U.S. GOVERNMENT ACCOUNTABILITY OFFICE
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Washington, DC 20548

Accessible Version

July 22, 2016

The Honorable Mike Rogers
Chairman
Subcommittee on Strategic Forces
Committee on Armed Services
House of Representatives

Evolved Expendable Launch Vehicle: DOD Is Assessing Data on Worldwide Launch Market to Inform New Acquisition Strategy

Dear Mr. Chairman:

This report formally transmits the information we provided in a briefing on June 7, 2016, in response to your request to examine issues related to foreign space launch capabilities and the Department of Defense's (DOD) efforts to incorporate consideration of the global launch market into the next Evolved Expendable Launch Vehicle (EELV) program acquisition strategy. The United States government is striving to help develop a competitive market for space launches from which it can acquire its military satellite launches in order to help lower the price of launch and assure its access to space. Questions have been raised about whether competition among U.S. launch providers can be sustained in the long run given market conditions and competition from foreign launch providers in the global commercial launch market. A key question is the extent to which other countries that launch satellites rely on more than one launch provider with similar capabilities or have been able to foster competition to the extent that the United States is seeking. In 2015, there were 86 global satellite launches, 22 of which were considered commercial launches.[1] Table 1 provides the number of civil government, military, and commercial launches by country in 2015.

[1] Three of the 86 launches failed; these included two commercial launches—one provided by International Launch Services (ILS) of a Proton M launch vehicle and one provided by Space Exploration Technologies (SpaceX) of a Falcon 9 launch vehicle — and one U.S. Air Force-sponsored Super Strypi vehicle launched from Hawaii.

Table 1. Civil Government, Military, and Commercial Launches by Country in 2015

	Country	Civil	Military	Commercial	Total
	Russia	14	7	5	**26**
	United States	4	8	8	**20**
	China	12	7	0	**19**
	European Union[a]	5	0	6	**11**
	India	3	0	2	**5**
	Japan	1	2	1	**4**
	Iran	1	0	0	**1**
	Total	**40**	**24**	**22**	**86**

Source: Federal Aviation Administration's Annual Compendium of Commercial Space Transportation: 2016 Report. | GAO-16-661R

[a] For the purposes of this report, we refer to the European Union as a country because the Federal Aviation Administration's (FAA) 2016 Compendium on Commercial Space Transportation categorizes it as a country or jurisdiction with operational space launch capability. The main government organizations who use launch services are the European Union, two intergovernmental organizations – the European Space Agency and Eumetsat – France, Germany, Italy, Spain and the United Kingdom. These organizations have a different set of member countries and procurement rules.

Data Table for Civil Government, Military, and Commercial Launches by Country in 2015

	Civil	Military	Commercial	Total
Russia	14	7	5	26
United States	4	8	8	20
China	12	7	0	19
European Union	5	0	6	11
India	3	0	2	5
Japan	1	2	1	4
Iran	1	0	0	1

This report addresses the following questions: (1) What is known about foreign launch capabilities, and which, if any, foreign governments rely on more than one launch provider with similar capabilities for access to space? (2) What is known about the range and types of government support that foreign launch providers receive? (3) To what extent is DOD incorporating consideration of the current and predicted national security, civil government, and commercial launches into its acquisition strategy for the EELV program?

To describe what is known about foreign satellite launch capabilities, and which, if any, foreign governments rely on more than one launch provider with similar capabilities for access to space, we reviewed the Federal Aviation Administration's Commercial Space Transportation 2014 Year in Review, the 2015 Commercial Space Transportation Forecasts, and the 2016 Annual Compendium of Commercial Space Transportation reports which provide a summary of the global commercial satellite launch industry and emerging trends relating to payload size, number of launch missions, and which countries and companies are competing for services. We also interviewed FAA officials regarding the types of information collected to produce the reports and met with both domestic and foreign launch companies to understand their perspective relating to the industry as well as to discuss the findings of the FAA reports with officials from the domestic companies.

To describe what is known about the range and types of government support that foreign launch providers receive, we interviewed officials from the European Space Agency (ESA),the Japan Aerospace Exploration Agency (JAXA), and interviewed and spoke with Arianespace and International Launch Services (ILS) to obtain insights on how foreign government launch services and infrastructure are funded. We also obtained information from Department of Commerce, National Aeronautics and Space Administration (NASA), DOD, Federal Aviation Administration, Department of State officials, and domestic commercial launch providers to obtain their insights on foreign government involvement with space launch providers. We also reviewed publically available information from foreign launch provider company websites.

To describe the extent DOD has incorporated consideration of the current and predicted military, civil and commercial launch markets into its acquisition strategy, we obtained information from Air Force and DOD officials regarding the development of the EELV acquisition strategy and reviewed market research documentation. We also interviewed domestic launch providers regarding the EELV program.

We conducted this performance audit from March 2016 to July 2016 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.

Foreign Launch Capabilities

In summary, five countries outside of the United States have operational space launch capabilities — the European Union, Russia, India, Japan, and China — for launching civil government, military, and commercial payloads.[2] Most countries primarily depend on a single launch provider for launches of specific capability within their country to meet civil and military launch requirements. Arianespace is the primary launch provider to the ESA, who also frequently purchases launches for scientific payloads from other non-European launch providers. The United States is unique in that it has more than two launch providers with some overlapping capabilities to meet U.S. civil and military launch needs, two of which are certified to launch national security payloads. U.S. based providers are United Launch Alliance (ULA), Space Exploration Technologies Corporation (SpaceX), and Orbital ATK. Countries we reviewed did have more than one launch provider in some instances, but, in countries with multiple providers, the providers had different capabilities.[3] Commercial launches are those that are open to international competition or were licensed by the FAA. Companies select from global launch providers based on a number of factors, including price, capability, and reliability of the launch vehicle. Governments play a significant role in stimulating the launch market since they constitute a large portion of demand. The United States' budget for space programs, which includes launch services, is much larger than any other country. The U.S. budget for space is

[2] For the purposes of this report, we refer to the European Union as a country because FAA's 2016 Compendium on Commercial Space Transportation categorizes it as a country or jurisdiction with operational space launch capability. The main government organizations who use launch services are the European Union, two intergovernmental organizations – the European Space Agency and Eumetsat – France, Germany, Italy, Spain and the United Kingdom. These organizations have a different set of member countries and procurement rules.

[3] Payloads are generally distinguished by their weight, called a payload mass class. Small payloads are those weighing approximately 1-2,600 lbs. Medium class payloads weigh between 2,600-5,500 lbs. Intermediate payloads range in weight from 5,500-9,300 lbs. Large payloads range in weight from 9,300-12,00lbs, while the Heavy payload class weighs over 12,000 lbs.

approximately $39 billion, which is roughly one-half of all government space budgets, globally. Iran, Israel, North Korea, and South Korea also have space launch capability. However, little information is readily available about their launch vehicles, launch payload capabilities, or launch providers. While the FAA did report one successful civil mission for Iran in 2015, because so little information is readily available, we did not include Iran, Israel, North Korea, and South Korea in our review. However, agency officials we spoke with said that South Korea's Korea Aerospace Research Institute (KARI) has plans to develop a launch vehicle capability, but does not currently have a self-sufficient indigenous launch capability.

Government Support of Foreign Launch Providers

Data on how foreign governments support their launch providers are limited. Based on what general information is available, experts we spoke with said that launch providers receive some support from their respective governments through provision of historical launch vehicle research and development funding, direct payments to cover launch system operating costs, government-provided infrastructure, government ownership, government as a customer or indemnity insurance.[4] For example, launch providers in Russia, China, and India are fully or partially owned by their governments. The Russian launch provider Khrunichev, which is owned by the Russian government, operates and maintains launch infrastructure for civil, military, and commercial launch services. Arianespace, ESA's preferred launch provider, receives direct payments annually to cover the cost of operating three launch systems. Japan researches and develops space technologies such as launch vehicles, and transfers the technologies to its main launch provider, Mitsubishi Heavy Industries for production. In the United States, the U.S. government has provided support in the form of early expenditures on launch vehicle development, and launch providers made significant investments in developing capabilities as well. DOD officials said that launch providers in the United States, in general, own their testing and launch infrastructure but lease the land for their launch pads from the U.S. government and pay a fee to the U.S. government for Range operations support. Since 2005, DOD has paid separately for EELV's launch service and launch capability, including, among other things, the costs associated with operating and maintaining the United Launch Alliance (ULA) launch infrastructure. ULA reimburses DOD for a portion of the cost when ULA launches a non-DOD customer.

Extent DOD Is Incorporating Information of the Global Launch Market into the EELV Acquisition Strategy

As DOD considers options in developing a new acquisition strategy for the EELV program, it is gathering and analyzing information on the global launch market to help ensure multiple U.S.-based launch providers can remain viable to compete for future launches. Additionally, the EELV program office is using FAA information on the global demand for launches and results from a 2014 Request for Information to solicit industry inputs on propulsion and launch systems, which included information about the number of launches potential domestic providers require to stay in business. Furthermore, the Office of the Secretary for Defense (OSD) Cost Assessment and Program Evaluation (CAPE) is working with the Air Force Cost Analysis Agency to analyze the business cases of potential launch providers for the EELV program. The FAA provides

[4] In anticipation of a catastrophic commercial launch accident, which could result in injuries or property damage to the uninvolved public or "third parties", a launch company must purchase a fixed amount of insurance for each launch and reentry, per calculation by FAA; the federal government may indemnify the launch provider against claims above that amount up to an additional $3.06 billion, adjusted for inflation in 2015 dollars and subject to congressional appropriations. 51 U.S.C. §§ 50914-50915.

launch market information on commercial launch forecasts, foreign launch capabilities, and historical global launch demand. Although DOD is taking steps to gather data, history has proven that it is difficult to reliably predict growth in the demand for launch services. Many factors influence the quantity, size, and frequency of satellite launches for both government and commercial use. For additional information on the results of our work, see the enclosure: Briefing on Foreign Space Launch.

Agency Comments

We are not making recommendations in this report. We provided a draft of this report to the Departments of Defense, Commerce, State, Transportation, and NASA for comment. Departments of Defense, Commerce, and Transportation provided technical comments, which were incorporated as appropriate. The Department of State and NASA did not provide comments.

We are sending copies of this report to the appropriate congressional committees, the Secretary of Defense, the Secretary of the Air Force, the Secretaries of State and Commerce, the NASA Administrator, and other interested parties. This report is also available at no charge on the GAO website at http://www.gao.gov.

Should you or your staff have questions about this report, please contact me at (202) 512-4841 or at chaplain@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. GAO staff who made key contributions to this report were Rich Horiuchi, Assistant Director; Emily Bond, Erin Cohen, Lorraine Ettaro, Kurt Gurka, Jordan Kudrna, Keith Hudson, and Carol Petersen.

Sincerely yours,

Cristina T. Chaplain
Director
Acquisition and Sourcing Management

Enclosure

Enclosure Briefing on Foreign Space Launce

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Foreign Space Launch

Briefing to the House Armed Services Committee

Strategic Forces Subcommittee

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Introduction

- The United States is striving to help develop a competitive market for space launches from which it can acquire its national security launches in order to help lower the price of launch and assure its access to space. Questions have been raised about whether competition among U.S. providers can be sustained in the long run given market conditions and competition from foreign launch providers in the global commercial market.
- A key question is the extent to which other countries that launch payloads rely on more than one launch provider with similar capabilities or have been able to foster competition to the extent that the United States is seeking.
- In 2015, there were 86 total global launches, 22 of which were considered commercial launches.[1] Table 1 provides the civil government, military/national security, or commercial launches by country in 2015.

[1] Three of the 86 launches failed; these included two commercial launches—one provided by International Launch Services (ILS) of a Proton M launch vehicle and one provided by Space Exploration Technologies Corporation (SpaceX) of a Falcon 9 launch vehicle—and one U.S. Air Force-sponsored Super Strypi vehicle launched from Hawaii.

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Introduction

Table 1. Civil Government, Military/National Security, or Commercial Launches by Country in 2015

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Objectives

This briefing addresses the following questions:

(1) What is known about foreign launch capabilities, and which, if any, foreign governments rely on more than one launch provider with similar capabilities for access to space?

(2) What is known about the range and types of government support that foreign launch providers receive?

(3) To what extent is the Department of Defense (DOD) incorporating consideration of the current and predicted national security, civil government, and commercial launches into its acquisition strategy for the Evolved Expendable Launch Vehicle (EELV) program?

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Summary: Objective 1

GAO found:

- Five countries outside of the U.S. have operational space launch capabilities – the European Union, Russia, India, Japan, and China – for launching civil government, military, and commercial payloads.[2] Most countries primarily depend on a single launch provider for launches of a specific capability within their country to meet civil and military launch requirements. Arianespace is the primary launch provider to the European Space Agency (ESA), who also frequently purchases launches for scientific payloads from other non-European launch providers. The United States is unique in that it has more than two launch providers with some overlapping capabilities to meet U.S. civil and national security launch needs. Countries we reviewed did have more than one launch provider in some instances, but the providers had different capabilities. Governments play a significant role in stimulating the launch market because they constitute a large portion of demand, and the United States' budget for space programs, which includes launch services, is much larger than any other country at approximately $39 billion and is roughly half of all governments' space budgets. For commercial payloads, launches are generally open to international competition. Companies select from available launch providers based on a number of factors, including price, capability, and reliability of the launch vehicle.

[2] For the purposes of this report, we refer to the European Union as a country because FAA's 2016 Compendium on Commercial Space Transportation categorizes it as a country or jurisdiction with operational space launch capability. The main government agencies who use launch services are the European Union, two intergovernmental organizations – the European Space Agency and Eumetsat – France, Germany, Italy, Spain and the United Kingdom.

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Summary: Objective 2

- Data on how foreign governments support their launch providers are limited. Based on what general information is available, experts we spoke with said that foreign launch providers receive some support from their respective governments through provision of launch vehicle research and development funding, direct payments to cover launch system operating costs, government-provided infrastructure, government ownership, government as a customer, or indemnity insurance. For example, launch providers in Russia, China, and India are owned by their governments. The Russian launch provider Khrunichev, which is owned by the Russian government, operates and maintains launch infrastructure for civil, military and commercial launch services. In the United States, the U.S. government has provided support in the form of early expenditures on launch vehicle development with the understanding that launch providers make significant investments in developing capabilities as well. Additionally, launch providers in the United States, in general, own their testing and launch infrastructure but lease the land for their launch pads from the U.S. government and pay a fee to the U.S. government for Range operations support.

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Summary: Objective 3

- As DOD considers options in its development of a new acquisition strategy for the EELV program, it is gathering and analyzing information on the global launch market to help ensure at least two U.S.-based launch providers can compete for future launches.
  - The Federal Aviation Administration (FAA) provides launch market information on commercial launch forecasts, foreign launch capabilities, and historical global launch demand to DOD. Additionally, the EELV program office is using information on the global demand for launches and results from a 2014 Request for Information from domestic launch service and rocket propulsion providers.
  - Furthermore, the Office of the Secretary for Defense (OSD) Cost Assessment and Program Evaluation (CAPE) is working with the Air Force Cost Analysis Agency (AFCAA) to analyze the number of civil government, national security, and commercial launches that current and potential launch providers for the EELV program need to stay in business.

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Summary: Objective 3 (continued)

- Although DOD is taking steps to gather data, history has proven it is difficult to reliably predict growth in the demand for launch services. Many factors influence the quantity, size and frequency of launches for both government and commercial use.

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Background: Space Launch

- Space launches are divided into categories based on orbits and whether they are for civil, military/national security, or commercial purposes:
  - Low Earth orbit (LEO) is the region of space up to an altitude of approximately 1,491 miles (2,400km). Launches to the geosynchronous Earth orbit (GEO) must reach altitudes of approximately 22,277 miles (35,852km) above earth.[3]
  - National security launches are not typically available for competition outside of the country for which they are launched. Non-U.S. civil government launches are sometimes internationally competed and include those for payloads that perform scientific data gathering missions, such as for monitoring global weather conditions.
  - Commercial launches are those that are available for international competition or licensed by the FAA. Launch providers around the world can compete for launches on the global market. Some examples of commercial launches are those that provide launch services for commercial satellite telecommunication companies or earth observation satellites.

*Geosynchronous (GEO) is a broader category used for any circular orbit at an altitude of 22,277 miles on or near the equator. A satellite in geostationary Earth orbit is synchronized with the Earth's rotation, orbiting once every 24 hours, and appears to an observer on the ground to be stationary in the sky. Non-geosynchronous orbit (NGSO) payloads are those in orbits other than GEO. They are located in low Earth orbit (LEO) at about 1,491 miles, medium Earth orbit (MEO), Sun Synchronous Orbit and all other orbits or trajectories.

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Background: Assured Access to Space

- To help assure access to space, U.S. law and national policy require that, to the maximum extent practicable, the Secretary of Defense have available at least two space launch vehicles, or families of vehicles, capable of delivering any national security payload into space.[4] This is so that if there is a problem with one launch vehicle family, the DOD retains access through the other family. United Launch Alliance's (ULA) Atlas V and Delta IV families of launch vehicles have provided for assured access to space under the Air Force's EELV program.
- Generally, the United States government must acquire space transportation services from U.S. providers.[5] Exceptions include scientific missions from NASA and National Oceanic and Atmospheric Administration (NOAA) that may be launched on foreign launch vehicles through international agreements.[6]
- Other countries assure their access to space by developing indigenous launch capabilities or through cooperative arrangements with other countries. For example, Arianespace is the primary launch provider for the ESA but has developed back up arrangements with Japan's Mitsubishi Heavy Industries (MHI) for launch in the case that Arianespace is not available. India has contracted with other foreign launch providers for GEO launches because their vehicle cannot lift heavy satellites and has experienced reliability issues with its launch vehicle. Japan developed a launch vehicle for civil and scientific missions and is reconstructing a second launch pad for its launch vehicle and can rely on contracts with other foreign providers, if necessary.

[4] 10 U.S.C. § 2273(a) & (b); National Space Transportation Policy (21 November 2013).
[5] 51 U.S.C. § 50131(a).
[6] 51 U.S.C. § 50131(b)(5) & (c).

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Background: United States Space Access

- The EELV program is responsible for acquiring U.S. national security space launches for DOD and the intelligence community. Space launch is essential for placing critical U.S. government payloads on orbit, such as for navigation, reconnaissance, weather monitoring, and communications capabilities.
- NASA acquires launch services from domestic launch providers to serve its mission and other civil missions for NOAA and for the U.S. Geological Survey. NASA's portfolio of major projects ranges from satellites equipped with advanced sensors to study the Earth, and the space environment, to spacecraft that visit and study other planets. NASA is also responsible for the transport of humans and cargo to and from the International Space Station, and is also developing the Space Launch System (SLS) for beyond LEO human exploration missions. In some cases, NASA relies on foreign launch providers per agreements with its international partners.
- The U.S. government satisfies its civil government and national security launch requirements from U.S.-based launch providers, including ULA, SpaceX, and Orbital ATK.

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Background: EELV Program

- For over 10 years, the Air Force's EELV program has been awarding space launch contracts to a single incumbent provider, ULA, because there were no other U.S. launch providers in a position to compete for national security launches.
- In recent years, the prospects for competition for national security launches have been improving, with several companies becoming or working to become certified to compete for national security launches. In 2011, the Air Force established a process for certifying new competitors to be able to launch national security satellites. This has enabled the EELV program to pursue a competitive acquisition strategy.
- In 2015, SpaceX was certified to launch national security payloads and recently won a contract to launch the second Global Positioning System (GPS) III satellite.[7]

[7] SpaceX earned certification for its Falcon 9 launch vehicle in May 2015, but Falcon 9 can only launch part of the DOD launch manifest. EELV-class payloads range from 6,000 to 29,000 lbs to Geosynchronous Transfer Orbit (GTO). They are divided into intermediate (6,000-16,000 lbs to GTO), and heavy (16,000-29,000 lbs to GTO) classes. The Falcon 9 can lift 10,992 lbs to GTO. SpaceX is certified to launch to four of DOD's eight required orbits for national security launches.

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Background: EELV Program (continued)

- As part of establishing a competitive acquisition strategy, the Air Force awarded a Phase 1 contract to ULA. The contract allows the Air Force to purchase up to 35 launch vehicle booster cores from fiscal year 2013 to fiscal year 2017 and to purchase launch services through fiscal year 2019.
- In November 2012, the Under Secretary of Defense for Acquisition, Technology, and Logistics directed the Air Force to introduce a competitive procurement environment for up to 14 launches.[8] The period in which these first competitive launches are being competed is called Phase 1A. Phase 1A runs concurrently with Phase 1 and launches may be awarded one at a time with a separate contract for each one, competed for by certified launch providers.
- The acquisition approach for the next procurement of launch services, called Phase 2, is currently under development. Phase 2 is intended to be a period of open competition between all certified launch providers to the extent possible while still ensuring access to space.

[8] According to DOD officials, the number of Phase 1A launches is currently 9. Changes to the number of competitive national security launches in Phase 1A is driven by changes to constellation health and the EELV launch manifest.

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Background: Worldwide Space Program Budgets and Launch Demand Information

- According to Tauri Group data, the total U.S. government budget for space programs is estimated to be $39 billion, or roughly one-half of all governments' space budgets, globally.[9] Europe had the next largest government space budget at an estimated $15 billion. China's space budget was estimated to be $11 billion, while Russia/Ukraine/Central Asia had a combined space budget of $9 billion. The Asia/Pacific region, which includes Japan, had a space budget estimated at $4 billion. The South Asia space budget, which includes India, was estimated to be $4 billion. The global combined government space budget is estimated to be between $76 and nearly $83 billion.

- The Commercial Space Transportation Advisory Committee (COMSTAC), in coordination with the Federal Aviation Administration (FAA), has prepared publically available annual reports on the commercial geosynchronous orbit satellite launch demand forecast. FAA prepares a similar annual forecast for commercial launch demand to non-geosynchronous orbits, which has been published annually since 1994. Each forecast relies on input from the United States and international space industry including satellite operators, satellite manufacturers, launch providers, and insurers.

[9] Tauri Group data are considered the industry standard for data on space launch. The Tauri Group is the contractor for FAA reports on commercial space transportation.

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Objective 1: Five Countries Outside of the United States Have Space Launch Capability and Each Primarily Use One Launch Provider for Launches of Specific Capabilities for Space Access

- Five countries outside of the U.S. have operational space launch capabilities – the European Union, Russia, India, Japan, and China – for launching civil government, military, and commercial payloads. Most countries primarily depend on a single launch provider for launches of a specific capability within their country to meet their civil and military launch requirements.[10] Arianespace is the primary launch provider to ESA, who also frequently purchases launches for scientific spacecraft from other non-European launch providers. The United States relies on three launch providers to meet its civil and national security launch requirements, of which two are certified by the Air Force to launch national security satellites.
- Commercial launches are open to international competition. Companies select from available launch providers based on a number of factors, including price, capability, and reliability of the launch vehicle. According to agency officials, launch providers, and experts we spoke with, launch providers in Europe, Russia, and the United States primarily compete for global commercial launch opportunities. Table 2 provides detailed information on launch vehicles available commercially and total 2015 worldwide launches.

[10] Iran, Israel, North Korea, and South Korea also have space launch capability. While the FAA reported one successful civil mission for Iran in 2015, because so little information is readily available, we did not include these countries in our review. However, agency officials we spoke with said that South Korea's Korea Aerospace Research Institute (KARI) has plans to develop a launch vehicle capability, but does not currently have a self-sufficient indigenous launch capability.

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Objective 1: Table 2. Launch Vehicles Available Commercially and 2015 Worldwide Launches

Country	Vehicle	Launch Provider	Estimated price of launch (million USD)	Range of capability to LEO (kg)	Range of capability to GTO (kg)	2015 worldwide commercial launch events
China	Long March 2D	People's Liberation Army of China/ China Great Wall Industry Corporation	$30	3,500	N/A	0
	Long March 3A		$70	8,500	2,600	0
European Union*	Vega	Arianespace	$37	1,963	N/A	0
	Ariane 5		$178	21,000	9,500	6
	Soyuz 2		$80	1,820-2,150	3,250	0
India	PSLV	Indian Space Research Organization/Antrix	$33	3,250	1,425	2
	GSLV		$27	5,000	2,500	0
Japan	Epsilon	Japan Aerospace Exploration Agency	$39	700-1,200	N/A	0
	H-IIA/B	Mitsubishi Heavy Industries Launch Services	$90-112.5	10,000-16,500	4,000-6,000	1
Russia	Proton M	Roscosmos/International Launch Services (ILS)	$65	23,000	6,920	4
	Rockot	Eurockot	$41.8	1,820-2,150	N/A	0
	Dnepr	ISC Kosmotras	$29	3,200	N/A	1
	Zenit 3SL/3SLB	Sea Launch AG*	$85-$95	N/A	6,160 (3SL) 3,750 (3SLB)	0
USA	Falcon 9	SpaceX	$61.2	13,150	4,850	6
	Atlas V	ULA/Lockheed Martin Commercial Launch Services	$110-$230	8,123-18,814	3,460-8,900	2
	Delta IV Medium/Heavy	United Launch Alliance (ULA)	$164-$400	9,420-28,790	3,060-14,220	0
	Minotaur-C	Orbital ATK	$40-$50	1,278-1,458	N/A	0
	Antares		$80-$85	3,500-7,000	N/A	0
	Pegasus XL		$40	450	N/A	0

Source: GAO summary of Federal Aviation Administration's data of the Annual Compendium of Commercial Space Transportation: 2016 Report. | GAO-16-661R

* For the purposes of this report, we refer to the European Union as a country because FAA's "2016 Compendium on Commercial Space Transportation" categorizes it as a country or jurisdiction with operational space launch capability. The main government organizations who use launch services are the European Union, two intergovernmental organizations – the European Space Agency and Eumetsat – France, Germany, Italy, Spain and the United Kingdom.

* The FAA's Annual Compendium on Commercial Space Transportation: 2016 reported that Sea Launch has essentially ceased operations.

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Objective 1: Five Countries Outside of the United States Have Space Launch Capability and Each Primarily Use One Launch Provider for Launches of Specific Capabilities for Space Access (continued)

- According to FAA data, agency officials, and experts we spoke with, only the United States has more than one launch provider with similar capabilities who may compete for national security launches as well as commercially available launches on the domestic and global markets.
- Other countries with launch capabilities generally have one launch provider for specific capabilities. While these countries or their launch providers might have multiple launch vehicles, there generally is little overlap in the vehicles' capabilities.[11] However, the FAA 2016 Annual Compendium on Commercial Space Transportation reported that Russia has two commercially available launch vehicles – the Dnepr and Rockot, sold by two different launch providers, with some overlapping capability to Sun Synchronous Orbit. According to a launch expert, these launch vehicles are no longer considered by commercial customers because of technical difficulties with the Rockot launch vehicle and the availability of the Dnepr launch vehicle is unknown after the conflict in Crimea and eastern Ukraine.
- Governments play a significant role in stimulating the launch market since they constitute a large portion of demand. The United States' budget for launch services is much larger than any other country. As noted earlier, the U.S. government space budget is nearly half of the total worldwide space budget.

[11] Payloads are generally distinguished by their weight, called a payload mass class. There is no widely accepted definition for mass classes, in particular for small payloads that continually evolve with advances in technology. In this report, small payloads are those weighing approximately 1-2,600lbs. Medium class payloads weigh between 2,600 - 5,500 lbs. Intermediate payloads range in weight from 5,500 - 9,300 lbs. Large payloads range in weight from 9,300 -12,000lbs, while the Heavy payload class weighs more than 12,000lbs

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Objective 2: Foreign Government Involvement with Launch Providers

- According to launch providers, government agencies, and industry experts we interviewed, there is limited data on how foreign governments support their launch providers.
- Based on what general information is available, experts we spoke with said that U.S. and foreign launch providers receive some support from their respective governments through provision of launch vehicle research and development funding, direct payments to cover launch system operating costs, government-provided infrastructure, government ownership of the launch provider, government as a customer, or indemnity insurance.[12] The type of support varies between countries and how their space programs are structured.

[12] For example, in anticipation of a catastrophic commercial launch accident which could result in injuries or property damage to the uninvolved public or "third parties", a launch company must purchase a fixed amount of insurance for each launch and reentry, per calculation by FAA; the federal government may indemnify the launch provider against claims above that amount up to an additional $9.09 billion, adjusted for inflation to 2015 dollars and subject to congressional appropriations. 51 U.S.C. §§ 50914-50915.

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Objective 2: Government Involvement with Launch Providers – Types of Support

- **Launch Vehicle Development**: In each of the countries we reviewed, launch vehicle research and development was historically conducted or paid for (in whole or in part) by the government to meet a government need for access to space, according to agency officials and industry experts. In one case, once the launch vehicle development was completed, the government transferred ownership to the launch provider. The Japan Aerospace Exploration Administration (JAXA) provided initial research and development for its H-IIA and H-IIB vehicles and then transferred the technologies and responsibilities for launch service operations to the launch provider, Mitsubishi Heavy Industries (MHI).
  - Beginning in 1995, the Air Force awarded $30 million firm fixed-price contracts to four companies to develop EELV system concepts and complete preliminary system designs, followed in 1996 by $60 million cost-plus fixed-fee contracts awarded to two of the companies, McDonnell Douglas (before it merged with Boeing) and Lockheed Martin, to continue design activities. In 1998, the Air Force awarded two $500 million "other transaction agreements" to these companies to complete the development of EELV launch vehicles and launch infrastructure, resulting in the Delta IV and Atlas V launch vehicles. These government expenditures were made with the understanding that they would be supported with private investment from Lockheed Martin and Boeing, who would retain ownership. The Delta IV and Atlas V are the primary launch vehicles used in the EELV program. In 2005, Boeing and Lockheed Martin formed a joint venture called United Launch Alliance.
  - In August 2006, NASA awarded a $278 million Space Act agreement to SpaceX to develop and demonstrate end-to-end transportation systems, which included the Falcon 9 launch vehicle and Dragon spacecraft. In February 2008, NASA awarded a $170 million Space Act agreement to Orbital ATK (then Orbital Sciences Corporation) to develop two Commercial Orbital Transportation Services (COTS) project cargo capabilities to culminate in one demonstration flight of its Taurus II launch vehicle and Cygnus spacecraft. SpaceX and Orbital ATK have made significant investments in developing these capabilities.[19] SpaceX has stated that its development costs for the Falcon 9 vehicle were $300 million over four and one-half years.

[19] GAO, *Commercial Launch Vehicles: NASA Taking Measures to Manage Delays and Risks*, GAO-11-692T (Washington, D.C.: May 26, 2011)

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Objective 2: Government Involvement with Launch Providers – Types of Support

- **Launch Infrastructure Support**: In each of the countries we reviewed, launch providers had access to government-owned land or launch infrastructure. For example, Arianespace, the primary launch provider for the ESA, uses launch infrastructure located in French Guiana, owned by the French Space Agency, Centre National d'Études Spatiales (CNES), ESA, Arianespace, and other industrial suppliers. DOD officials said that launch providers in the United States, in general, own their testing and launch infrastructure but lease the land for their launch pads from the U.S. government and pay a fee to the U.S. government for range operations support. Since 2005, DOD has paid separately for EELV's launch service and launch capability, including, among other things, the costs associated with operating and maintaining the ULA launch infrastructure. ULA reimburses DOD for a portion of the capability cost when ULA launches a non-DOD customer.

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Objective 2: Government Involvement with Launch Providers – Types of Support

- **Direct Payments**: In Europe, the launch provider received direct payments annually which were mainly used to cover the cost of operating three launch systems.
- **Extent of government ownership**: In three of the countries we reviewed – Russia, China, and India - the governments own part or all of the launch providers, according to agency officials. In the United States, launch providers are owned by private entities. For example, SpaceX is a private company while ULA is a joint venture between two publicly traded companies.
- **Government as a customer**: In all of the countries we reviewed, the government was a customer of the launch provider. In Europe, Arianespace is primarily a commercial launch services provider but is also the preferred launch provider for civil and military space launches, although government organizations are not required to use Arianespace for launches. In Japan, JAXA is the primary customer for the H-IIA and H-IIB vehicles, provided by MHI. In the United States, the Air Force and NASA are major customers of ULA. ULA provided launch services for one commercial launch in 2015. SpaceX is on contract to perform its first national security launch for the Air Force in 2018, and launched three successful payloads for NASA in 2015. Orbital ATK launched two successful payloads for NASA in 2014.
- **Indemnity Insurance**: We reported in 2012 that the United States provides less total third party liability coverage than China, Europe, or Russia. These countries each have an indemnification regime in which the government states that it will assume a greater share of the risk compared to that of the United States because China, Europe, and Russia each have a two-tiered system with no limit on the amount of government indemnification.[14] All FAA-licensed commercial launches and reentries by U.S. companies, whether unmanned or manned and from the United States or overseas, are covered by federal indemnification for third party damages that result from the launch or reentry.[15]

[14] GAO, *Commercial Space Launches: FAA Should Update How It Assesses Federal Liability Risk*, GAO-12-599 (Washington, D.C.: July 30, 2012).
[15] 51 U.S.C. § 50914(a)(1)(A).

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Objective 2: Foreign Government Involvement with Launch Providers - Europe

Europe

- **Government Space Entity:** Arianespace has several European government customers. The three largest are the European Union, the ESA and Eumetsat. The French Space Agency Centre National d'Etudes Spatiales (CNES) together with ESA, Arianespace, and other industrial suppliers, own the Guiana Space Center in French Guiana. CNES is responsible for safety, security, tracking and weather related activities. Arianespace operates the launch vehicles on the base with support from their industrial suppliers. ESA owns several facilities on the launch range but does not operate them.
- **Launch Provider:** Arianespace sells and provides launches for civil, military, and commercial payloads to all orbits using the Ariane 5, Soyuz 2, and Vega launch vehicles.[16] Historically, the Ariane 5 launch vehicle consistently captured a large portion of available global commercial launches.
- **Government Support:** According to Arianespace, they receive approximately €100 million ($112 million) in annual support from ESA to cover the cost of operating three launch systems at the Guiana Space Center. ESA is responsible for research and development of space projects, and on completion of qualification, the projects are handed to outside entities for production and exploitation. According to ESA officials, launch facilities, including the range and launch complexes, are owned by ESA, France, Arianespace, and other European entities.

[16] ESA and Arianespace officials said that Arianespace is owned by approximately 20 European shareholders (incl. from countries outside the European Union). Arianespace shares owned by CNES on behalf of the French Government to date are in the process of being sold to Airbus Safran Launchers, the Ariane industrial prime contractor. Airbus Safran Launchers will own a 74 percent controlling stake in Arianespace once the sale is complete.

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Objective 2: Foreign Government Involvement with Launch Providers - Russia

Russia

- **Government Space entity:** The Russian Federal Space Agency (Roscosmos) is the Russian government agency responsible for providing access to space, managing international cooperation in joint space programs, facilitating industry cooperation among rocket and space industry entities, and overseeing military-based space technologies. Roscosmos oversees the Russian launch provider, Khrunichev State Research and Production Space Center (Khrunichev), which is a Federal State Unitary Enterprise of the Russian Government. Russia sells launches on the Soyuz vehicle, including those sold to NASA for human space flight missions to the International Space Station.[17]
- **Launch Provider:** According to a launch provider we spoke with, Khrunichev is one of the primary launch providers for Russia and directly handles launches for Russia's civil and military payloads. International Launch Services (ILS) is Khrunichev's commercial entity for selling launch services to global satellite operators for commercial launches using the Proton and Angara launch vehicles. Khrunichev is a majority shareholder of ILS. Additionally, the Proton launch vehicle, manufactured by Khrunichev and sold commercially by ILS, has typically captured a large share of the commercial launch market in its heavy lift payload class.
  - Other Russian launch entities that sell launch services for Russia are Eurokot Launch Services and the International Space Company Kosmotras. Through a joint venture, Khrunichev and Airbus Safran Launchers own Eurockot Launch Services, which sells the commercially available Rockot launch vehicle for launches to LEO. Khrunichev launches the Rockot vehicle. International Space Company Kosmotras provides and sells the Dnepr launch vehicle, which has capability to launch payloads to LEO. However, according to a launch expert, the Dnepr and Rockot launch vehicles have not been active in the commercial market for the past year. The Rockot has had technical difficulties and schedule delays that have harmed its standing in the commercial market. According to the launch expert, since the conflict in Crimea and eastern Ukraine, Russia is no longer supporting Dnepr launches from the Dombarovsky military base in Russia's Orenburg Oblast province.

[17] The European-Russian organization, Starsem, sells commercial launches on the Soyuz vehicle.

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Objective 2: Foreign Government Involvement with Launch Providers – Russia (continued)

- **Government Support:** According to ILS officials, Khrunichev is owned and operated by the Russian government under Roscosmos. ILS buys launch services from Khrunichev as a subsidiary and uses launch infrastructure provided by Khrunichev. According to ILS officials, it does not receive direct payments from Khrunichev or the Russian government, relying solely on commercial launches for income.

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Objective 2: Foreign Government Involvement with Launch Providers - Japan

Japan

- **Government Space entity:** JAXA is a national research and development agency with the goal of supporting the Japanese government's overall aerospace development. JAXA is responsible for developing launch vehicles and transferring ownership and technologies to its launch provider to produce the launch vehicles for government use and commercial markets.
- **Launch Providers:** MHI is the space launch provider for Japan, and works alongside JAXA. JAXA developed the HII-A and HII-B launch vehicles, which MHI produces. According to JAXA officials, JAXA privatized the HII-A and HII-B in 2007 and 2011, respectively, by transferring the technologies to MHI. However, according to multiple industry experts, the HII-A is currently too expensive to be commercially viable. Additionally, an industry expert we spoke with said Japan intends for the Epsilon launch vehicle, which has launch capability to LEO, to compete for commercially available launches. IHI Aerospace Co., Ltd. is the prime contractor for the Epsilon. According to an industry expert we spoke with, the Epsilon may provide a more reliable and responsive space launch system with a low life-cycle cost for various small satellite customers.
- **Government Support:** JAXA provided the research and development funds for the H-IIA and H-IIB launch vehicles and maintains and owns launch infrastructure. JAXA buys launch services from MHI as necessary. Additionally, if a launch vehicle fails as a result of a design problem, then JAXA is responsible for investigating and resolving the problem.

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Objective 2: Foreign Government Involvement with Launch Providers - India

India

- **Government Space Entity:** India's Department of Space (DOS) is primarily responsible for promoting development of space science & technology for India. The DOS is also responsible for design and development of launch vehicles through its Indian Space Research Organization (ISRO). ISRO also operates India's sole launch site, the Satish Dhawan Space Center.
- **Launch Provider:** ISRO develops launch vehicles for India. Antrix Corporation Limited (Antrix), a wholly owned Government of India Company under the administrative control of DOS, is ISRO's commercial arm. Antrix promotes and commercially sells the products and services emanating from the ISRO, such as launch vehicles, remote sensing satellites, and satellite sub-systems.
- **Government Support:** According to industry experts, India solely owns and funds its space program, including its launch provider.

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Objective 2: Foreign Government Involvement with Launch Providers - China

China

- **Government Space entity:** The China National Space Administration is the government agency responsible for planning and developing space activities, including implementing China's major space projects and programs. According to a recent FAA report, China continues to develop its human spaceflight capabilities and conduct robotic investigations of the Moon.
- **Launch Provider:** Various government organizations within China coordinate to provide launches for China's government payloads. According to agency officials at the Department of Commerce and State, as well as industry experts we spoke with, China currently does not compete for launches with U.S. satellites on the global commercial market because U.S. law severely limits the launch of U.S. satellites and related items on Chinese launch vehicles.[18] According to an industry expert we spoke with, China has traded launch services for commodities with other countries.
- **Government Support:** Industry experts we interviewed stated that Chinese space organizations are largely state-owned. One industry expert said that there is little information available about the types and ranges of government support available to launch providers in China.

[18] Pub. L. No. 101-246, § 902(a)(5); Pub. L. No. 112-239, § 1261(c).

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Objective 3: DOD is Considering Information on the Global Launch Market In Its Analysis for Phase 2 Acquisition Strategy

- As they analyze options for the EELV program Phase 2 acquisition strategy for assuring its access to space by having open competition between multiple providers, DOD officials told us they are assessing FAA Commercial Space Transportation Committee (COMSTAC) forecasts and Year in Review reports on foreign launch capabilities and historical global launch demand.
  - DOD officials stated they also use publicly available internet information on global launches as well as receive launch reports from subscription services.

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Objective 3: DOD is Taking Other Steps to Determine Options for Its Phase 2 EELV Acquisition Strategy

- The Air Force released a Request for Information (RFI) in August 2014 to solicit industry inputs on propulsion and launch systems, which included information about the number of launches potential domestic providers require to stay in business.

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Objective 3: DOD is Taking Other Steps to Determine Options for Its Phase 2 EELV Acquisition Strategy (continued)

- In 2016, the Secretary of the Air Force requested that OSD CAPE work with AFCAA to analyze the viability of potential launch providers for the EELV program, according to DOD officials.
  - A CAPE official stated that the goal of this review is to provide Air Force decision makers insights into costs associated with scenarios they are considering for future acquisition strategies. The CAPE official said that the scenarios they are developing cost estimates for are driven by a requirement to have assured access to space. These scenarios consider new launch vehicles currently in development from U.S. launch providers.
  - This review is expected to be completed by June 2016, prior to the EELV acquisition strategy being updated at the beginning of fiscal year 2017.

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Objective 3: Status of the Launch Market

- The FAA's recent annual reports indicate a stable demand for competitive commercial launches with 22 launches globally in 2015. Industry experts we spoke with agreed and do not expect demand to grow significantly.
- The Air Force estimates that the demand for national security launches will decline from approximately 8 in 2015 to about 4 per year beginning in 2020. Launch providers we spoke with generally support a mix of civil, national security, and commercial launches. DOD officials we spoke with said that launch providers will have to rely more heavily on civil government and commercial launches as national security launches decline, which, according to these officials, may prove challenging. However, NASA has stated that there appears to be sufficient launch demand available for U.S. launch providers to support more than one domestic launch provider.

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Objective 3: Status of the Launch Market (continued)

- The FAA 2015 Commercial Space Transportation Forecasts report indicates there are some signs the commercial launch market for launches to LEO may be expanding. The FAA report indicates that demand for launches to LEO may be higher than in previous years because some major telecommunication constellations are being replenished and the NASA commercial crew and cargo resupply trips to the International Space Station will become more regular. The report also estimates that small commercial satellites may result in additional launches. Experts were uncertain about the extent to which a small launch vehicle market would materialize as demand for small satellites is still unclear.
- Industry and agency officials we spoke with said that demand for launches available on the commercial market is driven by demand for satellite telecommunications. There are many technical and market factors that impact that demand. Industry officials we spoke with said that while there is potential for growth in the small satellite industry, that demand won't necessarily increase needed launches as several small satellites can fit on one launch vehicle.

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Objective 3: Status of the Launch Market (continued)

- Although DOD is taking steps to gather data, history has proven that it is difficult to reliably predict growth in the demand for launch services. Many factors influence the quantity, size, and frequency of space launches for both government and commercial use. In our 2015 report, we found that FAA has consistently overestimated the number of forecasted commercial launches.[19]
- All of the countries we reviewed have launch providers who are developing a new launch vehicle to provide launch services for civil, military, and/or commercial launches. For example, ULA is developing the Vulcan launch vehicle, while SpaceX plans to begin operating its Falcon Heavy launch vehicle in 2016. Arianespace is developing the Ariane 6, intended to be a more affordable and commercially competitive launch vehicle to replace the Ariane 5, that, according to Arianespace officials, will have fewer associated costs. Some launch provider representatives we spoke with expressed concern over excess supply of launch vehicles in the commercial market while opportunities to win launches are not expected to grow significantly in the GEO commercial launch market. Other agency and industry officials did not agree, however, stating that launch manifests and limits on infrastructure, including the time it takes to ready a launch pad between one launch for another, limit the potential growth in the number of launches that can be accommodated.

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

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Scope and Methodology

(1) To describe what is known about foreign launch capabilities, and which, if any, foreign governments rely on more than one launch provider with similar capabilities for access to space, we reviewed the FAA Commercial Space Transportation 2014 Year in Review, and the 2015 Commercial Space Transportation Forecasts, and the 2016 Compendium of Commercial Space Transportation reports, which provide a summary of the global commercial satellite launch industry and emerging trends relating to payload size, number of launch missions, and which countries and companies are competing for services. We also interviewed FAA officials regarding the types of information collected to produce the report and met with both domestic and foreign launch companies to understand their perspective relating to the industry as well as discuss the findings of the FAA reports with officials from the domestic companies.

(2) To describe what is known about the range and types of government support that foreign launch providers receive, we interviewed officials from the European Space Agency (ESA) and Japan Aerospace Exploration Agency (JAXA) and interviewed Arianespace and International Launch Services officials to obtain insights on how foreign government launch services and infrastructure are funded internationally. We also obtained information from Department of Commerce, National Aeronautics and Space Administration (NASA), DOD, Federal Aviation Administration (FAA) and Department of State officials and domestic commercial launch providers to obtain their insights on foreign government involvement with space launch providers. We also reviewed publically available information from foreign launch provider company websites.

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Scope and Methodology (continued)

(3) To describe the extent DOD has incorporated consideration of the current and predicted military, civil, and commercial launch markets into its acquisition strategy, we obtained information from Air Force and DOD officials regarding the development of the EELV acquisition strategy and reviewed market research documentation. We also interviewed domestic launch providers regarding the EELV program.

To ensure the accuracy and completeness of the information in these slides, we incorporated DOD, FAA, Commerce, and NASA technical comments, as appropriate.

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Scope and Methodology (continued)

Federal Agency and Foreign Government Space Agency Offices Interviewed

Federal Agencies

- Department of Defense
  - Office of the Under Secretary of Defense, Acquisition, Technology and Logistics
  - Office of the Secretary of Defense, Cost Assessment and Program Evaluation
  - U.S. Air Force, Space and Missile Systems Center Launch, Systems Enterprise Directorate
- Department of Commerce
  - International Trade Administration
  - Office of Space Commerce
  - National Oceanic and Atmospheric Administration
- Department of State
- Federal Aviation Administration
- National Aeronautics and Space Administration

Foreign Space Agencies

- European Space Agency
- Japan Aerospace Exploration Agency

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Space Contractors, Research Organizations, and Launch Insurer Interviewed

Contractors

- Arianespace (France)
- Orbital ATK (U.S.)
- United Launch Alliance (U.S.)
- SpaceX (U.S.)

Organizations that Conduct Space Research

- Rand Corporation
- Space Policy Institute at George Washington University
- The Tauri Group

Launch Indemnity Insurance

- XL Catlin Insurance

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