnitude, however, and these are described for each of the scenarios and two different price points.

Baseline scenario $250K

For the baseline scenario at the $250,000 price point, the number of seats and seat equivalents remains relatively low during the period 2020 to 2025, and begins to increase substantially from 2026 through 2030, continuing to grow before leveling off by 2040. The total number of seats and seat equivalents during the forecast period is 9,167, with the following near-, mid-, and long-term breakout (Figure 2):

- Near-term (2020-2025): 427
- Mid-term (2026-2030): 1,329
- Long-term (2031-2040): 7,411



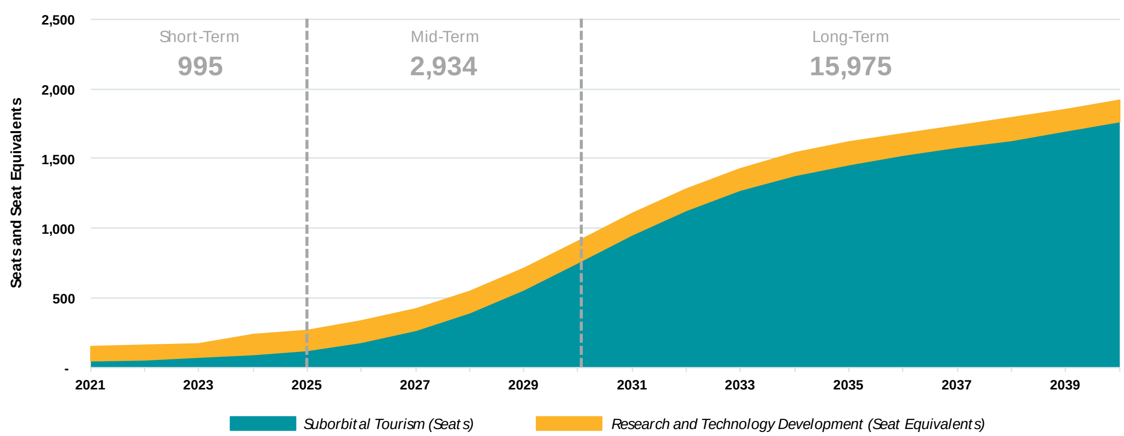
	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Tourist Seats	23	27	33	43	60	86	128	187	265	356	448	532	599	650	687	717	743	769	798	831
R&D Seat Equivalents	41	42	42	58	58	60	61	62	62	62	63	63	63	64	64	64	64	64	64	64

Figure 2. Number of seats and seat equivalents demanded, baseline scenario - $250K price point.
Source: Bryce Space and Technology.

Baseline scenario $100K

For the baseline scenario at the $100,000 price point, the number of seats and seat equivalents follows the same trend. As expected, the total number of seats and seat equivalents is higher than seen in the forecast for tickets at the $250,000 price point. The total number of seats and seat equivalents during the forecast period is 19,904, with the following near-, mid-, and long-term breakout (Figure 3):

- Near-term (2020-2025): 995
- Mid-term (2026-2030): 2,934
- Long-term (2031-2040): 15,975



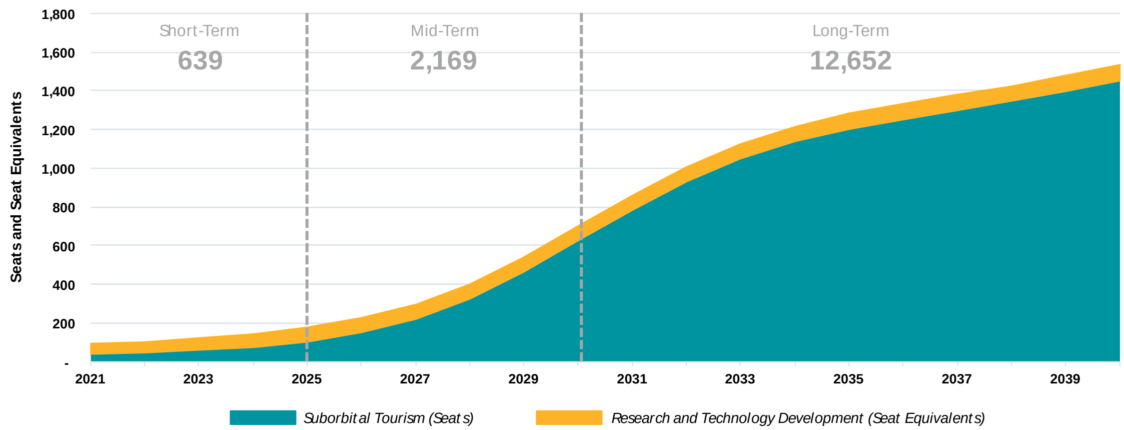
	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Tourist Seats	49	57	71	92	127	184	272	398	563	755	953	1,130	1,273	1,380	1,460	1,523	1,578	1,635	1,696	1,766
R&D Seat Equivalents	103	104	104	144	144	149	151	154	154	154	156	156	156	159	159	159	159	159	159	159

Figure 3. Number of seats and seat equivalents demanded, baseline scenario - $100K price point.
Source: Bryce Space and Technology.

Growth scenario $250K

For the growth scenario at the $250,000 price point the total number of seats and seat equivalents during the forecast period is 15,460, with the following near-, mid-, and long-term breakout (Figure 4):

- Near-term (2020-2025): 639
- Mid-term (2026-2030): 2,169
- Long-term (2031-2040): 12,652



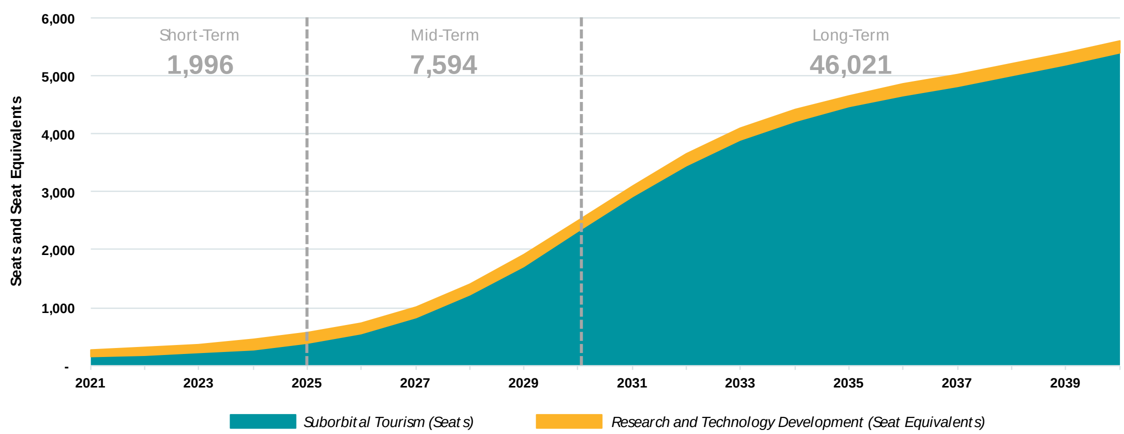
	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Tourist Seats	40	47	58	76	105	151	224	327	463	622	785	931	1,049	1,137	1,202	1,254	1,300	1,346	1,397	1,454
R&D Seat Equivalents	54	55	63	70	71	74	75	75	79	79	79	79	79	80	80	80	80	80	80	80

Figure 4. Number of seats and seat equivalents demanded, growth scenario - $250K price point.
Source: Bryce Space and Technology.

<u>Growth scenario $100K</u>

For the growth scenario at the $100,000 price point the total number of seats and seat equivalents during the forecast period is the highest of the projections at 55,611, with the following near-, mid-, and long-term breakout (Figure 5):

- Near-term (2020-2025): 1,996
- Mid-term (2026-2030): 7,594
- Long-term (2031-2040): 46,021



	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Tourist Seats	149	176	217	282	390	562	831	1,216	1,721	2,311	2,915	3,458	3,895	4,222	4,465	4,657	4,828	5,000	5,188	5,402
R&D Seat Equivalents	134	138	158	175	177	185	187	187	197	197	197	197	197	200	200	200	200	200	200	200

Figure 5. Number of seats and seat equivalents demanded, growth scenario - $100K price point.
Source: Bryce Space and Technology.

4.1.3 CASP Addressable Market

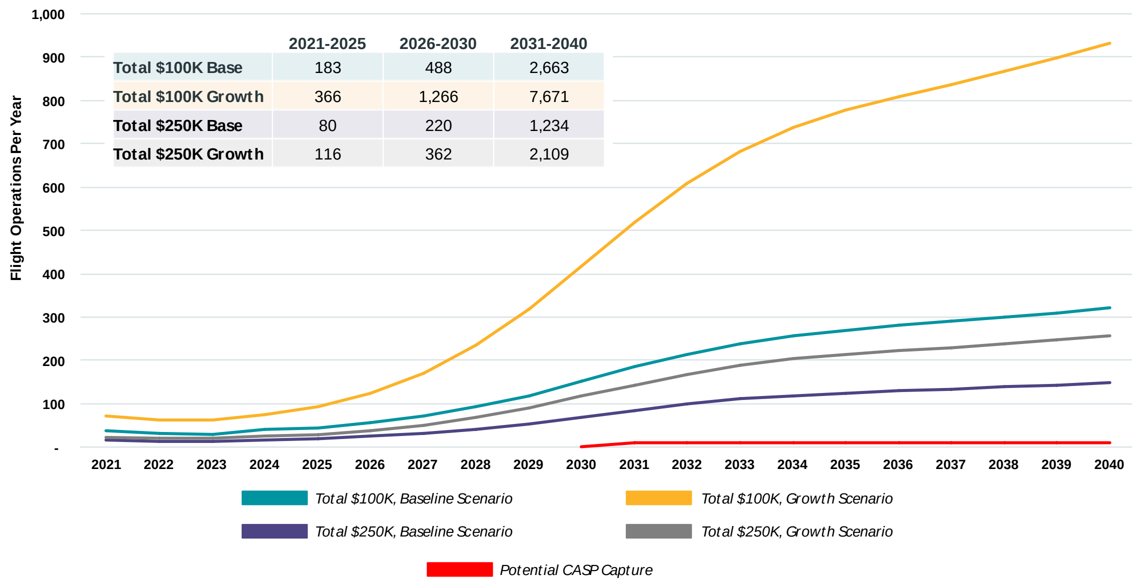
While the number of seats demanded is useful for estimating the overall size of the market for suborbital flights, the actual number of flight operations is more useful to spaceports seeking to service launch systems. The demand forecast of seats and seat equivalents on suborbital flights previously discussed will serve as a baseline for estimating the total amount of activity addressable by CASP. It is important to note that the demand forecast is launch system agnostic; vertical and horizontal launch systems are not considered differently by consumers in this model, and neither are the different Concept X, Y, and Z vehicles. While demand represented by the entire forecast is CASP-addressable, it is not realistic for one launch provider operating out of one spaceport to capture the entire market. Moreover, CASP will not accommodate vertically launched vehicles. This next step beyond the demand forecast aims to produce a reasonable estimate of the number of suborbital flights that could occur at CASP given expected market conditions.

Converting to Number of Flight Operations

As previously discussed, Virgin Galactic's SpaceShipTwo and Blue Origin's New Shepard systems are the only suborbital launch systems nearing commercial operation. Both vehicle systems support up to six passengers per flight. At full operation, this means the number of seats can be converted to a number of flight operations irrespective of the split in the market between providers. However, neither provider will have each flight at maximum capacity in the first years of operation. In investor filings with the SEC, Virgin Galactic indicated that in the first year of commercial operation flights would have only four passengers and that the number of passengers per flight would increase one per year until all flights were at the maximum capacity of six passengers in the third year of operation. Blue Origin has not publicly disclosed operational plans. However, its New Shepard vehicle does not have a pilot and the six-seat configuration includes all passengers. This unconventional design may make passengers uneasy and reduce the number of passengers per flight until the absence of a Blue Origin pilot or controller is normalized. Bryce assumes that any additional systems developed in the forecast period would have a similar configuration.

Without technical details or published business cases, it is not possible to determine when new vehicles will be introduced or how many flights such vehicles might make. In addition, precedent has established that development lead time for a suborbital RLV capable of carrying people is about ten years, making it unlikely these vehicles would enter commercial service until after 2040. Still, these vehicles would require test flights, which CASP could support with the appropriate license. Based on the number of glide and powered test flights conducted by Virgin Galactic, the only commercial HTHL suborbital RLV system ever developed, it can be assumed that an average of about ten test flight operations per year can be expected.

The estimated total number of flight operations per year is shown in Figure 6.



	2021-2025	2026-2030	2031-2040
Total $100K Base	183	488	2,663
Total $100K Growth	366	1,266	7,671
Total $250K Base	80	220	1,234
Total $250K Growth	116	362	2,109

Figure 6. Total number of flight operations per year by scenario and price point.
Source: Bryce Space and Technology and Kimley-Horn.

Factors Influencing the Vehicle Mix

For several reasons it is difficult to accurately predict the shares of suborbital flight operations that each type of vehicle will undertake. Vertical and horizontal vehicles do not have a strong distinction of service in themselves that will drive to demand to one form or the other. The division of demand will largely be driven by the differentiation of offerings between providers and the cost and availability of flight opportunities. Blue Origin is planning a vertical launch, vertical landing system and Virgin Galactic is planning a horizontal launch and horizontal landing, Concept Z-class system. Blue Origin's New Shepard will reach a higher altitude than Virgin Galactic's system, leading to a longer period of microgravity. Passengers will experience higher g-forces on the vertical launch system than the air-launched system.

Both Virgin Galactic and Blue Origin have repeatedly revised projections on their commencement of commercial operations. Original development timelines put the first commercial suborbital tourism flights as early as 2008. This historical inaccuracy makes it difficult to rely on current company projections for commercial service. Virgin Galactic has flown pilots and one passenger in previous test flights. The company has a backlog of over 600 paid spaceflight participants and an additional pool of over 700 customers with small down payments, representing over five years of backlog in all forecast scenarios. These two factors make Virgin Galactic the most likely to enter commercial service first, with operations likely to be the limiting factor in the first few years rather than demand.

As a privately owned company, Blue Origin has not disclosed much information about its intended pricing or operation. Rough estimates based on environmental assessments for the launch sites used by both companies, and current forecasts provided by Virgin Galactic as part of its SEC filings, indicate that initially the two providers will have close to even numbers of launches in the first year of commercial operation. Blue Origin has not established a price for service nor begun selling tickets for its future flights.

Over the period of 2020-2030, the proportion of flight operations between Virgin Galactic and Blue Origin is likely to change based on several related factors. The lack of historical information or accurate projections from both companies makes it too difficult to determine the overall effect of these factors with an acceptable degree of certainty. However, it is possible to determine the way they will influence the proportion of flights by these two providers. These factors include the target markets of the two companies, the overall experience, and the differences in the flight profiles of the two vehicles.

Virgin Galactic is targeting very HNWIs and is billing SpaceShipTwo as a luxury experience. It has indicated that ticket prices are likely to rise once commercial flights begin, sentiment that is mirrored in investor presentations that suggest there is additional room to raise prices without negatively impacting the number of reservations. In contrast, Blue Origin is positioning itself to target adventure tourists. Though no published information is available, this suggests a lower price point for seats on New Shepard compared to SpaceShipTwo. Over time, demand might shift towards one or the other depending on revealed consumer preferences, or one strategy may capture a larger portion of the population of HNWI. Blue Origin has not yet flown any astronauts or spaceflight participants but has flown more than 50 payloads and experiments for customers.[99]

Virgin Galactic's suborbital tourism experience includes corporate partnerships with Under Armour and Land Rover to provide space suits and transportation to the launch pad, respectively. Virgin Galactic anticipates its tourist launches taking place from its purpose-built facilities Spaceport America as a four-day experience from arrival to spaceflight. The experience with Blue Origin is expected to last two days from arrival at the site to spaceflight. Additionally, there are differences in the flight profiles of the two systems. SpaceShipTwo has a smoother flight with less acceleration on ascent than New Shepard, which hits 3Gs of acceleration on ascent. SpaceShipTwo glides to land on a runway, as opposed to the parachute landing of the New Shepard capsule.

The differences in the flight profiles are driven by the different technologies used and will likely evolve as those technologies continue to mature prior to and during commercial operations. SpaceShipTwo flies under its carrier aircraft for 90 minutes

[99] Clark, Stephen, "Blue Origin reschedules New Shepard launch for Wednesday," *SpaceflightNow* (January 23, 2019); Clark, Stephen, "Blue Origin 'one step closer' to human flights after successful suborbital launch," *SpaceflightNow* (May 9, 2019); and "New Shepard Mission NS-12 Updates," Blue Origin press release (December 10, 2019).

from takeoff to landing, and has around four minutes of microgravity. New Shepard flies for only 11 minutes but has more time in microgravity and reaches a higher altitude. The exact duration of the flight and time in microgravity may change as improvements are made to the vehicles, but the underlying difference between the horizontal and vertical flight may cause consumers to favor one over the other.

Initially, the estimated number of flight operations may be weighted toward the pre-sales of Virgin Galactic for the tourism market. This advantage will likely level out after a few years and may shift toward Blue Origin if they offer a price advantage that provides access to a greater pool of potential customers. Blue Origin is likely to have an advantage of the research and development market with a longer period of microgravity per flight, lower cost, and a greater focus on the market.

These factors will cause the proportion of suborbital flights between Virgin Galactic and Blue Origin to shift from a relatively even split over the period of 2021-2030. Beyond that, it is possible, but unlikely, that additional competing suborbital flight systems will be developed. This could include Concept X and Y vehicles, or additional Concept Z or VTVL systems. Presently, it is unlikely that such vehicles would be commercially viable within the window of this forecast. This conclusion is based on historical precedent, as several other suborbital development programs over the past decade have failed, including Rocketplane XP and the Lynx Mark II/III. Further, the two systems that are anticipated to finally begin commercial operations have been under development for almost two decades with significant financial resources provided by the personal financial support of billionaires. Given the circumstances and difficulty for a company to successfully develop a suborbital launch system, it is unlikely that a third serious competitor will enter the market before 2040. The chances of a third entrant succeeding would likely be driven by the success of the suborbital spaceflight market between Virgin Galactic and Blue Origin.[100] With a proven business model and sustained demand, a vibrant suborbital spaceflight sector might attract the investment necessary to develop a third vehicle, which could take market share from either Virgin Galactic or Blue Origin. Without knowing the specifications it is impossible to forecast the number of commercial flights this vehicle system might make. Absent the development of a third competing system, from 2030-2040 Virgin Galactic and Blue Origin will continue to share the market for suborbital tourism, with the shares of the market determined by the factors previously discussed.

The CASP Addressable Markets

Given the factors that will influence the proportions of horizontally and vertically launched suborbital flights, a basic picture of the number of flights that could occur

[100] SpaceX is developing the Starship, a two-stage system composed of the Super Heavy booster and a large vehicle called Starship. It is conceived as an orbital launch system, but Elon Musk, the company CEO has proposed using Starship as a suborbital PTP transportation system. In this report and because of a lack of details on this approach, it is assumed the vehicle will be used exclusively for orbital missions.

at CASP can be pieced together. CASP is not suitable for vertical launch systems like New Shepard. This accounts for approximately half of the flights over the first 10 years of the forecast period. CASP is not licensed for Concept Z-type horizontal suborbital systems like SpaceShipTwo, but with the appropriate FAA license modifications those flights could occur at CASP. That would be approximately half of the flights through 2030. Beyond 2030, the deployment of new vehicles would influence the number of flights that could occur at CASP. Should one be developed, flights of a Concept X vehicle could occur at CASP without a license modification. Meanwhile, CASP would require a license modification if a new Concept Y vehicle was developed. Without technical details or published business cases, it is not possible to determine how many flights such vehicles might make. Further, because development lead times are at least ten years (based on progress by existing, well-funded providers), it is unlikely these vehicles would enter commercial service by 2040. Regardless of new competition, from 2030-2040 both Virgin Galactic and Blue Origin will still be major competitors in the suborbital RLV markets.

While it is possible for Virgin Galactic to operate at CASP with the appropriate license modifications, there are constraints on the proportion of its missions that could occur. Under its lease terms at Spaceport America, Virgin Galactic must operate a certain number of flights at Spaceport America before operating at additional spaceports (estimated to be 240 flights annually and 1,369 seats), and cannot operate less than 75% of its total flights at Spaceport America.[101] Based on Virgin Galactic's own projections, it will not meet the minimum number of flight operations stipulated by the lease, which means it will not operate at another spaceport until the lease ends in 2028. The lease could be renewed for another five years, but the flight requirements might not be the same as the original term. Additionally, Virgin Galactic has signed memoranda of understanding to operate in Italy and the United Arab Emirates, signaling its intent to start operations at global spaceports sometime in the future.

Table 7 summarizes a reasonable scenario based on findings that project horizontal takeoff/horizontal landing suborbital RLVs at CASP by estimated number of spaceflight participants, number of operations (launch and reentry), and number of vehicles based at the site. As described earlier, no suborbital RLV activity is anticipated during the period 2021-2030; however, during the following decade, it is possible that some suborbital activity could take place at CASP. Successful business development on the part of CASP and growth of the suborbital RLV market generally increase the likelihood this activity is realized. Both conditions may lead

[101] This estimate is based on a review of the lease document. It seems to indicate that until the lease expires in 2028, at best 25% of Virgin Galactic's flights can be addressed outside of Spaceport America. According to the minimums in Exhibit H, this translates to 240 flights and 1,369 seats annually (~5.7 seats/flight), possible only once Virgin Galactic has hit the minimum amount of activity at Spaceport America.

to expansion of operations by existing providers in terms of number of vehicles and launch sites, but also the introduction of competitors.

The number of HTHL suborbital RLV operations at CASP under these conditions could be expected to be between 30 and 100, reflecting a mix of test flights under FAA AST Experimental Permits and licensed operational flights. Suborbital RLV launches from CASP are expected to reenter and land at CASP. The number of spaceflight participants depends on several factors, including regulatory requirements (an operator license authorizing commercial activity versus an experimental permit, which does not authorize commercial activity), vehicle flight rate, vehicle capacity, and other parameters. Based on the number of operations and assuming that the notional vehicles used in this analysis can carry 6 individuals on no more than 5 flights per year, it is assumed that up to 300 spaceflight participants may be launched from CASP. It is assumed that to support this level of flight operations, at least 2 suborbital RLVs would be based at CASP such that flight tests or operations can continue in the event one vehicle is down for maintenance or inspection.

	Current	2021-2025	2026-2030	2031-2040	CAGR	Remarks
Number of Spaceflight Participants						
TOTAL SPACEFLIGHT PARTICIPANTS	0	0	0	0-300	N/A	Assume up to 6 spaceflight participants per vehicle. An FAA AST license is required for commercial operations to carry spaceflight participants. An Experimental Permit enables testing of vehicles, but commercial operations are not authorized. Therefore, a range of 0-300 is anticipated as vehicle testing transitions to operational flights.
Number of Operations						
Launches of Suborbital HTHL Vehicles	0	0	0	15-50	N/A	The assumption is that for every launch from CASP, a reentry occurs at CASP. The type of vehicle (Concept X, Y, or Z) will be determined by individual system development over the next decade.
Reentries of Suborbital HTHL Vehicles	0	0	0	15-50	N/A	
TOTAL OPERATIONS	0	0	0	30-100	N/A	
Based Suborbital RLV						
Suborbital HTHL Vehicles	0	0	0	Up to 2	N/A	To support the number of flights above, it is assumed that 2 suborbital RLVs would be preferred at the site to maintain assured activity in the event a vehicle is grounded.
TOTAL BASED SUBORBITAL RLV	0	0	0	Up to 2	N/A	

Table 7. Summary of CASP projections. *Source: Bryce Space and Technology and Kimley-Horn.*

4.2 Determination of CASP's Critical Suborbital Vehicles

This subsection identifies the selection and recommendation of critical suborbital vehicles for use in subsequent facility planning evaluations using actual systems that were pursued in sufficient detail. The selection and recommendation of vehicles is not an endorsement or otherwise meant as a final determination of which companies or systems will operate at CASP. It is meant only as a tool for assessing potential needs and facilitate site planning.

The critical suborbital vehicle will consist of a single suborbital vehicle in each of the three licensed suborbital vehicle categories described earlier in the report and reviewed here:

- Concept X: Vehicles that take off from and land on a runway under jet power, but also carry a rocket engine which is used to propel the vehicle into suborbital space.
- Concept Y: Vehicles that use a rocket engine for take off from a runway and glide to a landing following completion of the mission.
- Concept Z: Vehicles composed of two stages; one is a jet-powered carrier aircraft that releases a rocket-powered spacecraft capable of suborbital flight, which then glides to a landing on a runway.[102]

4.2.1 Concept X Vehicles

There are currently no Concept X vehicles in operation, despite several systems that have been under development during the past several decades. An historic vehicle of this type is the NF-104A, a modified jet-powered aircraft outfitted with a rocket engine that could propel its single occupant to an altitude of 22.4 miles (36 kilometers). Though it did not come close to reaching a 62-mile (100-kilometer) altitude, the NF-104A, flown from 1963 to 1971, was used to test reaction control thrusters in a near vacuum environment, among other things.

Some vehicles of this type were proposed in the early 2000s, including Rocketplane XP, being developed by Pioneer Rocketplane (now Rocketplane Global Inc., based in Wisconsin). This vehicle would have used two jet engines for take off and landing, and use a single rocket engine to achieve an altitude above 100 km. The company has revised the vehicle design to enable aerial fueling of rocket propellants prior to powered flight into suborbital space. The company is likely still seeking financing to continue pursuing this project, though updates have not been published since 2017.[103]

Japan-based PD Aerospace, founded in 2007, is a small company (28 employees) developing a suborbital spaceplane featuring a jet-rocket hybrid engine.[104] The

102 file:///Users/phil.smith/Downloads/global-wealth-report-2018-en.pdf.
103 http://www.rocketplane.com/IndexXS.html.
104 https://pdas.co.jp/en/company.html (accessed September 4, 2020).

company intends to sell suborbital tourism tickets for an estimated $153,000.[105] Though the company plans to introduce an operational vehicle by 2023, few updates have occurred since 2018.

UK-based Reaction Engines is developing a vehicle system that is similar to a Concept X vehicle, the Skylon, derived in part from work in the 1980s toward development of the Horizontal Take-Off and Landing (HOTOL) vehicle. Though the Skylon employs a hybrid jet-rocket engine called SABRE, it is designed to achieve orbital velocities. Despite focus by the media on Skylon, the company is exploring the use of the SABRE engine in hypersonic and suborbital applications, specifically point-to-point (PTP) transportation.[106] Reaction Engines is pursing development of a hypersonic aircraft called the Hypersonic Test Bed (HTB) designed to demonstrate use of SABRE.

Because of its relatively advanced stage of development before cancelation in 2010, the Rocketplane XP is recommended as a basis for modeling CASP capabilities designed to support Concept X vehicles.

Company	Rocketplane Global, Inc.
Crew/Passengers	1 crew, 5 passengers
Maximum Altitude	62+ mi (100+ km)
Maximum Payload	Undisclosed
Maximum Speed on Ascent	Undisclosed, likely Mach 2-3
Primary Propellant (Jet Engine)	Jet A-1
Primary Propellant (Rocket Engine)	LOX/RP-1
RCS Propellant	Undisclosed
Launch Site(s) (Proposed)	Cecil Spaceport, Oklahoma Air and Space Port, Houston Spaceport
Minimum Preferred Runway Length	10,000 ft (3,048 m)

Table 8. Concept X baseline vehicle. *Sources: "Final Environmental Assessment, Finding of No Significant Impact, and Record of Decision for the Houston Spaceport, City of Houston, Harris County, Texas" (June 2015) and "Final Environmental Assessment for the Oklahoma Spaceport" (May 2006).*

4.2.2 Concept Y Vehicles

As is the case with Concept X vehicles, there are no Concept Y vehicles in operation. The EZ-Rocket was a Rutan-designed Long-EZ aircraft modified by XCOR Aerospace by replacing its propeller engine with rocket engines. The experimental aircraft, which never exceeded an altitude of 1,219 feet (4,000 meters), informed development of XCOR's Xerus vehicle and later the Lynx, both of which would have been classified as Concept Y vehicles but never came to fruition. The Lynx Mark II

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105 "Japan's PD Aerospace Defines Spaceplane Plans, Costs, And Timeline," *SpaceWatch.com* (September 17, 2018).

106 https://www.reactionengines.co.uk/beyond-possible/flight-applications.

was designed to exceed an altitude of 62 miles (100 kilometers). The Lynx Mark III was essentially the same vehicle, but would have featured a dorsal compartment carrying an upper stage for the deployment of small satellites.

Because of its relatively advanced stage of development before cancelation in 2017, the Lynx Mark II/III is recommended as a basis for modeling CASP capabilities designed to support Concept Y vehicles.

Company	XCOR Aerospace
Crew	1-2
Maximum Altitude	66.5 mi (107 km)
Maximum Payload (Suborbital Apogee)	264.6 lb (120 kg)
Maximum Payload (LEO)	1,433 lb (650 kg), smallsat plus upper stage
Maximum Speed on Ascent	Mach 2
Primary Propellant	LOX/RP-1
RCS Propellant	Undisclosed non-toxic formula
Launch Site(s) (Proposed)	Mojave Air and Space Port, Midland International Air and Space Port, KSC LLF, Oklahoma Air and Space Port
Minimum Preferred Runway Length	9,501 ft (2,896 m)

Table 9. Concept Y baseline vehicle. *Sources: "Final Environmental Assessment for the Midland International Air and Space Port, City of Midland, Midland County, Texas" (September 2014) and "Final Environmental Assessment for the Oklahoma Spaceport" (May 2006).*

4.2.3 Concept Z Vehicles

Virgin Galactic's Tier 1b system, composed of WhiteKnightTwo and SpaceShipTwo, represent an active Concept Z vehicle. Though the system is still undergoing test flights, it is expected to become operational in late 2020 or early 2021. Virgin Galactic has obtained a licensed from FAA to operate SpaceShipTwo as a commercial system, a necessary step allowing the company to conduct powered test flights of the vehicle.

Stratolaunch LLC, based in Seattle, Washington, offers a large carrier aircraft (built by Scaled Composites) as a platform for carrying a launch vehicle. Current plans for the carrier aircraft remain in flux, though plans for it to carry up to three Northrop Grumman Pegasus XL launch vehicles continue to be pursued. Stratolaunch is reportedly developing an orbital spaceplane called Black Ice and a hypersonic test vehicle called Talon-A, both uncrewed systems. The latter would achieve speeds up to Mach 7 and may be used for suborbital flight testing by 2022. Talon-A may lead to the development of a larger version called Talon-Z. The carrier aircraft, nicknamed Roc, flew for the first time in 2019 from Mojave Air and Space Port, using a 12,503-foot (3,811-meter) runway. It is unclear of Roc requires a runway of this length; CASP runways may need to be reinforced and lengthened to support the aircraft.

SpaceShipTwo (together with its carrier aircraft) is recommended as a basis for modeling CASP capabilities designed to support Concept Z systems.

Company	Virgin Galactic
Crew/Passengers	2 crew, 6 passengers
Maximum Altitude	68.4 mi (110 km)
Maximum Payload	Undisclosed
Maximum Speed on Ascent	Mach 3
Primary Propellant (WhiteKnightTwo)	Jet A-1
Primary Propellant (SpaceShipTwo)	Hydroxyl-terminated polybutadiene (HTPB) fuel and liquid nitrous oxide
RCS Propellant	None (no RCS)
Launch Site(s)	Mojave Air and Space Port, Spaceport America
Minimum Preferred Runway Length	12,000 ft (3,657 m)

Table 10. Concept Z baseline vehicle. *Source: "Environmental Assessment for the Launch and Reentry of SpaceShipTwo Reusable Suborbital Rockets at the Mojave Air and Space Port" (March 2012).*

4.3 Projection of Potential Orbital Spacecraft Reentry Candidates

Several orbital vehicles requiring horizontal reentry and landing support represent potential opportunities for CASP, including the Air Force's X-37B, Sierra Nevada Corporation's Dream Chaser, and UK-based Reaction Engines' Skylon. The X-37B is in operation and the others are in varying stages of development.

Figure 8 illustrates the projected number of reentry events by orbital winged spacecraft during the forecast period. These are vertically launched systems for orbital missions and represent a different market than the suborbital forecasts previously discussed. One of the vehicles, the Air Force's classified X-37B Orbital Test Vehicle (OTV), is operational and is assumed to remain so during the forecast period.[107] As of August 2020, two X-37B vehicles are in operation. Dream Chaser, manufactured and operated by SNC, is expected to become operational in 2021, delivering cargo to the ISS at least once per year. Finally, this forecast assumes UK-based Reaction Engines will develop a suborbital flight article designed to test the company's SABRE engine in a real-world operational environment. This vehicle is a notional sub-scale version of the Skylon, which is an orbital launch vehicle expected to become operational after 2040, assuming financing and demand are capable of sustaining such a system.

[107] The X-37B is an Air Force asset, but launch, on-orbit operations, and landing are managed by the U.S. Space Force.

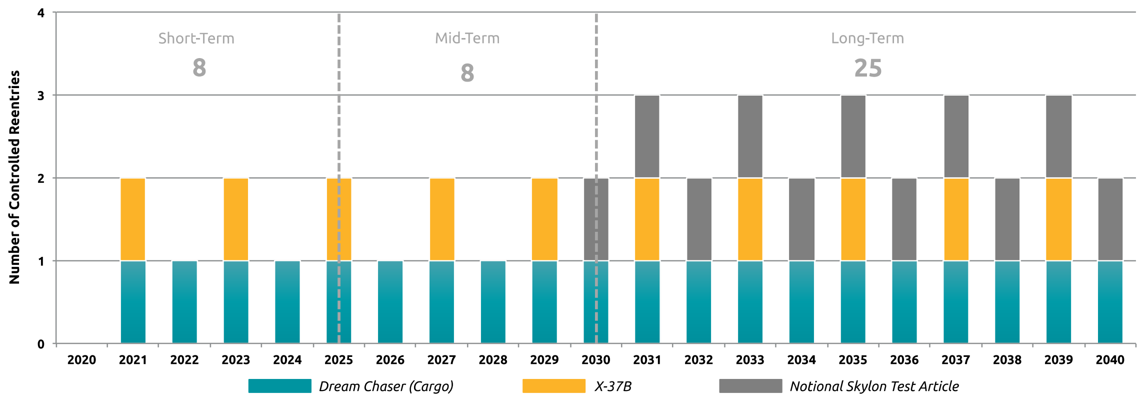

Figure 8. Projected reentry events by orbital winged spacecraft.

The orbital reentry events shown in Figure 8 are potentially CASP-addressable, though unlikely. CASP could theoretically serve as alternate (backup) landing sites for the X-37B and Dream Chaser. Following landing of OTV-4 at KSC in 2017, the Air Force indicated its intent to shift all X-37B activities next door to Cape Canaveral Air Force Station;[108] indeed, the X-37B did land at the LLF following OTV-5 in 2019. VAFB is likely a secondary landing site, having already proven its viability. Likewise, SNC's Dream Chaser will be launched from CCAFS and will land at the LLF. CASP could be designated as an alternate landing site for Dream Chaser, but there are no published plans for this.

For this forecast, it is assumed that should development of Reaction Engines' Skylon proceed as planned it will not become operational by 2040. However, it is probable that a subscale suborbital system will be developed to bridge the gap between SABRE engine testing on the ground and atmosphere to testing in the space environment. Such a vehicle could use CASP as a U.S. landing site if testing requires point-to-point scenarios. This testing would probably occur sometime after 2030.

The only operational system is the reusable X-37B, owned by the U.S. Air Force and operated by the U.S. Space Force (USSF). The OTV, first launched in 2010, is a small, autonomous space plane designed to support research and technology development. The OTV is launched vertically, covered by a payload fairing. The USSF operates two of these vehicles, which are launched from CCAFS either aboard an Atlas V 501 or a Falcon 9. After significant time in orbit (the longest mission was 780 days), the vehicle reenters the atmosphere and lands on a runway at KSC or VAFB, with Edwards AFB used as a backup. The runways at KSC and VAFB are 4,572 meters (15,000 feet) long. Vehicle processing takes place at Orbiter Processing Facilities 1 and 2 (OPF-1 and OPF-2) at KSC; therefore, a cargo plane is required to transport the vehicle from VAFB or Edwards to KSC. Operational and processing procedures for the X-37B are classified and as a result it is not known with certainty what facilities are required to support the X-37B upon landing and it subsequent preparation for return to CCAFS. However, it is known that special handling is

[108] Ray, Justin, "X-37B spaceplane returns to Earth and makes autopilot landing in Florida, *Spaceflightnow.com*, May 7, 2017.

required because the vehicle is powered by a single AR2-3, an Aerojet Rocketdyne engine that uses highly toxic hypergolic propellants. In addition, strict security measures are necessary during all phases of vehicle processing and operations.

The reusable Dream Chaser is a cargo space plane manufactured and operated by SNC. Like the X-37B, this vehicle is launched vertically, with wings folded and shrouded within a payload fairing (the crew version, should it be pursued, will not be enclosed in a fairing as the wings cannot be folded). An Orbitec Vortex engine provides primary propulsion, burning relatively benign propellants propane and nitrous oxide. After completing its cargo delivery mission to the ISS, it reenters the atmosphere and lands on a runway, nominally the KSC LLF.[109] It is then safed and transported to the Commercial Crew and Cargo Processing Facility (C3PF) adjacent to the LLF for processing. The company expects to launch Dream Chaser for the first time in late 2021 aboard a Vulcan launch vehicle. It is notable that SNC's Space Systems division, where Dream Chaser is manufactured, is located in Louisville, Colorado, relatively nearby to CASP.[110] Notably, SNC signed a contract with the DoD for a Dream Chaser mission using the Shooting Star space transport vehicle, a non-returnable autonomous platform carried behind the Dream Chaser for selected missions.[111]

Several non-U.S. space plane concepts are under development. Most of these are not expected to be addressable to CASP, as they are government programs and preference will be placed on supporting indigenous capabilities. These include ESA's Space RIDER, a small space plane planned for initial launch in 2022 aboard a Vega-C rocket; the European multinational Air Launch space Transportation using an Automated aircraft and an Innovative Rocket (ALTAIR); PD Aerospace's X07 space plane with planned first launch in 2023; and the Indian Space Research Organization's (ISRO) RLV-TD prototype currently undergoing flight tests.

Potential non-U.S. opportunities exist with two commercial systems being developed in the UK. The SABRE engine being developed by Reaction Engines, a CASP business partner, is essentially an air-breathing rocket propulsion system that burns liquid hydrogen and liquid oxygen. This engine is key to the larger scale development program involving the uncrewed Skylon single-stage-to-orbit (SSTO) vehicle, which may, at least in prototype form, fly during the forecast period. Reaction Engines has received nearly $200 million in funding from a variety of sources, including the UK government, and is likely to continue development activities through the next several years.[112] In its current configuration, Skylon will require an unprecedented 5,900-meter (19,357-foot) runway, making operations at

[109] Miller, Amanda, "Landing site sought for UN's Dream Chaser mission," *Room* (October 23, 2019).
[110] https://www.sncorp.com/who-we-are/business-areas/space-systems/.
[111] Trevithick, Joseph, "The Pentagon Moves To Launch Its Own Experimental Mini Space Station," *The Drive* (July 15, 2020).
[112] Bryce start-up space investment database.

CASP unlikely without significant development.[113] However, the company anticipates conducting flight tests of its SABRE engine beginning in 2025, presumably with a scaled-down vehicle.[114] Another UK-based company, Orbital Access, is developing the Orbital 500R space plane, a small spacecraft that would be launched from a conventional airport. Orbital Access has received some investment, but not nearly at the same level as Reaction Engines. The Orbital Access system could theoretically be serviced at CASP.

4.4 General Characterization of Manufacturing, Infrastructure, and Transportation Modes Supporting Suborbital RLVs

4.4.1 Manufacturing

Because of their reusability and the relatively small markets involved, suborbital RLVs will likely continue to be manufactured artisanally, with only a few vehicles built and each likely to exhibit unique characteristics. Virgin Galactic, for example, envisions building five vehicles during the forecast period. Other companies, especially those with less financing, will not build as many.

Vehicle reusability, however, presents new opportunities for the space industry in the form of ongoing maintenance. SpaceX is the first launch service company to routinely reuse launch vehicle first stages. The company has refurbished about 60 Falcon 9 cores to date, proving that systems employing rocket engines and cryogenic propellants can be returned following a very dynamic flight regime. While the company has not published how or at what cost it refurbishes first stages, it is reasonable to conclude that this involves a set of standards, technical procedures, quality assurance inspections, and, of course, pre-flight engine hot fire testing. This type of activity is anticipated for suborbital RLVs, though unlike the SpaceX Falcon 9 refurbishment, these vehicles will resemble aircraft in terms of maintenance schedules and processes. Part of the process will involve on-site manufacturing of replacement parts using a variety of methods including machining, casting, and additive manufacturing. Supporting this effort may entail warehousing of parts, though additive manufacturing should reduce the need for large facilities.

Suborbital RLV design, development, testing, and production will likely occur at the same site. Due to the nature of propulsion and vehicle test flights, certain types of ground testing may be geographically separated to reduce the potential hazards to local population and property. Several benefits relating to manufacturing exist when consolidating all activities at one site. During the development process, rapid prototyping using additive manufacturing and machining equipment help inform production needs and design enhancements. Even during the production process,

[113] Hempsell, Mark, "A Technical Overview of a SKYLON Based European Launch Service Operator," 65th International Astronautical Congress (IAC 2014): D2 Space Transportation Solutions and Innovations symposium. Reaction Engines Ltd. IAC-14.D2.4.5.
[114] "BAE invests in space engine firm Reaction Engines," *BBC News* (November 2, 2015).

improvements can be made immediately anywhere along the manufacturing chain or design shop.

Related to manufacturing is the development and production of rocket engines and motors. Several companies prefer to develop their own test stands and related equipment in close proximity to manufacturing facilities, as this approach is convenient and keeps costs down.[115] Spaceport America recently acquired a Space Propulsion Center, developed by UP Aerospace and Cesaroni Aerospace, designed to accommodate the manufacturing and testing of solid motors.[116]

In addition to the practical considerations inherent in centralizing activities, consolidating administrative, developmental, manufacturing, and operational divisions has been a characteristic of vertically integrated start-up space companies. Vertical integration enables full control of the supply chain, which reduces costs and lead times, essential in a highly competitive environment.

In terms of the competitive environment, security is a key concern for most, if not all companies. For example, when looking for a production site, Relatively Space desired ample room and adequate security to help ensure protection of its proprietary additive manufacturing techniques and management of vehicle production.[117]

Vehicles manufactured as operational systems, of course, can be flown from the manufacturing site to other sites as the business case requires. Wherever the vehicles are based, maintenance, which may require on-site manufacturing, will be necessary. An example of this approach is provided by Virgin Galactic, which builds its vehicles at Mojave Air and Space Port and operates out of Spaceport America. The now-defunct XCOR Aerospace, which planned to conduct flight operations from Midland International Air and Space Port, expected to continue its flight test activities at its original home base in Mojave.

4.4.2 Infrastructure

The infrastructure necessary to support suborbital RLV processing, launch, reentry, and landing are similar to that required by conventional aircraft. For example, for horizontal take off and/or landing, a runway is required. These typical infrastructure elements include, but are not limited to the following:

- Runway
- Air Traffic Control
- Power
- Communication (telephone, fiber optic, etc.)
- Weather data forecasting
- Emergency services

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[115] Interview (September 5, 2019).
[116] "State-of-the-art solid rocket motor development and manufacturing facility completed at Spaceport America," *SpaceNewsfeed.com* (October 24, 2017).
[117] Interview (October 24, 2019).

- Water
- Sewage
- Amenities (hotels, restaurants, entertainment, gas stations, etc.) for visitors

CASP and its peer spaceports have the infrastructure elements listed above, with some having little or no amenities for visitors. For example, access to hotels, restaurants, and entertainment is limited at Oklahoma Air and Space Port (12 miles, in Elk City to the west) and nonexistent at Spaceport America.

Some unique elements may be required to support suborbital RLVs. These include:

- Vehicle processing facilities
- Propellant storage and transfer
- Solid motor storage
- Designated reentry corridor (note that FAA's NextGen effort will incorporate Space Transition Corridors to more efficiently handle the expected increase in spaceflight operations in the decades to come)

Table 11 provides highlights of these unique elements by spaceport.

Spaceport	Vehicle Processing	Propellant Storage and Transfer	Designated Reentry Corridor	Amenities
Cape Canaveral Spaceport (CCS) Launch and Landing Facility (LLF)	Yes – Hangars at LLF and spacecraft processing throughout KSC and CCAFS. Opportunities at Exploration Park	Yes – Cryogenic and solid motor facilities available at LLF or nearby	Yes	Yes – Many options within a 15 mile radius
Cecil Spaceport	Limited – Hangars and opportunities at planned on-site industrial park	Limited – Jet fuel available; LOX and solid motor storage and processing in development	Yes	Yes - Jacksonville
Colorado Air and Space Port	Limited – Hangars and opportunities at planned on-site industrial park	Limited – Jet fuel available	No	Yes – Denver area
Houston Spaceport	Limited – Hangars and opportunities at planned on-site industrial park	Limited – Jet fuel available	No	Yes – Houston area
Midland International Air and Space Port	Limited – Hangars and opportunities at planned on-site industrial park	Limited – Jet fuel available	No	Yes – Midland area
Mojave Air and Space Port	Yes	Yes – Jet fuel available; some limited cryogenic and solid motor storage and processing	No	Limited – Palmdale (35 miles) and Lancaster (26 miles). Few amenities in Mojave
Oklahoma Air and Space Port	Limited – Hangars and opportunities at planned on-site industrial park	Limited – Jet fuel available	Yes	Limited – Elk City (12 miles)
Spaceport America	Yes – Operational VG hangar and terminal building. In 2018, NM legislature approved $10M for new satellite facility and $500K for a payload integration facility[118]	Yes – Jet fuel available; solid motor facility. In 2018, NM legislature approved $5M for fuel farm	No	None

Table 11. Brief description of transportation access to CASP and its peer spaceports. *Source: Bryce Space and Technology.*

[118] Messier, Doug, "New Mexico Pours $17 Million More into Spaceport America," *Parabolic Arc* (March 20, 2018).

4.4.3 Transportation

Transportation support includes the use of roads, rail, air, and sea that enable the transfer of goods and services to and from the spaceport. All CASP peer spaceports will have access to air and road transport. Some will have access to rail. Notably, Cape Canaveral Spaceport leverages the fact that is a multimodal site, with access to road, rail, air, and sea. If Stennis International Air and Space Port comes to fruition, it would have a similar advantage, though access would be through Stennis Space Center, rather than the spaceport itself. Table 12 lists the spaceports evaluated in this study and their transportation elements.

Spaceport	Road	Rail	Air	Sea
Cape Canaveral Spaceport (CCS) Launch and Landing Facility (LLF)	Yes – Access from Florida state highway 520, state road A1A, or the NASA Causeway directly into KSC	Yes – Rail system used to transport large solid rocket motor segments and other large components	Yes – Fully operational airport at either LLF or CCAFS landing strip to the south	Yes – Port Canaveral can accommodate large barges
Cecil Spaceport	Yes – Access from state roads 228 (Normandy Blvd.) and 134 (103rd St.). Near to State highway 23	None – No immediate access to rail	Yes – Fully operational airport	None
Colorado Air and Space Port	Yes – Access from U.S. Route 36 and U.S. Route 40 to the south	Possible – No connection to spaceport, but direct access could be constructed two miles to the south	Yes – Fully operational airport	None
Houston Spaceport	Yes – Access from Texas state highway 3 (Galveston Road)	Possible – Rail immediately adjacent to spaceport, but would require a spur or junction to have access	Yes – Fully operational airport	Yes - Galveston Bay is less than 10 miles away
Midland International Air and Space Port	Yes – Access from Interstate 20 (I-20) and North State Highway 349	Possible – Rail immediately adjacent to spaceport, but would require a spur or junction to have access	Yes – Fully operational airport	None
Mojave Air and Space Port	Yes – Access from California state route 14 (Aerospace Highway) and state route 58 (Mojave Barstow Highway)	Yes – Direct access to rail service	Yes – Fully operational airport	None
Oklahoma Air and Space Port	Yes – Adjacent to state Highway 44 (OK-44), a two lane highway, approximately 11 kilometers (7 miles) south of Interstate 40 (I-40), a transcontinental interstate highway	Yes – Farmrail railroad via 11-mile spur	Yes – Fully operational airport	None
Spaceport America	Yes – Access via Co Road A021	Possible – potential access to rail 2 miles to the west	Yes – Fully operational airport	None

Table 12. Brief description of transportation access to CASP and its peer spaceports. *Bryce Space and Technology database.*

5 Conclusion

Based on the forecast presented in Section 4, a basic picture of the number of flights that could occur at CASP emerges. Because CASP is not suitable for vertical launch systems, notably New Shepard, approximately half of all projected flights over the first 10 years of the forecast period are not addressable. In addition, CASP is not licensed for Concept Z-type horizontal suborbital RLVs like SpaceShipTwo, which constitute the other half of the projected suborbital flights through 2030. Though CASP could obtain the appropriate license to support SpaceShipTwo missions, it is more likely that Virgin Galactic would select a non-U.S. site to address international demand, while maintaining its presence at Spaceport America to address U.S. demand.

The deployment of new vehicles during 2030-2040 would influence the number of flights that could occur at CASP. Without technical details or published business cases, it is not possible to determine when such vehicles will be introduced or how many flights such vehicles might make. Further, precedent has established that development lead time for a suborbital vehicle capable of carrying people is about ten years, making it unlikely these vehicles would enter commercial service until after 2040. Still, these vehicles would require test flights, which CASP could support with the appropriate license. Based on the number of glide and powered test flights conducted by Virgin Galactic, the only commercial HTHL suborbital RLV system ever developed, it can be assumed that an average of less than ten test flight operations per year can be expected. This does not include the requisite number of propulsion ground tests, taxi, and captive carry tests.

In addition to potential suborbital RLV test flights, it is possible that CASP could serve as a backup to LLF as a landing site for Dream Chaser. While Sierra Nevada Corporation is located nearby, Dream Chaser will be launched from Cape Canaveral. In addition, CASP could serve as a test site for a notional test vehicle that may be developed by Reaction Engines to flight prove the SABRE engine prior to its integration with the much larger Skylon vehicle planned for operations during the 2040s. CASP has an advantage in this regard as the UK-based company already has a propulsion test site at CASP, and the company makes its test facility available to other researchers. However, it is unclear if such a vehicle will require a runway longer than 8,000 feet (2,438 meters).

Related to suborbital RLVs specifically and the space industry generally is education and training. The Boulder-Denver-Colorado Springs area serves as a nexus of aerospace education that directly supports development and sales of launch vehicles and spacecraft, provision of satellite services, and pursuit of scientific research. Companies that provide training for spaceflight participants, like Pennsylvania-based NASTAR and Washington-based Orbite Corporation, could establish a presence at CASP. Complementary companies like ZERO-G could also establish CASP as a flight location, providing lower-cost opportunities for researchers and to those seeking an opportunity to experience weightlessness. CASP could serve as a start to finish spaceflight experience that combines classroom instruction with real-world training and actual flights into space.

In short, the future of CASP cannot depend on suborbital RLV flight operations alone, since the projected demand is expected to be relatively low. Flight support for suborbital RLVs should constitute part of a broader set of capabilities in the CASP portfolio, one that is admittedly high profile but not necessarily a defining characteristic. Rather, CASP represents a multi-faceted gateway to the space industry where industry, government, academia, and trade organizations come together to help usher in a new era in spaceflight.