



May 2019

COMMERCIAL SPACE TRANSPORTATION

Improvements to FAA's Workforce Planning Needed to Prepare for the Industry's Anticipated Growth

GAO Highlights

Highlights of [GAO-19-437](#), a report to congressional requesters

Why GAO Did This Study

The commercial space transportation industry provides launch services that enable national-security and commercial satellites, among other things, to be sent into orbit for government and private customers. Continued growth and evolution in the industry is expected as reliance on space-based applications increases. AST is charged with overseeing the industry, including licensing and monitoring launch vehicle operations.

GAO was asked to review developments in this industry. This report (1) describes FAA's actions to integrate commercial space launches into the national airspace and (2) examines how well-positioned AST is to determine its current and future workforce needs, among other objectives. GAO reviewed relevant statutes, regulations, and FAA guidance; compared FAA's workforce management efforts to key principles for effective workforce planning; and interviewed FAA officials and U.S. commercial launch providers that had conducted an FAA-licensed launch as of January 2018, among other industry stakeholders.

What GAO Recommends

GAO is making four recommendations on workforce planning to AST, including that AST establish a timeline for finalizing longer-term workload projections and that AST ensure that it collects information from staff on skills and competencies in those areas that are currently needed and may be needed in the future. AST concurred with the recommendations.

View [GAO-19-437](#). For more information, contact Heather Krause at (202) 512-2834 or KrauseH@gao.gov.

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Improvements to FAA's Workforce Planning Needed to Prepare for the Industry's Anticipated Growth

What GAO Found

The Office of Commercial Space Transportation (AST) within the Federal Aviation Administration (FAA), in collaboration with other FAA offices, is taking a range of actions, such as testing new technologies, to improve how efficiently FAA integrates space vehicle launch operations into the national airspace. According to FAA officials, the amount of airspace that FAA closes to other airspace users is larger and remains closed longer than may be needed to ensure public safety. To help remedy this situation, FAA is piloting prototype technologies that would collect launch vehicles' location data in real-time and transmit them to air traffic controllers. Officials said the earliest these technologies could be implemented would be 2022. In March 2019, FAA published an announcement seeking interest from industry on partnering with FAA to further develop the technologies. Meanwhile, FAA is assessing how existing air traffic control technologies could be used to help reduce the effects of launches on other airspace users.

Since 2016, AST has taken steps to improve how it determines its current workforce needs to carry out its mission including licensing commercial launch vehicle operations. These steps include more comprehensively monitoring staff time spent on specific activities and measuring the volume of the staff's work. While AST officials told us that AST is planning to continue to improve its workforce-planning efforts, GAO found that some aspects of AST's efforts fall short of key principles of strategic workforce planning. Such principles underscore the importance of determining both current and future workforce needs and identifying potential gaps in employee skills. For example:

- AST does not project its workload beyond a 2-year budget cycle, limiting its ability to effectively and strategically plan for its longer-term workforce needs. According to officials, it can take a few years for engineers with certain skills to be trained and have sufficient experience to lead projects. Further, AST officials told GAO that hiring technically qualified personnel, including positions that require considerable training and experience to be a fully functioning employee, is challenging. AST officials said that they are considering projecting their workload estimates further into the future, but they have neither formally committed to doing so nor established a timeline with milestones.
- AST officials acknowledged that the information AST currently collects on the skills of its staff is not sufficient to allow them to identify gaps between the skills and competencies needed and those that its workforce currently possesses or may need in the future, such as expertise in flight safety analysis. AST officials told GAO that they plan to develop a tool that could collect information annually from staff and managers about the specific skills and competencies that individual staff currently possess. As of May 2019, however, AST had neither developed a draft of the tool nor established a timeline for finalizing it. Without this information, AST lacks reasonable assurance that its current workforce possesses the requisite skills and competencies, and AST may not be best positioned to proactively determine how to align its staff to carry out its mission.

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Abbreviations

AIP	Airport Improvement Program
ARC	Aviation Rulemaking Committee
AST	Office of Commercial Space Transportation
ATO	Air Traffic Organization
CCAFS	Cape Canaveral Air Force Station
DOD	Department of Defense
DOT	Department of Transportation
FAA	Federal Aviation Administration
HRAM	Hazard Risk Assessment and Management
KSC	Kennedy Space Center
LC	Launch Complex
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NPRM	notice of proposed rulemaking
SDI	Space Data Integrator
SLC	Space Launch Complex
USAF	United States Air Force
VAFB	Vandenberg Air Force Base

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May 23, 2019

The Honorable Peter DeFazio
Chairman
The Honorable Sam Graves
Ranking Member
Committee on Transportation and Infrastructure
House of Representatives

The Honorable Rick Larsen
Chairman
Subcommittee on Aviation
Committee on Transportation and Infrastructure
House of Representatives

The space transportation industry provides launch services that make it possible to send national security and commercial satellites into orbit, research probes into the solar system, and spacecraft carrying humans or cargo to space stations. In the United States, the Federal Aviation Administration (FAA) within the Department of Transportation (DOT) first assumed regulatory responsibility for the companies that operate commercial launch vehicles and the operators of launch sites in 1995.¹ Since that time, the U.S. commercial space transportation industry has undergone considerable changes, including the growth of the launch market and the development of new launch vehicles. In 2017, for example, U.S. commercial launch providers generated an estimated \$1.7 billion in revenue, up from about \$100 million in 2012. Both FAA and industry stakeholders have stated that due in part to these industry changes, many of FAA's current regulations for licensing launch operations are outdated. FAA is currently updating its regulations for licensing launch vehicle activities to accommodate the changing industry.

FAA and the commercial space transportation industry itself forecast continued growth and evolution as new space applications, such as deep-space asteroid mining and human space tourism, emerge and depend on space transportation services. Such developments may result in demand for more and different capabilities of launch vehicles and launch sites' infrastructure than that which has been used to place payloads into orbit

¹ This responsibility was previously held by the DOT Office of the Secretary.

to date. If the frequency of launch operations increases and the locations of those operations spread, this growth may also increase the need for FAA to more efficiently accommodate commercial space transportation operations into the nation's airspace to reduce the effects on other users, such as commercial airlines. Further, in 2015, we reported that FAA faced other challenges in estimating its future resource needs for licensing more launches as well as new types of vehicles and technologies.²

You asked us to review issues related to the continued maturation of the commercial space transportation industry. This report

- describes how the construction of infrastructure at selected U.S. commercial launch sites is funded,
- describes key factors that influence where orbital launches occur,
- summarizes actions taken by FAA to streamline its commercial space launch regulations,
- examines how well-positioned the Office of Commercial Space Transportation within FAA is to determine its current and future workforce needs, and
- identifies actions FAA is taking to improve how it integrates commercial space launch operations into the National Airspace System (NAS).

To address all objectives we reviewed relevant statutes, regulations, and directives governing FAA's regulation of the commercial space transportation industry. In addition, we interviewed officials from FAA's Office of Commercial Space Transportation (AST), which oversees the commercial space transportation industry. We conducted semi-structured interviews with selected industry stakeholders including: operators of the nine U.S. commercial launch sites that hosted FAA-licensed launches from 2015 through 2018, all seven commercial space launch providers that had conducted an FAA-licensed launch as of January 2018, and seven commercial space launch customers selected to include domestic and non-U.S. companies that use launch services for a variety of purposes. The views of the site operators, launch providers, and launch customers are not generalizable to those of all respective entities;

² GAO, *Federal Aviation Administration: Commercial Space Launch Industry Developments Present Multiple Challenges*, [GAO-15-706](#) (Washington, D.C.: Aug. 25, 2015).

however, the information obtained provides a balanced and informed perspective on the topics discussed.

In addition, to describe how infrastructure at the nine selected U.S. commercial launch sites is funded, we reviewed business plans, user guides, and other documents related to U.S. commercial launch sites and interviewed representatives of the Commercial Spaceflight Federation.³ To describe key factors influencing where orbital launches occur, we reviewed information on the locations of worldwide orbital launches from 2014 through 2018 in FAA's *Annual Compendium of Commercial Space Transportation*. To summarize actions taken by FAA to streamline its commercial space launch regulations, we reviewed FAA's rulemaking documents and interviewed AST officials. To examine how well-positioned AST is to make strategic decisions about its workforce needs, we reviewed FAA documents related to workforce management, including AST's workforce plans, and interviewed AST officials to identify its workforce planning efforts. We compared those efforts to key principles for effective strategic workforce planning that we have identified in previous work, focusing our analysis on those principles that are related to determining current and future workforce needs.⁴ We also interviewed officials from FAA's Air Traffic Organization and NextGen Office and attended an FAA-sponsored conference as part of our effort to identify actions taken by FAA to better integrate commercial space launch operations into the NAS.

We conducted this performance audit from July 2017 to May 2019 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

³ The Commercial Spaceflight Federation's mission is to promote the development of commercial human spaceflight and share best practices and expertise throughout the industry.

⁴ GAO, *Human Capital: Key Principles for Effective Strategic Workforce Planning*, [GAO-04-39](#) (Washington, D.C.: Dec. 11, 2003). For additional information on our work on strategic human capital management, see http://www.gao.gov/key_issues/strategic_human_capital_management/issue_summary.

Background

The Commercial Space Transportation Industry

Space transportation is the movement of objects, such as satellites and vehicles carrying cargo, scientific payloads, or passengers, to or from space. In the United States, commercial space transportation is carried out using orbital and suborbital launch vehicles owned and operated by private companies.⁵ Key parties involved in commercial space transportation activities include:

- The **commercial launch provider**—the entity that conducts the launch of a vehicle and the payload it carries.
- The **launch customer**—the entity that pays the launch provider to carry a payload into space. Customers include the U.S. government—which has not operated its own launch vehicles since the retirement of the Space Shuttle in 2011 and primarily relies on commercial launch providers to, among other things, resupply the International Space Station, launch satellites, and carry out national security and defense missions.⁶ Customers also include private companies, such as satellite owners, and researchers.
- The **launch site operator**—the entity that hosts the launch (or reentry, or both) of the launch vehicle from its launch site. Almost all launch site operators are either commercial launch providers or state or municipal government entities.

The U.S. share of the global commercial space transportation market has grown in recent years. For example, according to FAA, 64 percent of the

⁵ Orbital launch vehicles are those launched with enough velocity to place a payload into orbit around the Earth. Suborbital launch vehicles are those that reach space but do not have sufficient velocity to achieve orbit.

⁶ Federal launch customers include the Department of Defense (DOD) and National Aeronautics and Space Administration (NASA). Once development is complete, NASA's Space Launch System will operate as a NASA-owned launch vehicle for deep space human exploration.

33 worldwide commercial orbital launches in 2017 occurred at U.S. launch sites, up from about 48 percent in 2014.⁷

Commercial launch providers currently use, and are developing for future use, a variety of vehicles to launch payloads. Historically, launch providers have carried payloads into orbit using vertically launched expendable launch vehicles—those vehicles that launch only once. In more recent years, a launch provider, SpaceX, has introduced launch vehicles that can be reused for multiple launches, such as Falcon 9 and Falcon Heavy, where one part or all of the launch vehicle returns to a landing pad, either on land or on a converted barge offshore, after the payload is launched into orbit. Commercial launch providers are also moving toward reusable suborbital launch vehicles, some intended for human space tourism. These vehicles include horizontal hybrid suborbital launch vehicles,⁸ such as Virgin Galactic’s SpaceShipTwo, and vertical reusable suborbital launch vehicles, such as Blue Origin’s New Shepard. Figure 1 depicts examples of expendable and reusable vertical launch vehicles.

⁷ FAA, *The FAA’s Annual Compendium of Commercial Space Transportation: 2018* (Washington, D.C.: Jan. 2018). FAA’s compendium defines a commercial launch as one in which the contract for the main payload’s launch was open to international competition or the launch was privately financed without government support. The year 2017 is the most recent year for which complete data on global commercial orbital launches are available. According to an FAA official, FAA does not collect data on global commercial suborbital launches.

⁸ A hybrid launch vehicle launches horizontally from an aircraft runway by being carried to a set altitude by an aircraft and then launched into space, with the aircraft returning to the launch site (i.e., runway). Hybrid launch vehicles are currently in the experimental phase.

Figure 1: Examples of Expendable and Reusable Vertical Orbital Launch Vehicles

**Expendable launch vehicles at liftoff
(Atlas V and Antares)**

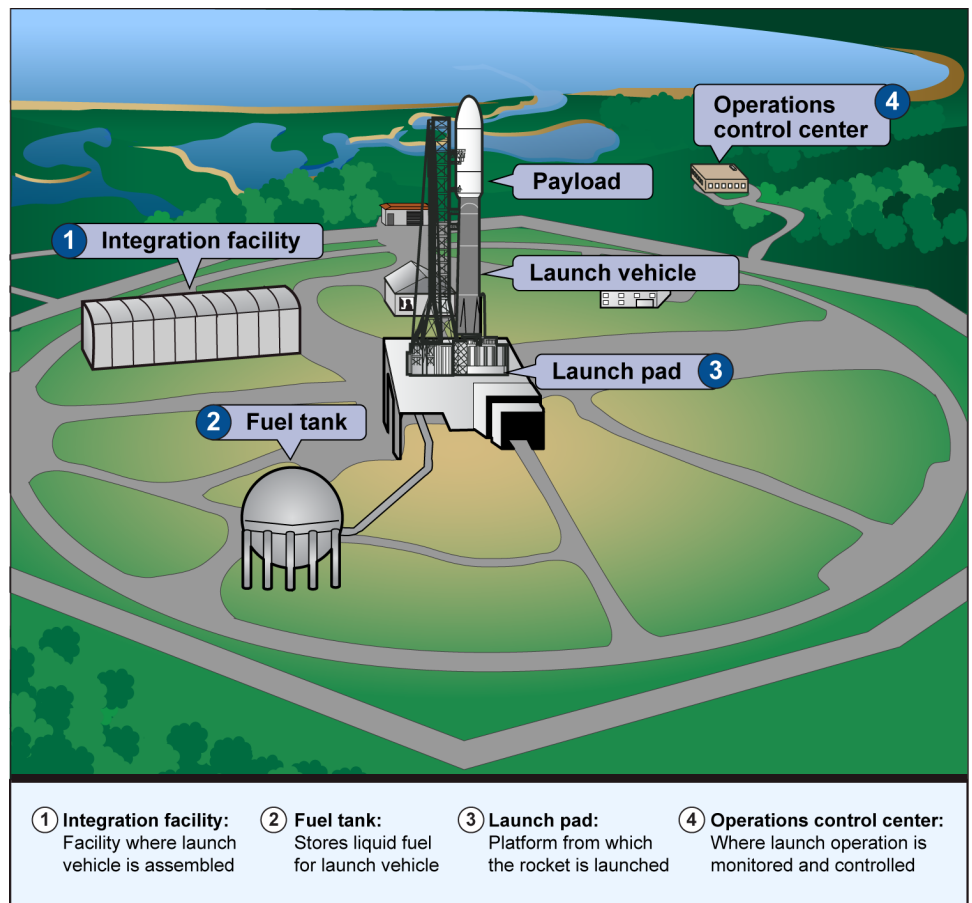
**Reusable launch vehicle at liftoff and landing
(Falcon 9)**



Sources: United Launch Alliance (Atlas V), Orbital ATK (Antares) and Space X (Falcon 9). Reprinted with permission. | GAO-19-437

Launch site infrastructure, and those who own and operate it, also varies across individual launch sites. The type of infrastructure and its design depends on the type of operations that the launch site supports. For example, some launch sites may have a launch pad for vertical launches but not a runway for horizontal launches; others may have infrastructure specifically to support launch vehicle reentry operations. While many different types and designs exist, figure 2 below shows a few examples of major pieces of launch site infrastructure.

Figure 2: Examples of Major Pieces of Launch Site Infrastructure



Source: GAO presentation of launch site documents. | GAO-19-437

AST's Roles and Organizational Structure

Within FAA, AST is responsible for regulatory oversight of the commercial space transportation industry.⁹ AST's primary means of oversight is licensing or permitting commercial launch and reentry vehicle operations and non-federal launch sites, as well as conducting safety inspections of licensed launch providers and site operators. AST is organized into three

⁹ AST's mission is to (1) protect public health and safety (i.e., people not participating in the launch), the safety of property, and U.S. national security and foreign policy interests during commercial launch and reentry operations and (2) encourage, facilitate, and promote U.S. commercial space transportation as articulated in a reaffirmation of policy in the Commercial Space Launch Act (1984).

management and support offices, including the Office of the Associate Administrator, and five operational divisions—responsible for the majority of AST’s primary mission areas, such as licensing and overseeing launches. In addition, the FAA Reauthorization Act of 2018, signed into law in October 2018, requires that AST develop an Office of Spaceports.¹⁰ According to FAA officials, as of May 2019, the size and design of this office have not yet been finalized.

AST’s workforce size is expected to increase to help accommodate anticipated growth in the industry and AST’s workload (see table 1).¹¹ As of February 2019, AST had 104 full-time equivalent positions and an operations budget of about \$25 million—an increase of 25 full-time equivalent positions and about \$8 million since fiscal year 2015.

Table 1: Office of Commercial Space Transportation Staffing and Operations Budget Fiscal Years 2015–2019

Fiscal year	Full time equivalents	Operations budget (in millions)
2015	79	\$16.61
2016	84	\$17.80
2017	98	\$19.83
2018	98	\$22.59
2019	104	\$24.95

Source: GAO presentation of FAA data. | GAO-19-437

Launch Licensing Regulations

FAA requires launch providers conducting a launch or reentry within U.S. borders to obtain a license or permit, as well as those conducting a launch or reentry abroad, if the launch provider is a U.S. entity. FAA considers a commercial launch to be one in which the contract for the

¹⁰ FAA Reauthorization Act of 2018, Pub. L. No. 115-254, § 580(b), 132 Stat. 3186 (2018).

¹¹ AST’s workforce size is anticipated to grow as evidenced by recent legislative actions that propose additional increases in appropriations toward workforce increases.

main payload's launch was open to international competition or the launch was privately financed without government support.¹²

FAA also requires, with some exceptions,¹³ a site operator's license, which authorizes an entity, such as a state or local government, to host commercial space launch operations from a specific launch site.¹⁴ FAA is to conduct safety inspections of licensed commercial space transportation launch operations, which involves monitoring of pre-operational, operational, and post operational activities.

In February 2018, the National Space Council recommended that DOT update the regulations on launch and re-entry licensing to better accommodate changes that have occurred in the industry.¹⁵ The White House subsequently directed DOT to publish a proposed rule by February 1, 2019, with a revised framework that allows more flexibility in how companies can meet the regulatory requirements. DOT published a notice of proposed rulemaking for the revisions to its licensing regulations in April 2019.¹⁶

¹² According to officials from FAA and National Aeronautics and Space Administration (NASA), U.S. governmental entities, such as Department of Defense or NASA, also acquire commercial launch services for their government-related launch needs. These launches are not subject to FAA's commercial licensing requirements unless these government entities determine to follow them. For example, FAA licenses all launches for NASA's cargo resupply missions to the International Space Station. The FAA launch license process, however, does not include any assurance activities related to the government's launch mission.

¹³ Launch sites that are owned and operated by a commercial launch provider for its sole use do not require a site operator's license, but do require a launch license for any launch operations occurring at that launch site.

¹⁴ Under 14 C.F.R. Part 420, FAA issues licenses to an operator of a commercial launch site. For the purposes of this report, we refer to the launch sites where there is an FAA-licensed operator as an FAA-licensed launch site.

¹⁵ The Space Council was initially established in 1989 and reestablished in 2017. It is comprised of the heads of federal agencies including the Secretaries of State, Defense, Commerce, and Transportation, among others.

¹⁶ Streamlined Launch and Reentry Licensing Requirements, 84 Fed. Reg. 15296 (Apr. 15, 2019) (to be codified at 14 C.F.R. §§ 401-450). According to DOT officials, DOT had planned to publish the notice of proposed rulemaking by February 1st, 2019, consistent with the deadline in the Presidential Directive, but the publication was delayed due to the department's lapse in appropriations that took place in early 2019.

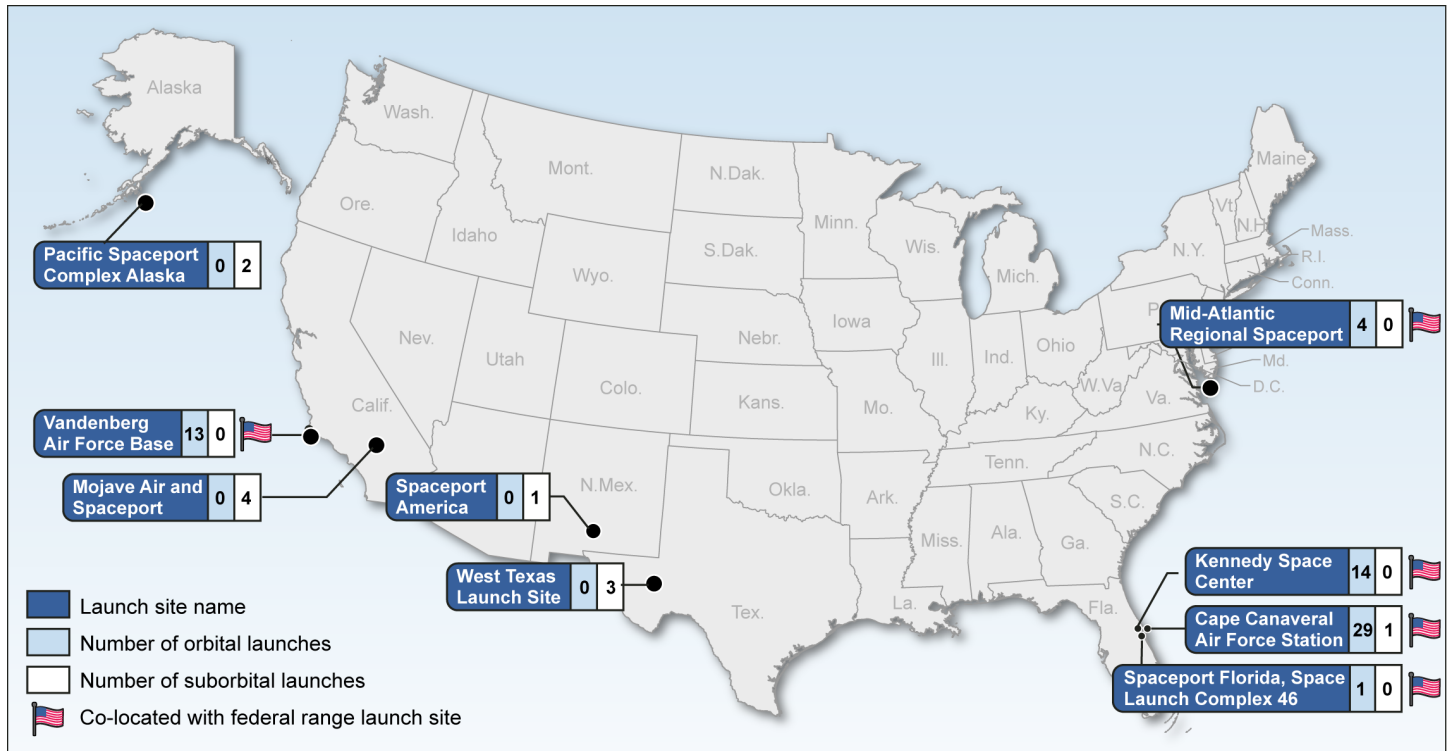
Funding for Infrastructure at Active U.S. Commercial Launch Sites Has Shifted from Federal to State, Local, and Private Sources

Federally Funded Construction

Around the mid-20th century, the federal government began constructing the infrastructure that supports the majority of commercial orbital space launches today. The Department of Defense (DOD) constructed launch sites to support ballistic missile testing and satellite launches, including sites that are now home to Cape Canaveral Air Force Station in Florida and Vandenberg Air Force Base in California. Those sites conducted their first test launches in 1950 and 1958, respectively. The National Aeronautics and Space Administration (NASA) was created in 1958, and began acquiring land adjacent to Cape Canaveral Air Force Station in 1962 to support its human spaceflight lunar program; this land is now home to the Kennedy Space Center.

In recent years, nearly all FAA-licensed launches in the United States occurred at three federal ranges, which were originally built by the federal government (see fig. 3). All 61 of the FAA-licensed commercial orbital launches from 2015 through 2018 occurred at launch sites that are on or co-located with federal ranges, with 44 of the 61 launches taking place at Cape Canaveral Air Force Station and Kennedy Space Center (collectively referred to as “Cape Canaveral”). In addition, one of the 11 licensed commercial suborbital launches occurred at a launch site co-located with a federal range.

Figure 3: Selected U.S. Commercial Launch Sites with Number of FAA-Licensed Orbital and Suborbital Launches, 2015–2018



Sources: GAO analysis of Federal Aviation Administration data and Map Resources. | GAO-19-437

While the federal government made the initial infrastructure investment at federal ranges, the launch complexes used for commercial launch operations at these sites are now operated under use agreements by non-federal entities, such as state governments or commercial launch providers.¹⁷ For example, four of the launch complexes at Cape Canaveral are operated by commercial launch providers, while two others are operated by the State of Florida.¹⁸ Two other federal ranges have launch pads that are also operated by non-federal entities—Vandenberg

¹⁷ A launch complex includes a launch pad and supporting launch infrastructure, such as operations control centers and launch vehicle and payload integration facilities—the facility where the launch vehicle is assembled before it is transported to the launch pad. The federal government still operates some launch complexes on its ranges. For example, NASA operates Kennedy Space Center Launch Complex 39B, which it plans to use for its new Space Launch System—a launch vehicle for deep space human exploration.

¹⁸ A single launch site may have more than one launch complex.

Air Force Base in California and the Mid-Atlantic Regional Spaceport, which is co-located with NASA's Wallops Flight Facility in Virginia.

The Air Force and NASA generally still have responsibility for maintaining common-use infrastructure—that is, infrastructure that may be shared by multiple users, such as access roads and fuel pipelines. As part of the operators' use agreements (the details of which vary depending on the launch site and launch site operator), however, funding for improvements to infrastructure used solely by that site operator is generally left to the site operator. This arrangement is in part because the infrastructure improvements are necessary to support the unique needs of specific commercial launch vehicles using those sites.

At another launch site, the federal government followed a different infrastructure investment model. In the 1990s, the Air Force partnered with the state of Alaska to help fund the construction of a state-owned site to support federal government launches and missile testing rather than constructing a new federal range. This site, known as the Pacific Spaceport Complex – Alaska, conducted its first government launch in 1998. Major infrastructure includes two launch pads with shared vehicle integration and transfer facilities. According to spaceport officials at this site, in addition to government launches, Alaska Aerospace, a state entity that operates the site, has contracts with three commercial launch providers, which anticipate conducting commercial orbital launches there in the future. Appendix II provides additional information on launch sites co-located with federal ranges, as well as funding sources and characteristics for other U.S. commercial launch sites.

State and Local Government Funding

While the federal government has not directly funded the construction of infrastructure at launch sites in recent years,¹⁹ state and local governments have done so. According to interviews we conducted and our review of publicly available documents of state-government entities that were formed to promote space-related development, state and local governments are investing in infrastructure to obtain the economic

¹⁹ FAA has provided small amounts of funding for commercial launch site infrastructure through the Space Transportation Infrastructure Matching Grants Program, which matches state, local, and private infrastructure investments up to 50 percent of the total project cost if at least 10 percent of the total cost of the project will be paid by the private sector. The grants were capped at \$250,000 each, from fiscal years 2010–2012. During those 3 years, FAA awarded 10 grants for a total of nearly \$1.5 million. The program is still authorized, but remains unfunded since 2012.

benefits of attracting space-related businesses to their areas. In two cases, state governments became operators of launch sites co-located with federal ranges and invested in infrastructure improvements at those sites to support commercial orbital launch vehicles.

- The Commonwealth of Virginia—through Virginia Commercial Space Flight Authority, an independent state entity created in part to develop and promote Virginia’s commercial space transportation industry—invested \$90 million in improvements to a launch pad at the Mid-Atlantic Regional Spaceport. This represented a share of the total costs, which were shared by Northrop Grumman Innovation Systems²⁰, a commercial launch provider that has an agreement to use the pad for commercial launches, including cargo resupply missions to the International Space Station.
- The State of Florida—through Space Florida, an independent special district that serves the state’s space-related needs—has provided over \$140 million in infrastructure investments. Those investments upgraded launch pads and the supporting infrastructure at Cape Canaveral, as well as provided grants matched by commercial launch providers for improvements to infrastructure used by those providers.

In other cases, state and local governments have invested in wholly new commercial launch sites or are adapting existing airport infrastructure to use as launch sites. According to these launch site operators, these sites are currently used for suborbital launches but could support orbital launches in the future.

- The state of New Mexico funded the construction of the commercial launch site known as Spaceport America through \$225 million in state appropriations and local taxes in two counties. The state also has a 20-year lease agreement with Virgin Galactic, which plans to conduct commercial suborbital space tourism launches from the site. This launch site, with its 12,000-foot-by-200-foot runway, hosted one FAA-licensed suborbital test launch in 2018.²¹
- In California, the Mojave Air and Space Port (Mojave) is a general aviation airport that obtained an FAA license to conduct commercial suborbital launches in 2004. In addition to continuing its general

²⁰ Orbital ATK was acquired by Northrop Grumman in 2018 and renamed Northrop Grumman Innovation Systems.

²¹ According to Spaceport America officials, the site hosted over 90 other launches that did not require an FAA-license.

aviation operations, Mojave currently provides a runway and mission preparation area to commercial launch providers testing vehicles designed for orbital and suborbital launches. This site hosted three FAA-licensed suborbital test flights in 2018.²² According to a representative from Mojave, the site generally funds infrastructure maintenance with rents and user fees, while launch providers build their own facilities. In July 2018, Mojave also received a \$1.4 million grant through FAA’s Airport Improvement Program for the purpose of extending an airport taxiway.²³ According to a Mojave representative, the location of the taxiway extension will be available for hangar development by both aviation and commercial space users on a first-come, first-serve basis. The project was completed in April 2019.

Private Funds

Commercial launch providers fund infrastructure improvements at existing launch sites—both co-located with federal ranges and elsewhere—to ensure the sites are tailored to their unique launch vehicles. For example, under its agreements to use launch pads at the federal ranges at Cape Canaveral and Vandenberg Air Force Base, SpaceX representatives told us they invested “hundreds of millions” of dollars²⁴ in new infrastructure and infrastructure improvements, such as constructing new liquid fuel lines and improving launch pad cooling systems. According to SpaceX representatives, the company made these investments to support the specific needs of its launch vehicles and the rapid pace at which it is currently launching. Virgin Galactic and Stratolaunch—two other commercial launch providers developing suborbital and orbital launch

²² Five other airports have received an FAA site operator license to conduct space launches, but have not hosted FAA-licensed launch activity. These five launch sites are not included in our review of infrastructure funding. See appendix II for more information.

²³ The Airport Improvement Program (AIP) provides grants to public agencies—and, in some cases, to private owners and entities—for the planning and development of public-use airports that are included in FAA’s National Plan of Integrated Airport Systems—a plan developed every 5 years that identifies all existing and proposed airports that are included in the national airport system, among other things. According to FAA officials, grants for projects that specifically support commercial space activities are not prohibited from receiving AIP grant funds. However, FAA has long-standing policies and criteria for reviewing AIP grant requests that were developed to evaluate aviation activities. As a result, FAA officials told us that they are in the process of reviewing how these policies and criteria may be applied to commercial space activities, as well as which types of commercial space activities represent “aeronautical” use, as outlined in the AIP’s authorizing legislation.

²⁴ Representatives from SpaceX told us that the actual amount of investment made in their launch sites is not public information.

vehicles, respectively—funded the construction of hangars and testing facilities for their launch vehicles at Mojave Air and Space Port.²⁵

Three of the seven commercial launch providers that we spoke with constructed or are currently constructing new launch sites for their exclusive use. Representatives from two of them said doing so allows them to schedule launches without having to compete with other launch providers at existing launch sites.²⁶ Two of these commercial launch providers also told us they had not received any government funding for these sites, while the third told us it had received some support from the state government where the site is located.

As the commercial space transportation industry continues to evolve, it may lead to more investments in launch sites that are not currently supporting commercial orbital launches.²⁷ For example, some commercial launch providers are developing launch vehicles consisting of a rocket launched from an airplane in flight, enabling launches from runways rather than launch pads. This could change how and which entities fund launch site infrastructure.

²⁵ The amount of investment made by these two launch providers is not public information.

²⁶ One of these launch providers further noted that a multi-user launch pad poses significant technical challenges and that it was not aware of any multi-user launch pads in the world as a result.

²⁷ The FAA Reauthorization Act of 2018 includes a provision for GAO to study and report on potential mechanisms to provide federal support to spaceports. FAA Reauthorization Act of 2018, Pub. L. No. 115-254, § 580(d), 132 Stat. 3186 (2018).

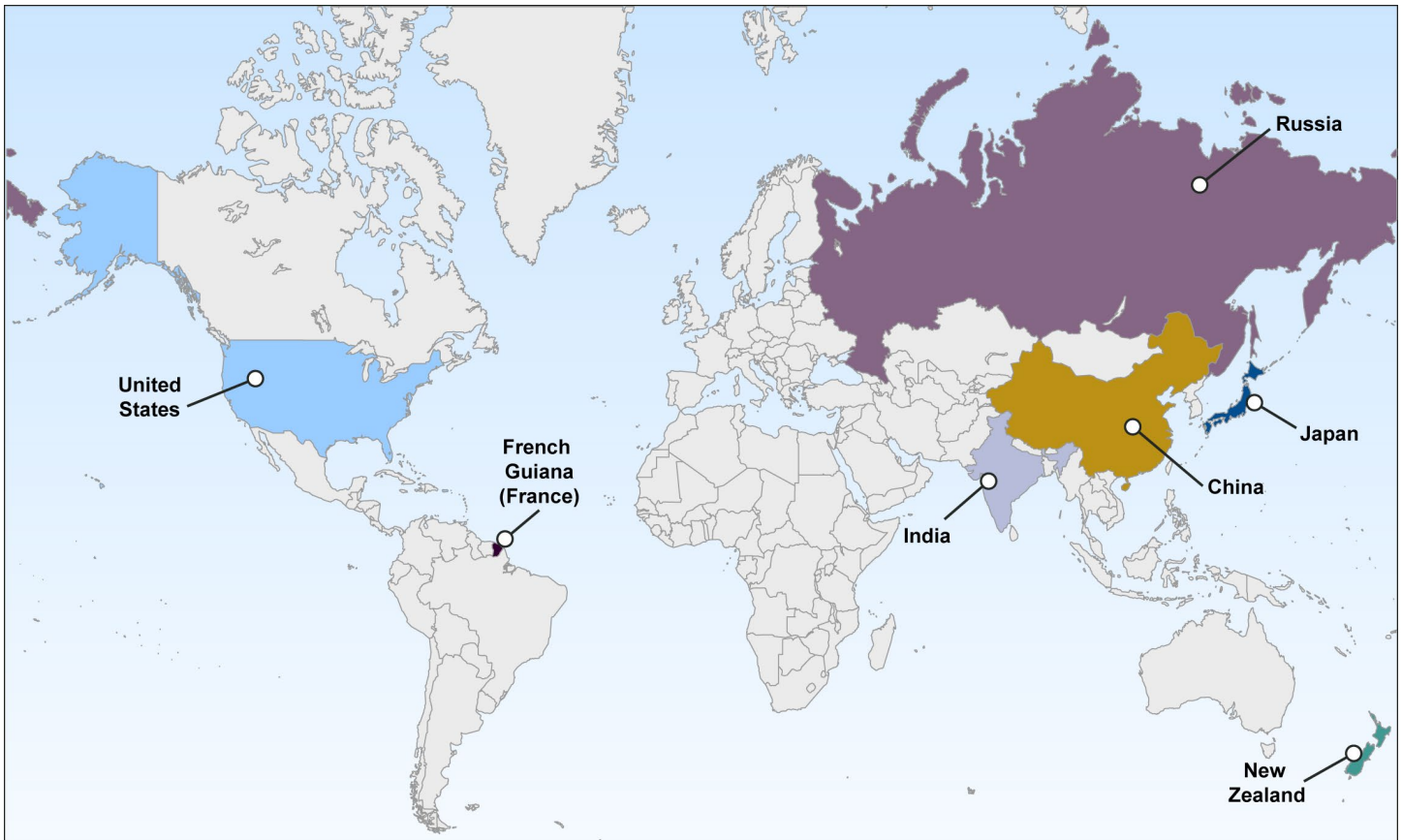
Launch Customers in Our Review Consider the Launch Provider's Capabilities and Price, among Other Factors, When Deciding Where to Launch

Commercial space transportation is a global industry. We identified seven countries, including the United States, that have launch providers with the capability to support an orbital launch of a commercial payload (see fig. 4).²⁸ In 2017, 7 of the 22 FAA-licensed launches conducted in the United States contained a payload from a non-U.S. launch customer, including several communications satellite operators and one civilian space agency, according to FAA. Similarly, some U.S. launch customers we interviewed said they have used non-U.S. launch providers.²⁹

²⁸ We identified these seven countries based on our review of FAA's annual compendium of commercial space transportation. We also identified additional countries that have orbital launch capabilities, but their use is limited to government missions.

²⁹ U.S. launch customers must meet various legal requirements in order to export certain equipment, such as software and technology. According to commercial space industry stakeholders that we spoke with, these requirements restrict U.S. launch customers from being able to launch in China.

Figure 4: Countries with Capability to Support Orbital Commercial Space Launches



Sources: GAO analysis of Federal Aviation Administration data and Map Resources. | GAO-19-437

According to representatives of the seven domestic and non-U.S. companies³⁰ we interviewed that use launch services for placing their products into Earth orbit or other trajectories, several factors influence

³⁰ We selected companies that are involved in traditional space activities, such as satellite communications, as well as companies pursuing non-traditional space activities, such as asteroid mining, among other criteria. See appendix I for more information on the companies selected.

their selection of a launch provider.³¹ Many of these representatives acknowledged that as part of their business decision, a prerequisite is that the launch provider's vehicle and launch site must have the capabilities to meet the customer's mission requirements, such as having the capability to bring the payload to the desired orbit at the desired time. That capability, in turn, depends on factors such as the lift capacity of a provider's launch vehicle—which dictates the maximum weight the vehicle can carry—and the geographic locations of its launch sites. For example, launch vehicles operating from sites closer to the equator can place payloads into certain orbits using less fuel due to Earth's rotational velocity. The direction a launch vehicle can travel from a launch site also affects the orbits into which the vehicle can most efficiently place a payload. For example, Vandenberg Air Force Base in California—which allows launch vehicles to travel west over the Pacific Ocean—is more efficient for certain orbits, while Cape Canaveral—which allows vehicles to travel east over the Atlantic Ocean—is more efficient for others.

Beyond selecting a launch provider that has capabilities to meet a launch customer's mission requirements, six of the seven launch customers we spoke with said the price of a launch is a key deciding factor.³² For example, a representative from an international satellite operations company told us that the company achieved significant savings by procuring a series of launches from its selected provider. According to the representative, using a different launch provider would have cost almost twice as much—a price that would have forced the company to delay its launch plans. According to data published in FAA's *Annual Compendium of Commercial Space Transportation: 2018*, there is wide variation in the commercial price of launches worldwide, ranging from an estimated \$62

³¹ A subcommittee of FAA's commercial space transportation advisory committee reported in October 2018 that because the U.S. does not have laws explicitly providing for authorization and ongoing supervision of on-orbit activities, as required by Article VI of the Outer Space Treaty (a 1967 international treaty that established principles governing the activities of nations in the exploration and use of outer space, including the moon and other celestial bodies), companies pursuing on-orbit or in-space activities (such as satellite servicing, space habitats, and space mining) may face challenges. We asked launch customers about the effect of different countries' legal requirements on their launch location decisions, and none of the launch customers we interviewed said Article VI implementation has affected their decisions.

³² The seventh customer—a company that operates small satellites, which relies on sharing launches with larger payloads—told us that price was not a top factor because there is not a significant price variation between launch providers for these types of launches.

million to \$178 million per launch.³³ The exact price paid for many launches is considered proprietary by both launch customers and commercial launch companies, and is therefore not reported publicly. Moreover, price can be affected by the size and weight of the payload, the intended orbit being reached, and other mission-related factors. As a result, direct comparison of launch prices is difficult.

In addition to price, a launch provider's availability and reliability are also key factors, according to launch customers we spoke with. Six of the launch customers we spoke with mentioned availability as a key factor, which is the launch customer's ability to reserve a place on the launch provider's launch schedule. For example, a representative from a domestic small satellite operations company said it can be difficult to find available launches in the United States because the company relies on sharing launches with larger payloads, and few U.S. launches travel to the company's desired orbit. As a result, the company has procured launch services from Indian and Russian launch providers. Five launch customers mentioned reliability—generally a launch vehicle's history of successful launches—as a key factor, in part due to the financial impact of a failed launch. For example, a representative from a non-U.S.-based satellite operations company said that in the event of a failed launch, insurance would generally cover the cost of the lost payload, but not lost revenue that would have been generated by the payload in orbit.

Some launch customers noted that choosing a launch provider is a complex decision, and that the key factors they consider can be interdependent. For example, the representative from the non-U.S.-based satellite operations company said that while a launch provider may offer a lower price on a less reliable vehicle, the lack of reliability could increase the customer's payload insurance costs, effectively increasing the launch price. A representative from a company seeking to launch into deep space told us they would only consider a provider that is not only reliable but also has years of successful operations and a proven business plan.

³³ FAA, *The Annual Compendium of Commercial Space Transportation: 2018*.

DOT Published a Proposed Rule in April 2019 but Related Rulemaking Activities Affect When Regulatory Changes Will Be in Full Effect

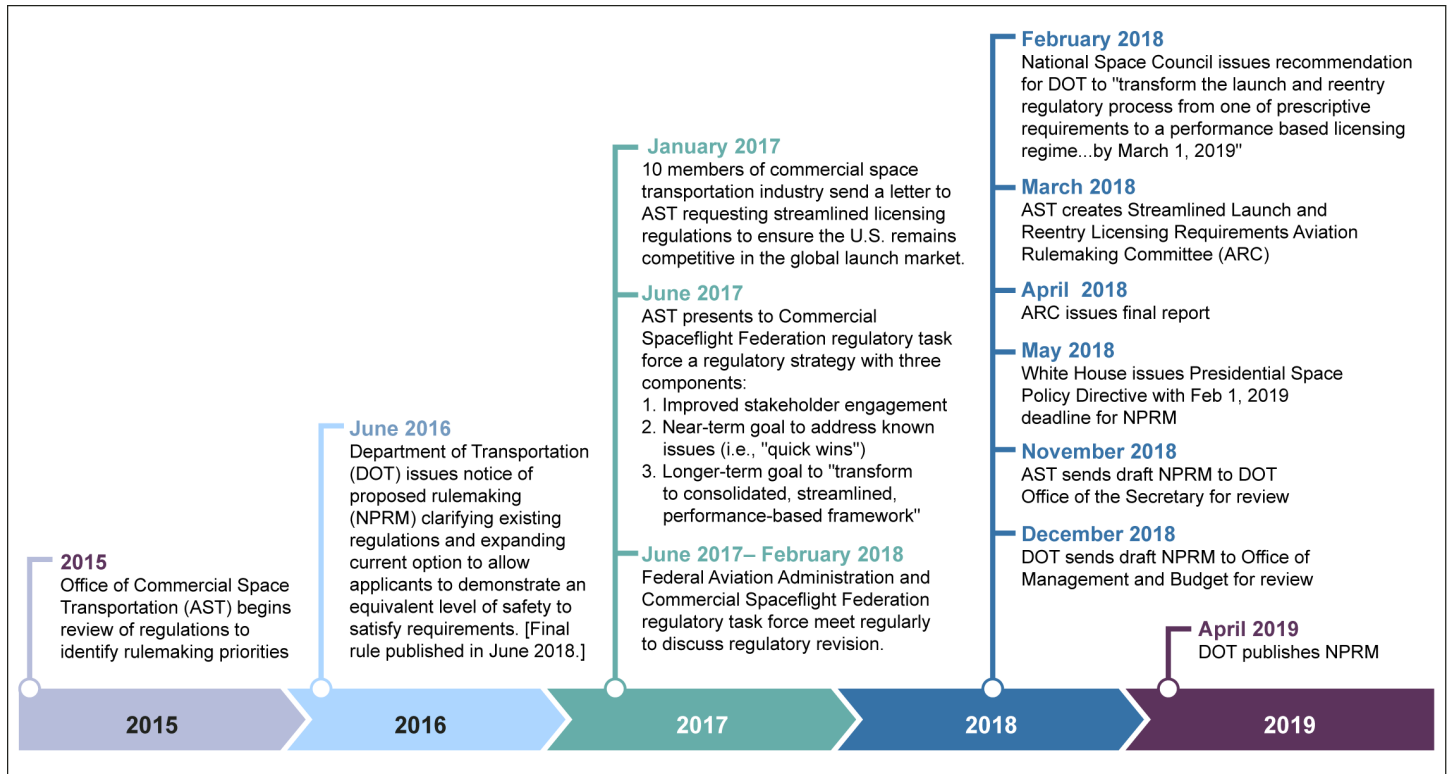
FAA Accelerated Plans to Streamline Regulations to Respond to a Presidential Directive

According to FAA officials, FAA has been considering changes in its licensing regulations since 2015 and recently has accelerated these efforts. Dating back to 2015, according to FAA officials, FAA had been taking an iterative approach by first making “quick wins”—that is, making administrative changes or straightforward regulatory revisions—with a long-term goal of fully consolidating and streamlining the regulations over a period of several years. FAA’s approach changed, however, when in May 2018, a Presidential Directive was issued that addressed both the timing and content of FAA’s regulatory updates. The directive contained a deadline to publish a proposed regulation for public comment by February 1, 2019. It also directed the Secretary of Transportation to replace the current prescriptive regulations for commercial space launch licensing—in which a certain technology or action is required—with a regulatory framework that is performance-based—in which applicants have flexibility in how they achieve required outcomes, such as a specific level of safety.

In response to this directive, DOT published a notice of proposed rulemaking (NPRM) in April 2019 to solicit comments on a proposed rule that will incorporate performance-based requirements.³⁴ According to FAA officials, they had planned for the NPRM to be published by February 1st, 2019, consistent with the deadline in the directive, but the publication was delayed due to the lapse in DOT’s appropriations that took place in early 2019. A timeline of key actions related to launch licensing regulation is shown in figure 5 below.

³⁴ Streamlined Launch and Reentry Licensing Requirements, 84 Fed. Reg. 15296.

Figure 5: Timeline of Key Actions Related to Updating Commercial Space Transportation Launch Licensing Regulations



Source: GAO analysis of Federal Aviation Administration information. | GAO-19-437

The preamble of the NPRM states that the proposed rule intends to satisfy the requirements of the Presidential Directive, including consolidating and revising multiple regulatory parts to apply a single set of licensing and safety regulations across several types of operations and vehicles,³⁵ and replacing prescriptive regulations with performance-based rules. The preamble further states that these changes will give industry greater flexibility to develop means of compliance that maximize their business objectives while maintaining public safety.

The proposed rule also seeks to address recommendations made by an Aviation Rulemaking Committee (ARC) that was created in March 2018

³⁵ Specifically, the proposed rule would consolidate 14 C.F.R. Parts 415 (Launch License); 417 (Launch Safety); 431 (Launch and Reentry of a Reusable Launch Vehicle); and 435 (Reentry of a Vehicle Other than a Reusable Launch Vehicle).

as a forum for industry to discuss procedures and requirements for launch and reentry licensing.³⁶ For example:

- The ARC recommended that FAA propose rules to eliminate potentially duplicative requirements for launches at federal ranges. Currently, launch providers at federal ranges are subject to FAA's requirements in addition to those of the range operator (NASA or the Air Force), which may be duplicative of each other. The preamble to the NPRM states that, while FAA has not included language to eliminate duplicative approvals, FAA would continue to work with the appropriate agencies to streamline launch and reentry requirements at ranges and federal facilities.
- The ARC also recommended more flexibility in licensing such that a single license structure could accommodate a variety of vehicle types and launch or re-entry sites. The preamble states that the proposed rule would, among other actions, eliminate the current limitation specifying a launch license covers only one launch site.

Completing Other Related Rulemaking Activities and Finalizing Guidance Will Affect When Applicants Operate under the Revised Regulation

As part of the rulemaking process, FAA must comply with a number of requirements before the final rule can be issued. FAA is statutorily required to provide a period of time to solicit public comments on the proposed regulation.³⁷ FAA must then reasonably respond to public comments submitted on the NPRM and determine whether any changes to the proposed rule may be required as a result of the comments. Some changes made in response to comments would allow AST to proceed with publication of the final regulation. However, major changes not contemplated in the NPRM could necessitate a supplemental NPRM, which could affect the timing of the final regulation's publication.³⁸

FAA provided 60 days after publication in the Federal Register for the public comment period. And, while officials told us that they plan to work toward publishing the final rule by the end of 2019, the schedule was

³⁶ ARCs provide FAA with information, advice, and recommendations on potential rulemakings. They are formed on an ad hoc basis, for a specific purpose, and are typically of limited duration. 49 U.S.C. § 106(p)(5). Members of this ARC represented 24 organizations, including commercial launch providers, spaceports, commercial space industry organizations, and aviation industry organizations.

³⁷ 5 U.S.C. § 553(c).

³⁸ 5 U.S.C. § 553; see also Jeffrey S. Lubbers, *A Guide to Federal Agency Rulemaking* 258 (5th ed. 2014).

affected by DOT's lapse in appropriations. They also noted that the quantity and content of the public comments and the time and resources required to respond to them will influence that date. Officials estimate that the public comments could number in the thousands. Further, there is a lack of industry consensus in some areas. For example, according to the cover letter accompanying the final ARC report, the report did not include specific recommendations that were agreed upon by all participants. Almost half of the industry stakeholders that participated in the ARC and provided comments on the ARC final report (8 of 19) did not fully concur with the report. Industry stakeholders disagreed on issues such as the requirements for testing flight safety systems, which would be considered as part of the licensing process. The lack of consensus among ARC participants suggests that the NPRM may also generate significantly different perspectives.

Furthermore, FAA officials emphasized that the NPRM addresses a highly complex and technical issue, using a wholly revised performance-based regulatory framework, an approach that could affect implementation timelines. We found in the past that the complexity of the issues addressed by rulemakings is a major factor influencing the time needed to issue a regulation.³⁹

FAA officials told us they intend to complete other related activities that support the rule, such as finalizing guidance documents to provide transparency and help ensure that licensing applicants understand the new requirements. Such guidance may, for example, provide examples of how to comply with the new performance-based requirements. FAA also intends to implement new administrative tools to help AST review licensing applications more quickly. Specifically:

- **Guidance:** FAA released a number of draft guidance documents in the form of Advisory Circulars with the NPRM. These Advisory Circulars cover a range of topics, such as providing ways for applicants to comply with requirements for flight safety analysis and lightning hazard mitigation, and provide at least one way an applicant could demonstrate compliance with each performance-based requirement in the proposed rule. FAA officials told us that they plan to publish these Advisory Circulars in final form simultaneous with

³⁹ GAO, *Federal Rulemaking: Improvements Needed to Monitoring and Evaluation of Rules Development as Well as to the Transparency of OMB Regulatory Reviews*, [GAO-09-205](#) (Washington, D.C.: Apr. 20, 2009).

publishing the final regulation. Through the ARC process, FAA sought input from industry on the standards that should be used to demonstrate compliance with the performance-based regulations. In the long term, however, FAA told us that they are encouraging the industry to develop voluntary consensus standards that the FAA could then accept as an acceptable way of demonstrating compliance.⁴⁰

- **Administrative Tools:** FAA officials said they are in the early stages of looking at ways to reduce the administrative burden on FAA and licensing applicants during the licensing process. For example, FAA officials told us that in 2019 they will be examining ways to automate and streamline the licensing process. FAA officials told us that they would like to implement a system whereby applicants, for the first time, would submit applications electronically to an FAA-sponsored system rather than by hard copy or attachments to an email. According to the preamble of the NPRM, FAA's proposal would allow an applicant to submit its application by email as a link to a secure server, and would remove the requirement that an application be in a format that cannot be altered. In addition to easing the burden of developing paper applications, FAA officials told us they envision that an electronic system would enable both FAA and industry to view the application during the application process and more easily communicate about its progress.

⁴⁰ Federal law and guidance provide that where possible, agencies are to use voluntary, private sector standards instead of creating their own unique standards. The National Technology Transfer and Advancement Act of 1995 states that federal agencies are generally to use technical standards developed or adopted by voluntary-consensus standards bodies. In addition, Office of Management and Budget (OMB) Circular A-119, as revised in 2016, sets forth the policy for federal participation in the development and use of voluntary consensus standards. National Technology Transfer and Advancement Act of 1995, Pub. L. No. 104-113, §12(d), 110 Stat. 775, 783 (1996). Office of Management and Budget, Circular A-119: *Federal Participation in the Development and Use of Voluntary Consensus Standards and in Conformity Assessment Activities* (Washington, D.C.: Jan. 27, 2016).

AST Has Taken Steps to Better Understand Current Workforce Needs, but Understanding of Future Needs Is Limited by a Lack of Information

In recent years, AST has improved some aspects of how it determines its workforce needs. Our work on strategic workforce planning underscores the importance of determining both current and future workforce needs and identifying potential gaps in employee skills. The improvements made to date provide AST with greater insight into the optimal number of people currently needed in certain positions. However, these improvements do not improve AST's ability to systematically assess the workforce needs of its management and support offices, nor does AST project its future workforce needs. Moreover, AST has yet to collect information on staff skills and competencies that would enable it to identify potential gaps in those skills, gaps that further limit AST's ability to effectively and efficiently align its available staff resources with current and future workloads.

AST Has Improved Measurement and Analysis of Workforce Needs, but Only for Part of Its Office and within Its 2-Year Budget Cycle

To assist FAA decision makers in understanding and meeting AST's staffing needs, AST developed and annually updates a 5-year workforce plan for its office. The current plan—covering the period from 2018 through 2022—indicates that AST's approach for workforce planning has a 5-year time frame. However, the plan discusses immediate workforce and resource needs in general terms. One of the key principles we identified in our prior work on effective strategic workforce planning is the importance of determining the workforce needs that are critical to achieving an organization's current and future programmatic goals.⁴¹ Such a determination of workforce needs should include both the optimal number of staff needed in specific positions and the required skillsets and levels of expertise for staff.⁴²

Since 2016, AST has taken several steps to better understand how it uses its staff resources in carrying out its mission to license and oversee space launch operations. The majority of AST's operations budget—about 75 percent in fiscal year 2018—was used to fund salaries and related expenses. AST now comprehensively monitors and measures staff time spent on specific activities and measures and tracks the volume

⁴¹ For AST, its programmatic goals include licensing launch operations and conducting safety inspections at the pace that the commercial space transportation industry demands, as well as updating its licensing regulations to reflect changes in the industry.

⁴² GAO, *Human Capital: Key Principles for Effective Strategic Workforce Planning*, [GAO-04-39](#) (Washington, D.C.: Dec. 11, 2003). For additional information on our work on strategic human capital management, see http://www.gao.gov/key_issues/strategic_human_capital_management/issue_summary.

of its work—information it can use to better understand workforce needs.⁴³ AST officials told us that these steps facilitate more informed decision-making about the number of staff needed in specific positions for the next budget cycle. However, these steps do not provide the information AST needs to determine the optimal size and composition of its entire workforce or enable it to project workforce needs sufficiently into the future.

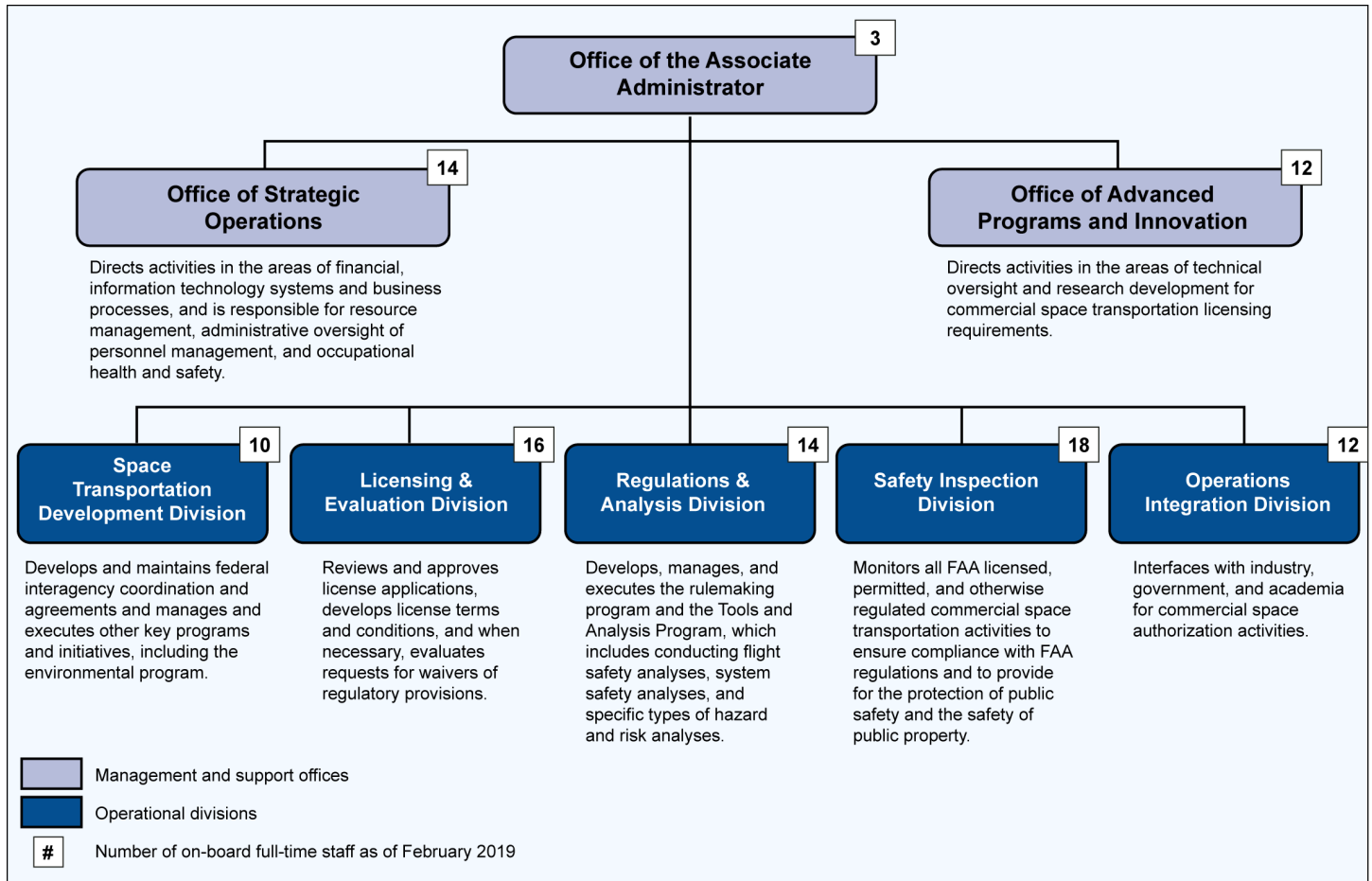
Revised Timecard System

AST launched a revised timecard system in June 2016 to more comprehensively account for staff time spent on specific activities. According to AST officials and our review of relevant documentation, including a list of revised time codes, the revised system allows staff to record hours worked on individual tasks, such as launch observations or consultations with launch companies prior to application submission (i.e., pre-application consultation), training, and leave.⁴⁴ Time codes were revised for all AST staff—that is, staff in its five operational divisions, management office, and two support offices (see fig. 6)—to account for all major tasks they perform. AST officials told us that the new timecard data, in combination with workload metrics, can help inform its current workforce needs.

⁴³ These improvements were implemented in part in response to a GAO recommendation for FAA to provide more detailed information in its budget submissions for AST regarding its workload. ([GAO-15-706](#)). FAA's fiscal year 2017 and 2018 budget submissions included data collected as part of this effort, such as those for pre-application consultations. This recommendation has been closed as implemented.

⁴⁴ Officials said that the previous timecard system was not specific enough for AST to determine how staff spent their time. For example, timecard data from 2014 to 2015 showed that AST staff charged more than 60 percent of hours to “regulating and promoting commercial space transportation.”

Figure 6: Organizational Chart with Number of On-Board, Full-Time Staff for FAA’s Office of Commercial Space Transportation, February 2019



Source: GAO analysis of Federal Aviation Administration (FAA) information. | GAO-19-437

Note: The FAA Reauthorization Act of 2018, signed into law in October 2018, required that AST develop an Office of Spaceports. FAA Reauthorization Act of 2018, Pub. L. No. 115-254, § 580(b), 132 Stat. 3186 (2018). According to FAA officials, as of May 2019, FAA is finalizing the design of and staffing for the office.

Workload Metrics

For its five operational divisions, AST officials have developed and continue to refine a set of workload metrics, which, along with other data, enable AST to identify the resources that are used to carry out key AST activities, such as licensing and overseeing launches. These metrics track the number of work activities (e.g., regulatory waivers issued or safety inspections conducted) that are ongoing or were completed over a certain time period. For example, in fiscal year 2018, AST was engaged in pre-application consultations with about 23 commercial launch providers and

was evaluating more than 16 license applications on average per month. Officials analyze these metrics in combination with timecard data to determine the number of staff hours and average number of days spent completing specific activities.⁴⁵ For example, between March and August 2017, FAA officials reported that for each ongoing project, staff spent an average of about 60 hours per month on pre-application consultations. Officials plan to use the results of this analysis in the fiscal years 2021–2022 budget cycle to help estimate the number of staff currently needed in specific positions within its five operational divisions.

However, with regard to its management and two support offices— which represent about one-third of AST’s total staff—AST has not yet developed workload metrics. Staff in AST’s management and support offices are responsible for overseeing research and development; advising and assisting other offices on technical matters; coordinating and liaising with international entities and other federal agencies; as well as performing other support operations, such as budget and financial planning.

Officials told us that although they would like to develop these metrics, they put the effort on hold because of competing priorities within AST, such as updating its licensing regulations. Officials said that they had first focused on better understanding the workforce needs of the operational divisions, which have responsibility for the majority of AST’s primary mission areas, such as licensing and overseeing launches. In discussing this approach AST officials stated that recent budget constraints have limited their ability to address all of their current identified workforce needs, which, according to their most recent workforce plan, are in nearly all areas of their office. As a result, officials said that they use their limited number of authorized positions to fill their most immediate workforce needs, typically in the operational divisions.

However, without workload metrics that would allow AST to determine the number of staff needed for its workload regardless of what office or division, it is difficult for AST to determine the appropriate number and composition of staff to most effectively carry out its statutory priorities and help ensure that it uses its limited resources in the most efficient way. In addition, AST officials told us that they recognize that past hiring decisions and balance of workload among staff may not have been fully

⁴⁵ AST officials demonstrated their ability to conduct this analysis by providing draft results to us.

aligned with AST's statutory priorities and that the composition and ratio of staff may no longer be appropriate given the evolution of the industry and the revised regulatory structure under way. As a result, officials stated that in the coming months they intend to take a fresh look at the organization of the Office of Commercial Space Transportation as a whole to better balance the needs of the industry with the organizational requirements. In addition to developing an Office of Spaceports, as required by the FAA Reauthorization Act of 2018,⁴⁶ officials told us that they will consider re-organizing the offices and divisions, as well as the workload and staff currently within them.

Workload Projections

AST also has taken steps to improve its ability to estimate its workload for a 2-year budget cycle, which, according to AST officials, will help them determine and justify near-term workforce needs. Specifically, from the new workload metrics discussed above, AST officials told us they had identified five key activities⁴⁷ that best reflect historical workload trends and that officials then plan to combine with their assumptions about how the industry will evolve over the next 2 years. Officials told us that they plan to use this approach for the first time in the fiscal years 2021–2022 budget cycle. In past budget cycles, AST relied primarily on the projected number of launches to estimate its workload; this number, officials noted, is the most important factor but resulted in an incomplete reflection of the five operational divisions' workload. For example, officials told us that the workload of its operational divisions encompasses a range of activities leading up to a launch that would not be captured in its workload estimates if AST only looked at the number of launches. Now, under their planned approach, AST officials said that they will better account for the full range of regulatory activities and the timeline of its licensing process.

While planned improvements to AST's workload estimates better account for the full range of AST's regulatory activities, limiting these estimates to the 2-year budget cycle reduces AST's ability to anticipate and respond to emerging workforce needs. AST recognizes the importance of longer-term workforce planning by developing and annually updating a 5-year workforce plan. Also, as noted above, key principles for effective strategic

⁴⁶ FAA Reauthorization Act of 2018, Pub. L. No. 115-254, § 580(b), 132 Stat. 3186 (2018).

⁴⁷ As of November 2018, the five metrics represent key activities throughout the licensing process and include the number of active initial discussions with prospective licensing applicants; active pre-application consultations with entities interested in submitting licensing applications; ongoing evaluations of site operator, reentry, or launch licenses; ongoing environmental reviews; and completed safety inspections.

workforce planning emphasize the importance of forward-thinking planning to help organizations align their workforce to meet future programmatic goals. According to AST officials, they estimate the workload for 2 years in part because it is intended to help them identify and justify workforce needs during the 2-year budget process, as well as prioritize addressing immediate workforce needs. Officials also said that substantial uncertainty surrounds longer-term industry forecasts, and consequently, any assessment of longer-term workforce needs. For example, they pointed to a number of factors that lead to the unpredictability of how the industry will evolve, including the variable pace at which new launch companies progress and the future of the commercial suborbital launch sector, particularly the nascent space launch tourism industry. They also noted that a launch vehicle accident or other risks could affect the industry's rate of growth.

In our prior work, we have discussed some approaches used by other agencies to help assess future workforce needs when faced with uncertainties. One approach involves scenario planning, in which a federal agency operating in a changing environment used a range of scenarios, each of which represented different future environments that the agency may face, to help predict how the scope and volume of its activities might change in each scenario.⁴⁸ For AST, such an approach could entail developing a range of workload projections based on different industry and regulatory environments that it thinks it may face, along with associated workforce management strategies to address those environments.

AST officials said that they were considering projecting their workload estimates further into the future and intend to work with FAA's Office of Aviation Policy and Plans—the office that helps develop FAA's 20-year aerospace industry forecasts—to leverage that office's forecasting expertise. However, AST has not established a timeline with milestones or formally committed to conducting longer-term workload projections. Longer-term workload projections may be particularly beneficial to AST to help make well-timed decisions about hiring and training staff and to help ensure AST has qualified staff available when they are needed. For example, according to officials, it can take a few years for systems safety engineers to be trained and have the sufficient experience to lead

⁴⁸ GAO, *Human Capital: Selected Agency Actions to Integrate Human Capital Approaches to Attain Mission Results*, [GAO-03-446](#) (Washington, D.C., Apr. 11, 2003) and [GAO-04-39](#).

projects. Further, AST officials told us that hiring technically qualified personnel, including positions that require considerable training and experience to be a fully functioning employee, is challenging. Without an understanding of its projected workload beyond a budget cycle, AST will be limited in its ability to effectively and strategically plan for its longer-term workforce needs and take action when the opportunity arises. As such, AST remains at risk of not having the right number of staff in the right positions to keep pace with and respond to changes in the commercial space transportation industry.

AST Lacks Information to Identify Gaps in Staff Skills and Competencies

Our prior work on strategic workforce planning underscores the importance for organizations to determine the skills and competencies that are critical to successfully achieving their current and future missions and goals.⁴⁹ Once the necessary skills and competencies have been identified, key principles for effective strategic workforce planning call for an organization to identify—and subsequently develop strategies to address—gaps between the skills and competencies needed and those that its workforce has. Those gaps should include both current skills gaps (i.e., skills that its workforce currently needs but does not possess) and emerging skills gaps (i.e., skills that its workforce may need in the future but does not possess). Further, according to federal *Standards for Internal Control*,⁵⁰ an organization’s management should ensure that the workforce skills necessary to achieve programmatic goals are continually assessed. This step is especially important as changes in national security, technology, budget constraints, long-term fiscal challenges, and other factors may occur in the environment within which federal agencies operate.⁵¹

AST, however, does not currently collect the information needed for it to conduct a skills gap analysis. Rather, AST has a basic understanding of the skills and competencies of its workforce. For example, its current workforce plan includes the following information on AST’s workforce:

⁴⁹ [GAO-04-39](#) and [GAO-15-223](#). The Office of Personnel Management’s definition of a competency refers to the knowledge, skills, abilities, behaviors, and other characteristics needed by an individual to successfully perform their work or occupation.

⁵⁰ GAO, *Standards for Internal Control in the Federal Government*, [GAO-14-704G](#) (Washington, D.C.: September 2014).

⁵¹ [GAO-04-39](#).

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- Level of education—the percentage and number of employees having attained bachelor’s, master’s, and doctorate degrees.
 - Occupation—the percentage and number of employees in mission-critical occupations (e.g., aerospace engineers).
 - Age—the percentage and number of employees by age range.
 - Tenure—the average number of years employees have been in their current position and employed by FAA.
 - Retirement eligibility—the number of employees who will be eligible to retire each year during the 5-year period of the staffing plan.

AST officials acknowledged that the workforce information it currently collects is insufficient to allow them to systematically identify gaps in specific staff skills or competencies—such as expertise in flight safety analysis or launch vehicle propulsion—needed for evaluating certain launch license applications. Officials told us that they do prioritize filling positions, through hiring or contracting, that address the organization’s most immediate needs. However, this strategy focuses on positions, as opposed to identifying specific skills or competencies within those positions.

AST officials told us that they are planning to develop and annually administer to staff and managers a skills assessment survey that would collect information about the specific skills and competencies that individual staff currently possess. Officials told us that the results of the survey would allow them to assess the current skills of AST’s workforce and in combination with other information, such as expected attrition and retirement rates, help identify current and emerging skills gaps. In July 2018, officials told us that they plan to complete the survey and administer it in time for inclusion in their workforce plan for fiscal years 2019–2023, estimated to be issued in April or May 2019. However, officials subsequently stated that their survey plans have been delayed for multiple reasons, including DOT’s lapse in appropriations. Accordingly, as of May 2019, AST had neither developed a draft of the skills assessment survey, nor established a formal timeline for finalizing it or a plan for periodically administering the survey. Furthermore, officials told us that they are currently negotiating with the union’s bargaining unit to gain approval to administer a survey that does not maintain anonymity to non-management staff. They said that if they cannot obtain the bargaining unit’s approval, they will need to develop an alternative plan because they do not believe that collecting anonymous data on staff skills would allow them to identify skills gaps for these staff.

Officials told us that they also intend to include in the survey skills and competencies that may be needed in the future. They stated that they did not know for certain if or how they would identify what those new skills might be, but that they are considering soliciting feedback from industry stakeholders, such as through FAA's Commercial Space Transportation Advisory Committee, to help identify any future competencies that may be needed as a result of the evolution in the industry.

Without systematic information on specific skills and competencies of its entire workforce, AST lacks reasonable assurance that its current workforce possesses the requisite skills and competencies and may not be able to efficiently identify opportunities to move staff within AST to help address identified skills gaps. And, ultimately, AST may not be prepared to make strategic decisions on how to address emerging skills gaps and align its staff to achieve future programmatic goals, such as identifying and acquiring potential new skills and competencies needed under a revised regulatory structure.

FAA Is Exploring Technological and Procedural Solutions to More Efficiently Accommodate Commercial Space Operations

FAA's Current Approach to Accommodating Launch and Reentry Operations Results in Inefficiencies for Airspace Users and FAA

FAA officials and representatives from the commercial space and aviation industries we met with agree that FAA's current approach to accommodating commercial space launch and reentry operations into the National Airspace System (NAS) is inefficient.⁵² FAA has the responsibility for ensuring the safe and efficient use of the NAS, a limited national resource, for and by all users, including commercial and business airlines and commercial launch providers, among others. To this end, according to FAA officials and documents describing operational procedures and risk evaluation, FAA takes measures during a commercial space operation aimed at preventing fatalities, injuries, and property damage, and ensuring that nothing interferes with the launch vehicle's operations.

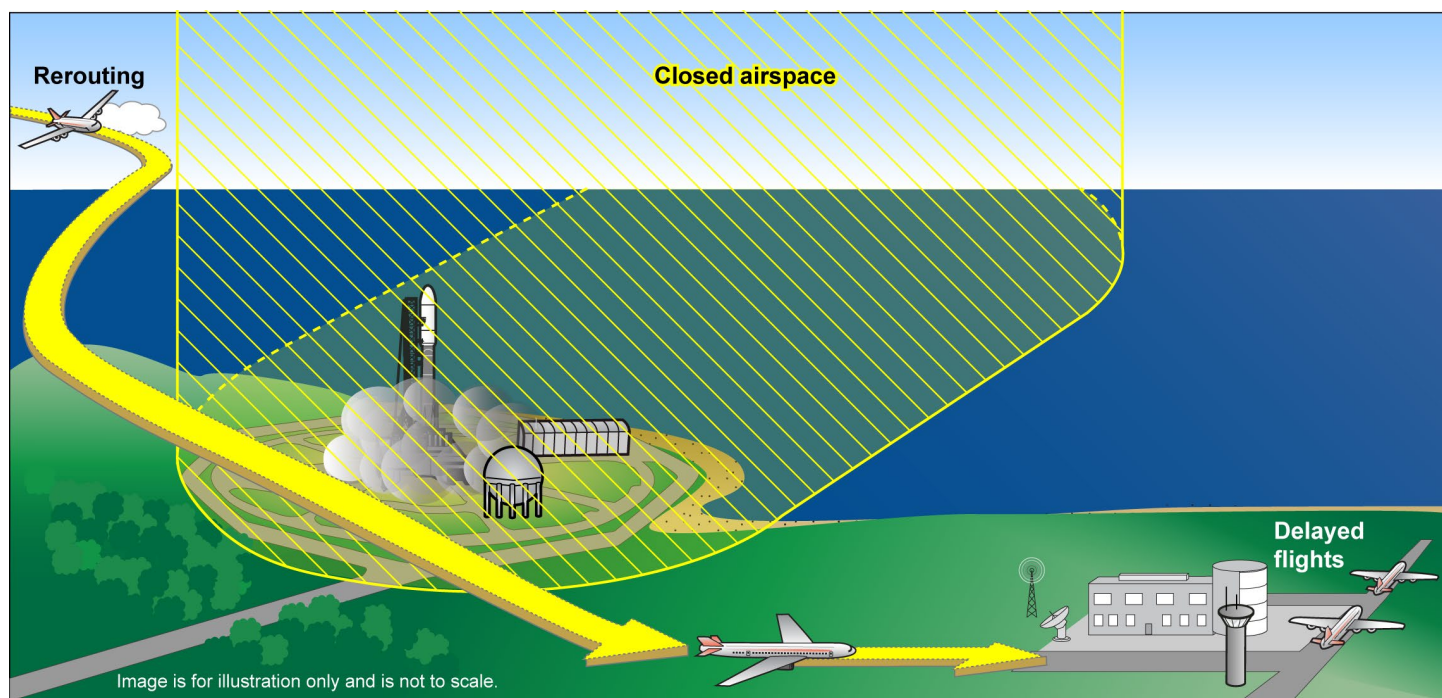
FAA's current approach, as described in documents that explain how FAA mitigates risk to people and property during a space launch, is to close the airspace around a commercial launch operation—in some cases hundreds of square miles for several hours—to other airspace users, such as commercial airlines.⁵³ Prior to launch, FAA establishes the size

⁵² For example, FAA has convened the Airspace Access Priorities Aviation Rulemaking Committee, drawing members from the commercial space and commercial airline industries together to advise FAA on how to more efficiently and equitably manage the airspace around commercial space launches. FAA also has sponsored studies on increasing efficiency of airspace integration through its Center of Excellence for Commercial Space Transportation.

⁵³ When the closed airspace extends to sea level, launch providers must notify the Coast Guard so it can issue a Notice to Mariners to avoid the airspace. FAA also works with the Coast Guard, when necessary, to monitor the hazard area during the launch window.

and duration of the airspace closure, also known as an aircraft hazard area, and, days ahead, notifies potentially affected airspace users about the upcoming closure. FAA calculates the size and boundaries of the aircraft hazard area generally based on the risk to life and property posed by a launch vehicle's expected trajectory, as well as potential trajectories in the case of a vehicle's failure and the subsequent paths of falling debris.⁵⁴ The duration of the closure is generally dependent on the period of time in which the launch or reentry is expected to occur—known as a launch window—which varies by the type of launch or reentry vehicle, among other things. The aircraft hazard area extends from sea level up to unlimited height, and generally does not change in size or shape during the entirety of the launch window (see fig. 7).

Figure 7: Example of Closed Airspace to Accommodate a Space Launch Vehicle Operation



Source: GAO. | GAO-19-437

⁵⁴ According to FAA documents and officials, FAA currently sets aircraft hazard areas based on the prescribed level of risk in 14 C.F.R. § 415.35—equal to one-in-a-million or less chance that a piece of debris from a failed space launch vehicle results in an injury to an individual member of the public.

According to FAA officials, the designated aircraft hazard areas are larger and remain in effect longer than may actually be needed to ensure public safety. For example, according to FAA officials and launch documentation, to protect public safety, the duration of an airspace closure is always longer than the launch window. In fact, in some cases, the airspace closure may be scheduled for more than 3 hours, which is substantially longer than the time typically required for space launch and reentry operations from Cape Canaveral (about 30 minutes). FAA officials explained that they are not able to monitor or respond to dynamic circumstances associated with space launch vehicles in the NAS in real-time. As a result, FAA closes the airspace for when and where it is potentially—rather than actually—hazardous.

FAA officials told us that the agency’s approach to date for accommodating space launch operations into the NAS has helped ensure public safety during launches.⁵⁵ For instance, during fiscal years 1989 through 2018, FAA reported that it licensed 357 launches or reentries, and in this time there were no fatalities, serious injuries, or significant property damage to the uninvolved public. However, according to FAA officials and research, FAA’s approach creates inefficiencies in how the airspace around launch operations is used—such as causing flight delays for commercial airlines. FAA officials and commercial space industry representatives said it also makes scheduling these operations more challenging for launch providers, and affects FAA’s operational efficiency. The effects on each of these groups are described below.

- **Commercial airlines.** FAA has estimated that, in fiscal year 2017, about 1,200 commercial airline flights were directly affected—that is, rerouted or delayed—around 22 space launch operations, resulting in an estimated 39,000 additional miles flown.⁵⁶ The majority of these miles were flown in proximity to Cape Canaveral in Florida, which hosted the majority of domestic launches that year. FAA further

⁵⁵ FAA schedules licensed commercial space launches and reentries to traverse the NAS at the locations indicated in the license, at a date and time that will facilitate the launch customer’s mission. Arrangements to use the NAS are finalized in advance with FAA, according to terms previously set in letters of agreement between the launch provider and FAA.

⁵⁶ GAO has reported in the past that, because of the interdependence of the nation’s airports, aircraft delays at one airport can cause a “ripple” effect of delays across the country. GAO, *National Airspace System: Initiatives to Reduce Flight Delays and Enhance Capacity are Ongoing but Challenges Remain*, [GAO-05-755T](#) (Washington, D.C., May 26, 2005).

estimated that, of the 15 space launches from January to October 2018 around Florida where airspace tends to be busy due to the high volume of commercial airline traffic along the East Coast, an average of 60 aircraft per launch were directly affected.⁵⁷ For all commercial launch sites, FAA estimates that the number of directly affected aircraft ranged up to 153 for an individual launch with an average of fewer than 10 aircraft per launch outside of the Florida area.⁵⁸

According to FAA officials, these estimates are based on historical data on the number of aircraft that typically fly through that area at the time of the airspace closure. Because launches can be delayed by hours or days for reasons such as unforeseen weather conditions or technological issues, airlines and other affected airspace users may face challenges when attempting to plan around a launch to avoid flight reroutings and delays. Representatives of a major airline trade association told us that the spread of launch activity beyond Cape Canaveral, as well as the development of new launch vehicles, has heightened their concerns about inefficiencies in how airspace around launch operations is used.

- **Launch providers.** The size and duration of aircraft hazard areas can make it difficult for FAA to find time slots to accommodate commercial space launches because of its responsibility to ensure the efficient use of the national airspace, a limited resource. All the launch providers we spoke with that had conducted launches at U.S. commercial launch sites said they have been able to find suitable launch windows that met with FAA approval. However, one launch provider told us of an occasion when FAA had denied the originally requested launch date and time because it fell within a time of unusually congested airspace.⁵⁹ In addition, more than half of the launch providers told us that they anticipate challenges obtaining approval for a requested launch date or time in the future.⁶⁰

⁵⁷ FAA estimates that the Falcon Heavy launch in February 2018 directly affected 563 aircraft.

⁵⁸ FAA officials also noted that some flights are considered higher-value than others (e.g., transpacific flights around Alaska), and that the quantity of aircraft rerouted or delayed is not the only indicator of level of impact.

⁵⁹ FAA officials said that FAA avoids scheduling commercial space launches when the airspace is more congested than usual.

⁶⁰ Evolution in the types of launch operations—for example, the increased use of reusable rockets—may also exacerbate these effects.

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- **FAA.** In addition to effects on NAS users, FAA officials told us that FAA itself also experiences operational inefficiencies in managing air traffic during launches. This inefficiency is, in part, because FAA's current policies and procedures were developed for aircraft operations and either have not yet been fully adapted for commercial space operations, or a relevant policy or process is missing altogether. For example, FAA's current procedures for launch providers and FAA to follow when they request, schedule, and conduct launches require different FAA facilities to negotiate unique agreements for each separately licensed operation or activity. This process can be time-consuming. For example, one launch provider told us that it took 1½ years to finalize minor changes to a letter of agreement. As we discuss later, FAA is taking steps to standardize these letters.

FAA Aims to Increase Efficiency of Launch Integration through New Technologies, Procedures, and Industry Coordination

According to FAA documentation and officials we spoke to, FAA aims in the long term to increase utilization of the NAS by integrating launch vehicle operations into the NAS with other users, rather than its current approach of segregating launch and reentry operations through airspace closures. Specifically in 2011, FAA began identifying actions it could take and developing plans to address challenges associated with closing portions of the airspace during launch operations.⁶¹ It did so in light of the increasing frequency of commercial space launch and reentry operations and the spread of operations to new locations. According to FAA officials, the actions and plans continue to evolve as FAA learns more and reacts to anticipated changes in the commercial space transportation industry.

Further, officials told us that FAA's vision for full integration of commercial space launch operations cannot be defined by a single solution or an end goal because the demands of these operations on the NAS are constantly changing. Consequently, FAA officials said that full integration of commercial space operations into the NAS will reflect a collection of visions or approaches that improve predictability and efficiency while maintaining safety. For example, according to FAA documents and officials we spoke to, FAA's approach for experimental launches will always be to close the airspace around the launch to other users. In contrast, FAA may develop standards for some launch vehicles, such as hybrid launch vehicles with repeated successful operations, which specify a safe distance and duration of separation in the airspace.

⁶¹ The fiscal year 2012 business plan for FAA's Air Traffic Organization (ATO), which manages the National Airspace System, includes activities related to safe, efficient, and secure operation of space vehicles in the NAS and in close proximity to air traffic.

FAA has two key internal documents to help guide the development and implementation of its actions as it seeks to better integrate commercial space launches and reentry operations into the NAS and reduce FAA's operational inefficiencies.

- **A concept of operations:** FAA officials expect to finalize a concept of operations in 2019, which will provide a long-term, high-level vision for FAA's efforts to efficiently integrate commercial space operations. According to FAA officials, it will describe, among other things, FAA's existing approach to and associated shortfalls in accommodating commercial space operations, as well as proposed tools, policies, and procedures to address those shortfalls. According to FAA officials, it also will inform FAA's current and future efforts to identify needs for new or modified technologies, tools, procedures, and policies.
- **Roadmap for the Integration of Space Operations in the National Airspace System (Roadmap):** This document serves as a planning and tracking tool for FAA's operational arm—the Air Traffic Organization—to use as it seeks to more efficiently manage the airspace during commercial space launch and reentry operations while maintaining safety. It identifies, prioritizes, and tracks the specific changes needed to begin addressing the related shortfalls that FAA officials told us will be discussed in the concept of operations. According to the Roadmap, some of the activities are exploratory, and FAA expects that new activities will be identified and added to the development schedule as FAA continues to work with stakeholders to determine how best to manage the airspace, and conceptualizes and develops key technologies. The first Roadmap was released in November 2016, and, according to FAA officials, FAA plans to update it annually. FAA officials told us they expect to release the third and most recent version in 2019. The activities it identifies are divided into: short-range (to have been completed in calendar year 2018); mid-range (through 2022); and long-range (through 2023 and beyond) time frames, during which FAA plans to develop and incorporate new technologies, policies, processes, and regulations.

In completing the actions needed to implement the approaches outlined in the Roadmap, FAA officials told us that they are actively working with FAA's Performance Analysis Directorate to develop a set of metrics to measure the progress and effectiveness of its actions. Officials also highlighted that because the demands of commercial space operations on the NAS are constantly changing, as noted above, there is no defined end goal. To this end, the purpose of any metrics officials develop will be to help determine if their actions are helping increase efficiency while maintaining safety, not measure their progress toward a goal of full

airspace integration. FAA officials told us they plan to have a set of metrics completed by early 2019. Some of these metrics will likely use currently available data, such as the number of aircraft rerouted and how many additional miles rerouted aircraft fly, while others are still being identified. Further, FAA officials told us that FAA coordinates actions related to commercial space integration through an interagency working group established in 2015. The group meets monthly and members include officials from across FAA lines of business, as well as other federal agencies, including the Department of Defense.

The Roadmap shows that FAA's actions to better integrate commercial space launch and reentry operations into the NAS include, but are not limited to:

- developing new technologies;
- updating and assessing needed changes to policies, procedures, and regulations; and
- coordinating with aviation- and space-industry stakeholders.

Technology

FAA's technology efforts are related primarily to collecting real-time data on a launch vehicle's position and path, automatically generating the required aircraft hazard area, and integrating those data into the existing structure of the air traffic control systems. As a result, FAA officials said that FAA may ultimately be able to dynamically change the size and duration of the aircraft hazard area in some types of launches, thereby reducing the amount and duration of airspace closed to other users.

In the short term, FAA is assessing how existing air-traffic control technologies and procedures could be used to help reduce the effects of launches on other NAS users. According to an FAA official, for example, four initiatives currently used to manage air traffic during other airspace constraints could potentially be used during space launch operations. One initiative would enable air traffic controllers to strategically control the number of flights approaching the aircraft hazard area so that if these flights were in the hazard area at the time of a launch vehicle failure, controllers could still clear the area quickly enough to protect public safety. This FAA official told us that if they decide to pursue these initiatives, they hope to complete some of the necessary steps to do so by summer 2019.

For potential use in the longer-term, FAA is piloting prototypes of two key technologies by running them alongside existing air-traffic control systems

during selected launches, thereby testing their capabilities without their being fully operational.

- The Space Data Integrator (SDI) is designed to receive real-time data on launch vehicle position and movement and display real-time aircraft hazard areas to enable improved situational awareness. FAA officials told us that, as FAA is assessing approaches to shift from static to more dynamic hazard area calculation capability, initial SDI capabilities will likely be deployed in advance of more integrated and improved real-time hazard area generation capabilities. In addition, FAA officials told us that they are exploring alternative acquisition strategies that could enable partial system implementation for the technology by 2022.⁶² Because FAA has not made a final investment decision, the date of system-wide implementation of SDI is unknown.
- According to FAA officials, the Hazard Risk Assessment and Management (HRAM) tool, if pursued, is intended to help automatically communicate SDI data to air traffic control systems and, in the future, to present air traffic controllers with information that would allow them to decide how to best manage the airspace. Officials also said that HRAM involves modifying an existing air traffic management tool, currently has very limited capabilities, and is still only under consideration as a possible approach. Over the next year these officials plan to work on some of the tool's components, assess what types of data are valuable to air traffic controllers, and determine whether to continue developing this technology or consider alternative technologies.

Policies, Procedures, and Regulations

According to the Roadmap, FAA has identified policies and standard operating procedures that need to be created or updated to enable it to better manage the operating environment during space launches. Actions taken to date include, for example:

- developing training materials to inform air traffic personnel about commercial space operations in the NAS;
- developing a high-level strategy for integrated space vehicle operations going forward; and

⁶² Officials said that they published in March 2019 an announcement seeking interest from industry on partnering with FAA to further develop the system. Officials told us that they have had success in the past when FAA partnered with an industry for system development, which involved providing industry with a business opportunity and allowing FAA to solve a technical problem without purchasing a new technology.

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- standardizing the terms of reference for commercial space operations for use by FAA, NASA, and DOD.

In addition, according to the Roadmap, FAA plans to standardize some letters of agreement—the document specifying procedures that a launch provider and FAA use to request, schedule, and conduct launches. Officials said they hope to issue documentation of these changes by September 2019. FAA officials told us that these changes will result in letter of agreement templates for use by FAA. FAA officials said FAA also plans to continue reviewing its regulations, policies, and procedures to identify other areas that need updating or entirely new language.

Industry Coordination

FAA is taking steps to foster coordination between commercial space and aviation industries to help develop and increase buy-in for new and revised approaches to improve the efficiency of the national airspace for all users. Most notably, in November 2017, FAA chartered an aviation rulemaking committee to examine the issue of equitable airspace access among various users. Committee members include a mix of commercial space transportation and aviation industry representatives.⁶³ Topics being addressed include identifying potential criteria that FAA may use when considering competing user priorities for airspace, as well as potential tools that could help mitigate the effects on other airspace users during launch operations. FAA officials told us that the committee anticipates issuing a report and recommendations to FAA in April 2019, and some members of the committee highlighted that the meetings benefited their understanding of other users' unique needs; economic benefits; and experiences with regard to integrating space operations.

Also, an FAA official said the agency has sponsored four “Industry Days” events since 2014 for the commercial space industry. At each event, multiple FAA offices discussed their roles and responsibilities associated with space launches and answered questions from industry. For the first time, at its 2018 event, FAA invited aviation industry representatives to encourage continued dialogue between the commercial space and aviation industries. FAA officials also noted that they solicited ideas on priority actions from participants and are currently reviewing those ideas to help inform their next steps. Separately, FAA expanded the membership of its Commercial Space Transportation Advisory Committee

⁶³This ARC is co-sponsored by FAA's Air Traffic Organization and Office of Commercial Space Transportation and is distinct from the launch licensing rulemaking ARC discussed in the report section discussing FAA's efforts to streamline its licensing regulations.

to include representatives of the aviation industry in addition to the commercial space transportation industry to foster further dialogue between these groups.

Conclusions

The commercial space transportation industry provides a service that has become essential to many aspects of government, business, and society. The capability to launch payloads into space enables national security missions, mobile communications, and scientific research, among many other applications. AST's role as a regulator of commercial space launch providers is fundamental to the continued safe growth of the industry. With the anticipated growth and potential organizational restructuring of AST, as well as the evolution of the commercial space transportation industry, it is vital that AST ensure that the size, composition, and skills of its workforce are aligned with its projected workload, based on anticipated future mission and programmatic goals. AST's workforce plan states that AST needs additional staff in nearly all areas. However, current budget and long-term fiscal pressures heighten the need for agencies to strategically manage their workforce, a process that includes making strategic decisions about how and where to prioritize limited resources. AST does not have a complete understanding of its current and projected workload, nor does it know the number of staff and types of staff skills and competencies necessary to meet those workload needs. Without this information, AST risks managing its workforce reactively to a rapidly changing environment instead of strategically planning for the future.

Recommendations for Executive Action

We are making the following four recommendations to FAA:

1. The Associate Administrator of AST should develop workload metrics that encompass the whole office and that would allow AST to determine an appropriate workforce size and composition. (Recommendation 1)
2. The Associate Administrator of AST should establish a timeline for finalizing workload projections that extend beyond the 2-year budget cycle and that include an approach for addressing uncertainty. (Recommendation 2)
3. The Associate Administrator of AST should ensure that its skills assessment survey collects information from staff on skills and competencies in those areas that are both currently needed and may be needed in the future. (Recommendation 3)

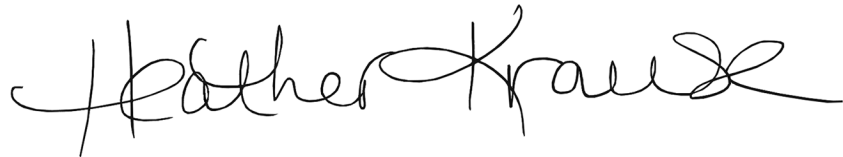
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4. The Associate Administrator of AST should develop and document a plan for periodically assessing whether staff possess the necessary skills and competencies to achieve programmatic goals, such as annually administering a skills assessment survey. (Recommendation 4)

Agency Comments

We provided a draft of this product to DOT and NASA for review and comment. In its written comments reproduced in appendix III, DOT concurred with our recommendations. DOT and NASA also provided technical comments that we incorporated, as appropriate.

We are sending copies of this report to the appropriate congressional committees, DOT, NASA, and other interested parties. In addition, the report is available at no charge on the GAO website at <http://www.gao.gov>.

If you or your staff members have any questions about this report, please contact me at 202-512-2834 or KrauseH@gao.gov. Contact points for our Office of Congressional Relations and Public Affairs may be found on the last page of this report. GAO staff who made major contributions to this report are listed in appendix IV.



Heather Krause
Director, Physical Infrastructure Issues

Appendix I: Objectives, Scope, and Methodology

Our objectives for this report were to: (1) describe how the construction of infrastructure at selected U.S. commercial launch sites has been funded; (2) describe key factors that influence where orbital launches occur; (3) summarize actions the Federal Aviation Administration (FAA) has taken to streamline its commercial space launch regulations; (4) examine how well-positioned FAA's Office of Commercial Space Transportation (AST) is to determine its current and future workforce needs; and (5) identify actions FAA is taking to better integrate commercial space launch operations into the National Airspace System (NAS).

The scope of this report focuses on topics related to FAA's oversight of the U.S. commercial space transportation industry. Therefore, the report does not discuss launch indemnification and the safety of human spaceflight, or examine international outer space treaty obligations.

For all objectives, we reviewed relevant statutes, regulations, and directives governing FAA's oversight of the U.S. commercial space transportation industry. In addition, we interviewed AST officials and conducted semi-structured interviews with all seven commercial space launch providers that had conducted an FAA-licensed launch operation as of January 2018.

To describe how infrastructure at selected commercial launch sites has been funded, we first identified, through review of FAA information on launch site operator licenses and launch licenses, all U.S. commercial launch sites—those that have an FAA site operator license to conduct commercial launch operations and those that may not have a site operator license but have hosted FAA-licensed launch operations. From these 15 identified U.S. commercial launch sites, we selected 9 for review because the launch site has hosted FAA-licensed launch operations between January 1, 2015, and December 31, 2018. We reviewed relevant publicly-available documents, such as launch sites' business plans, user guides, and other planning documents related to U.S. commercial launch sites. We interviewed the eight launch site operators of the nine selected launch sites.¹ The perspectives of the selected launch site operators are

¹ A launch site may have multiple launch site operators because, for example, each launch pad at the launch site may have a different operator. Also, a launch site operator can operate at multiple launch sites, such as SpaceX's launch operations at Vandenberg Air Force Base and Cape Canaveral. As a result, the number of U.S. launch site operators is not directly correlated to the number of U.S. commercial launch sites. One of the two launch site operators that has hosted FAA-licensed launches at Vandenberg Air Force Base did not respond to our requests for an interview.

not generalizable to those of all launch site operators; however, the information obtained provides a balanced and informed perspective on the topics discussed.

In addition, we interviewed members of the Commercial Spaceflight Federation’s working group on commercial launch sites.² See table 2 for a full list of entities interviewed.

Table 2: Commercial Space Transportation Industry Stakeholders Interviewed

Organization	U.S. commercial launch provider	Launch customer	U.S. commercial launch site operator ^a
Alaska Aerospace	X	X	✓
Astrobotic	X	✓	X
Blue Origin	✓	X	✓
Deep Space Industries ^b	X	✓	X
Eutelsat	X	✓	X
Exos Aerospace	✓	X	X
Iridium	X	✓	X
Mojave Air and Space Port	X	X	✓
Northrop Grumman Innovation Systems	✓	✓	X
Rocket Lab	✓	X	✓
Space Florida	X	X	✓
Spaceport America	X	X	✓
SpaceX	✓	X	✓
Spire	X	✓	X

²The Commercial Spaceflight Federation is a member organization representing commercial spaceflight developers, operators, and spaceport operators, among others.

Organization	U.S. commercial launch provider	Launch customer	U.S. commercial launch site operator ^a
SSL	X	✓	X
United Launch Alliance	✓	X	✓
Virgin Galactic	✓	X	X
Virginia Space	X	X	✓

Legend: ✓ = yes; X = no

Source: GAO. | GAO-19-437

^aWe define U.S. commercial launch site operator as one that either has an FAA site operator license or operates a site that has hosted FAA-licensed launch operations.

^bIn December 2018 Deep Space Industries was sold to Bradford Space.

To describe key factors influencing where orbital launches occur, we reviewed data from FAA’s 2018 *Annual Compendium of Commercial Space Transportation* as well as FAA data on recent launches within the United States. We interviewed representatives from seven launch customers, selected based on the following criteria:

- The company is not a government entity.
- The company’s payload was commercial, as documented in FAA’s commercial space launch compendiums.
- The customer had multiple launches in 2016 and 2017, with at least one of those launches occurring in 2017.
- The customer has had at least one launch in the United States that was licensed by FAA.

Among the companies that met these criteria, we chose our final selections to have a mix of the following characteristics:

- domestic and non-U.S. companies,
- those that had launched exclusively at one launch site versus multiple launch sites, and
- those that are involved in traditional space activities, such as satellite communications companies and remote-sensing companies and those that are pursuing non-traditional space activities, such as asteroid mining and satellite servicing.

The perspectives of the selected launch customers are not generalizable to those of all launch customers; however, the information obtained provides a balanced and informed perspective on the topics discussed.

To summarize actions FAA is taking to streamline its commercial space launch regulations, we reviewed relevant statutes, regulations, and FAA guidance. We also reviewed FAA's documents related to the rulemaking, including its schedule of rulemaking activities and the *Streamlined Launch and Reentry Licensing Requirements* notice of proposed rulemaking issued in April 2019, and reviewed and analyzed the *Streamlined Launch and Reentry Licensing Requirements Aviation Rulemaking Committee* final report. We interviewed FAA officials and representatives of the Commercial Spaceflight Federation about FAA's ongoing and planned actions related to the rulemaking. Finally, we reviewed the minutes from the June 2018 meeting and attended the October 2018 meeting of the Commercial Space Transportation Advisory Committee, in which FAA officials and industry representatives discussed FAA's actions on the rulemaking.

To examine how well-positioned AST is to make strategic decisions about its current and future workforce needs, we reviewed FAA documents, including its budget justification and workforce plans from the past 3 years. We also reviewed FAA's year-end reports on its workload metrics from fiscal years 2017 and 2018, and portions of FAA's preliminary labor analyses using its revised timecard data and workload metrics. We identified key principles on effective strategic workforce planning from our previous work to use as criteria to assess FAA's actions.³ We interviewed AST officials about their plans and actions to improve its workforce planning and assessed those actions against the identified key principles for effective strategic workforce planning. We focused our analysis on those principles that are related to determining current and future workforce needs.

To identify actions FAA is taking to better integrate commercial space launch operations into the National Airspace System, we reviewed and analyzed relevant FAA documents, including a document that discusses FAA's vision for integrating commercial space transportation operations into the NAS and the *Roadmap for the Integration of Space Operations in the National Airspace System*. In addition, we interviewed FAA officials within AST, Air Traffic Organization, and the Office of NextGen regarding their ongoing and planned actions for improving the integration of commercial space transportation operations into the NAS. We also interviewed industry stakeholders to obtain perspectives on this topic.

³ [GAO-04-39](#).

These stakeholders included representatives from Airlines for America, a trade association for the U.S. airline industry, and from launch providers. Finally, we attended an FAA-sponsored industry conference in October 2018 on FAA's airspace integration efforts.

We conducted this performance audit from July 2017 to May 2019 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Appendix II: Selected Characteristics and Capabilities of U.S. Commercial Launch Sites

Table 3 shows selected characteristics and capabilities of U.S. commercial launch sites included in our review of infrastructure funding. Table 4 includes other U.S. commercial launch sites that did not have FAA-licensed activity from 2015 to 2018 and were not included in our review of infrastructure funding.

Table 3: Commercial U.S. Launch Sites Included in GAO Review of Infrastructure Funding, 2018

Launch site	Owner	Operator	FAA launch site operator license	FAA-licensed activity	Purpose of infrastructure prior to commercial launch operations	Publicly funded improvements ^c	Privately funded improvements	Launch capability
Cape Canaveral Air Force Station (CCAFS), Space Launch Complex (SLC)-40 ^a	United States Air Force (USAF)	SpaceX	n/a	√	Federal launch site	√	√	vertical
CCAFS SLC-41 ^a	USAF	ULA	n/a	√	Federal launch site	√	√	vertical
Kennedy Space Center (KSC), Launch Complex (LC)-39A ^a	National Aeronautics and Space Administration (NASA)	SpaceX	n/a	√	Federal launch site	√	√	vertical
Spaceport Florida, SLC-46	USAF	Space Florida	√	√	Federal launch site	√	n/a	vertical
Mid-Atlantic Regional Spaceport, Pad 0A and 0B	Virginia Commercial Space Flight Authority	Virginia Commercial Space Flight Authority	√	√	Federal launch site	√	√	vertical
Spaceport America	State of New Mexico	New Mexico Spaceport Authority	√	√	Purpose-built	√	√	vertical, horizontal
Vandenberg Air Force Base (VAFB) SLC-576E ^b	USAF	Northrop Grumman ^d	n/a	√	Federal launch site	n/a ^d	n/a ^d	vertical
VAFB SLC-4 ^b	USAF	SpaceX	n/a	√	Federal launch site	n/a	√	vertical
West Texas Launch Site	Blue Origin	Blue Origin	n/a	√	Purpose-built	n/a	√	vertical

Appendix II: Selected Characteristics and Capabilities of U.S. Commercial Launch Sites

Launch site	Owner	Operator	FAA launch site operator license	FAA-licensed activity	Purpose of infrastructure prior to commercial launch operations	Publicly funded improvements ^c	Privately funded improvements	Launch capability
Mojave Air and Spaceport	Mojave Air and Space Port	Mojave Air and Space Port	√	√	Airport	√	√	horizontal
Pacific Spaceport Complex - Alaska	State of Alaska	Alaska Aerospace	√	√	Purpose-built	√	n/a	vertical

Source: GAO analysis of FAA and commercial launch site information. | GAO-19-437

^aFor the purposes of this report, we consider CCAFS LC-40, LC-41, and KSC, launch pad 39A, three distinct LCs (i.e., launch pads with associated infrastructure) within one commercial launch site (i.e., Cape Canaveral). Other launch pads/complexes exist at the Cape Canaveral launch site, but have not been used for commercial purposes.

^bFor the purposes of this report, we consider VAFB, SLC-576E and SLC-4E, two distinct SLCs (i.e., launch pads with associated infrastructure) within one commercial launch site (i.e., VAFB). Other launch pads/complexes exist at VAFB launch site, but have not been used for commercial purposes.

^cWe consider publicly funded improvements to include funding from any federal, state, or local government source.

^dNorthrop Grumman is a commercial launch provider that has conducted at least one FAA-licensed orbital launch at VAFB, SLC-576E. Northrop Grumman did not respond to our requests for information about infrastructure funding at this launch site.

Table 4: Commercial U.S. Launch Sites that Did Not Have FAA-Licensed Activity from 2015 to 2018

Launch site	Owner	Operator	FAA launch site operator license	FAA-licensed activity	Purpose of infrastructure prior to commercial launch operations	Launch capability
California Spaceport (Vandenberg Air Force Base, SLC-8)	United States Air Force (USAF)	Harris Corporation	√	n/a	Federal launch site	vertical
Oklahoma Spaceport	Oklahoma Space Industry Development Authority	Oklahoma Space Industry Development Authority	√	n/a	Airport	horizontal
Houston Spaceport	Houston Airport System	Houston Airport System	√	n/a	Airport	horizontal
Cecil Field Spaceport	Jacksonville Aviation Authority	Jacksonville Aviation Authority	√	n/a	Airport	horizontal

Appendix II: Selected Characteristics and Capabilities of U.S. Commercial Launch Sites

Launch site	Owner	Operator	FAA launch site operator license	FAA-licensed activity	Purpose of infrastructure prior to commercial launch operations	Launch capability
Midland International Air and Spaceport	Midland International Airport	Midland International Airport	√	n/a	Airport	horizontal
Colorado Air and Space Port	Adams County, CO	Adams County, CO	√	n/a	Airport	horizontal
Shuttle Landing Facility	National Aeronautics and Space Administration (NASA)	Space Florida	√	n/a	Federal launch site	horizontal

Source: GAO analysis of FAA and commercial launch site information. | GAO-19-437

Appendix III: Comments from the Department of Transportation



**U.S. Department
of Transportation**

Office of the Secretary
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1200 New Jersey Avenue, SE
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Heather Krause
Director, Physical Infrastructure Issues
U.S. Government Accountability Office (GAO)
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MAY 9 2019

The Federal Aviation Administration (FAA) effectively oversees and regulates the commercial space industry without stifling growth and innovation. Whether streamlining outdated regulations, or developing technology to better integrate commercial space launches into the National Airspace System (NAS), the FAA has diligently worked to protect the uninvolved public while overseeing a rapidly growing industry.

Upon review of GAO's draft report, we concur with the four workforce planning recommendations and will provide a detailed response to each recommendation within 180-days of the final report's issuance.

We appreciate the opportunity to review the GAO draft report. Please contact Madeline Chulumovich, Audit Relations and Program Improvement, at (202) 366-6512 with any questions.

Sincerely,

A handwritten signature in blue ink that reads "Keith Washington".

Keith Washington
Deputy Assistant Secretary for Administration

Appendix IV: GAO Contact and Staff Acknowledgments

GAO Contact

Heather Krause, 202-512-2834 or krauseh@gao.gov

Staff Acknowledgments

In addition to the individual named above, Heather Halliwell (Assistant Director); Gretchen Snoey (Analyst-in-Charge); Namita Bhatia Sabharwal; Giny Cheong; Gerald L. Dillingham; Camilo Flores; Joshua Garties; Richard Hung; Delwen Jones; Elke Kolodinski; Maureen Luna Long; Malika Rice; Travis Schwartz; and Andrew Stavisky made key contributions to this report.

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