Federal Aviation Administration

The Annual Compendium of Commercial Space Transportation: 2016

January 2016

About the FAA Office of Commercial Space Transportation

The Federal Aviation Administration's Office of Commercial Space Transportation (FAA AST) licenses and regulates U.S. commercial space launch and reentry activity, as well as the operation of non-federal launch and reentry sites, as authorized by Executive Order 12465 and Title 51 United States Code, Subtitle V, Chapter 509 (formerly the Commercial Space Launch Act). FAA AST's mission is to ensure public health and safety and the safety of property while protecting the national security and foreign policy interests of the United States during commercial launch and reentry operations. In addition, FAA AST is directed to encourage, facilitate, and promote commercial space launches and reentries. Additional information concerning commercial space transportation can be found on FAA AST's website:

http://www.faa.gov/go/ast

Cover art: Phil Smith, The Tauri Group (2015)

Publication produced for FAA AST by The Tauri Group under contract.

NOTICE

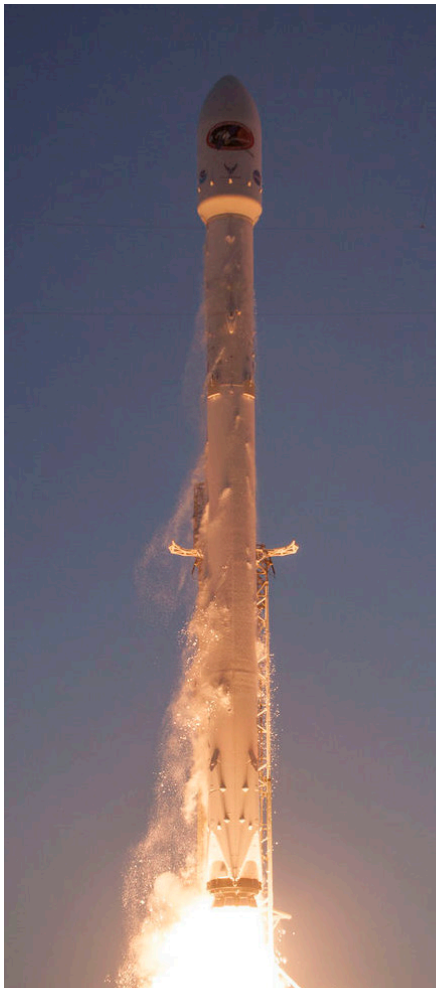
GENERAL CONTENTS

DETAILED CONTENTS

EXECUTIVE SUMMARY

The size of the global space industry, which combines satellite services and ground equipment, government space budgets, and global navigation satellite services (GNSS) equipment, is estimated to be about $324 billion. At $95 billion in revenues, or about 29 percent, satellite television represents the largest segment of activity. Following this is government space budgets at $76 billion, or 24 percent, and services enabled by GNSS represent, about $76 billion in revenues. Commercial satellite remote sensing companies generated on $1.6 billion in revenues, but the value added services enabled by these companies is believed to be magnitudes larger. Because remote sensing value added services includes imagery and data analytics from other sources beyond space-based platforms, only the satellite remote sensing component is included in the global space industry total.

All of this activity would not be possible without orbital launch services. Global launch services is estimated to account for $6 billion of the $324 billion total. Most of this launch activity is captive; that is, the majority of payload operators have existing agreements with launch service providers or do not otherwise “shop around” for a launch. About a third of this $6 billion represents internationally competed, or commercial, transactions.



A SpaceX Falcon 9 successfully launches DSCOVR from Cape Canaveral AFS in February 2015. Source. SpaceX

In 2015, there were a total of 86 orbital launches conducted by service providers in seven countries. This figure is elaborated upon in greater detail later in this report, but there are some interesting events worthy of note. Since 2014, U.S. providers have begun to cut into the existing share of commercial launches occupied by Russian providers. This is mostly due to a combination of factors. First is the entrance of Space Exploration Technologies (SpaceX), which has been offering its Falcon 9 and Falcon Heavy vehicles to the global market at low prices, attracting significant business. In addition, launch failures, quality control problems, and supply chain issues have plagued the Russian space industry, causing some customers to seek alternatives like SpaceX. In the meantime, Europe’s Arianespace remains a steadfast provider, offering reliable services via the Ariane 5 ECA, Soyuz 2, and Vega. Sea Launch, for a time a key player but never a dominant one, has essentially ceased operations. Meanwhile, Japan’s Mitsubishi Heavy Industries (MHI) Launch Services and India’s Antrix have become more aggressive at marketing their H-IIA/B and PSLV vehicles, respectively.

Since about 2004, the annual number of orbital launches conducted worldwide has steadily increased. This has been due to government activity. U.S. government launches remain steady. For example, retirement of the Space Shuttle in 2011 decreased the number of U.S. launches per year relative to the previous three decades. However, commercial cargo missions to the International Space Station (ISS) have helped to fill the resulting gap, along with anticipated commercial crew missions beginning in two years.

Perhaps most notable in terms of government launch activity is China. The number of orbital launches conducted by China has steadily increased each year since 2010, with a peak of 19 launches in 2012. The China Great Wall

Industry Corporation (CGWIC) has also been aggressively pursuing international clients via package deals that include satellite manufacturing and launch. These launches are not considered commercial since the launch contract is not internationally competed. In 2015, China introduced two new small-class launch vehicles, the Long March 6 and the Long March 11. The country continues to develop the Long March 5 and Long March 7, both of which are expected to be launched in 2016 from a new launch site on Hainan Island. Finally, China's human spaceflight program continues in a deliberate fashion, while the Chinese National Space Agency (CNSA) implements its robotic investigations of the Moon. These signs point to a robust future in Chinese spaceflight, expanding the Chinese slice of the pie.

An artist's impression of LauncherOne undergoing staging. Source: Virgin Galactic

Meanwhile, the commercial launch pie has not grown significantly during the past decade; instead, the slices of the pie have changed size. There are some signs the commercial launch pie may be expanding, however. Several new launch vehicles are being developed specifically to address what some believe is latent demand among small satellite operators. These vehicles are designed to launch payloads with masses under 500 kg (1,102 lb) to low Earth orbit (LEO). Though the price per kilogram remains high relative to larger vehicles, the value is in scheduling; small satellite operators, especially those with constellations of many satellites, can have greater control over their business plans. Previously, these small satellites would routinely "piggyback" as a secondary payload on a launch carrying a much larger payload. That primary payload dictated the schedule and the orbital destination. Some of these new vehicles are in advanced states of development, like the Electron by Rocket Lab and LauncherOne from Virgin Galactic, with some expected to start launching payloads in 2016. One vehicle that was under development for several years is U.S.-built Super Strypi. The Super Strypi was launched in November 2015 from Hawaii (the first orbital launch from the state), but failed soon after lift off. There were hopes that the vehicle would be offered commercially, but indications are the system will not attempt to fly again.

In addition to the failed Super Strypi flight, there were two other failures. One featured a Proton M provided by International Launch Services (ILS) carrying Mexsat-1 (Centenario). In that case, the third stage failed and the satellite and the Breeze-M fourth stage reentered the atmosphere shortly thereafter. The Proton M returned to flight in August 2015 carrying an Inmarsat satellite. The second failure was that of a SpaceX Falcon 9 carrying a Dragon cargo capsule to the ISS (Spx-7). In this case, the second stage experienced a structural failure just before staging. The Dragon capsule remained intact and operational, but its software was not programmed to deploy a parachute in the event of a launch failure. SpaceX returned to flight with the successful deployment of 11 ORBCOMM satellites in late December 2015. Both accidents delayed several commercial launches, many of which were rescheduled for 2016. For this reason, the number of commercial launches in 2015 will be slightly lower than in 2014.

Blue Origin's New Shepard just before landing on its historic flight. Source: Blue Origin

There were some notable activities in 2015 relating to suborbital reusable vehicles. Blue Origin's New Shepard vehicle successfully flew twice, launching from the company's site in western Texas. The second flight, which took place on November 23, 2015, featured the first time in history that a vehicle was launched vertically, entered space, then landed vertically. Of course, the vehicle was not designed to achieve orbital velocities, and its apogee was 100.5 km (62 mi). In 2015, The Spaceship Company pursued work on the second SpaceShipTwo vehicle as the accident investigation for the October 2014 accident of SpaceShipTwo continued. Virgin Galactic, the operator of the SpaceShipTwo vehicles, expects flight testing of the new vehicle to take place in 2016.

The year in space transportation represented activity similar to each of the previous five years. But it belies what is taking place behind the scenes. New vehicles are being developed to replace older ones or to augment capabilities, while new satellite operators stand poised to release large constellations of telecommunication and remote sensing satellites. Human spaceflight activities continue on both the orbital and suborbital front, with orbital test flights of commercial vehicles expected to take place by 2017 and suborbital tests scheduled for 2016.

INTRODUCTION

THE FEDERAL AVIATION ADMINISTRATION OFFICE OF COMMERCIAL SPACE TRANSPORTATION

The mission of the Federal Aviation Administration Office of Commercial Space Transportation (FAA AST) is to ensure protection of the public, property, and the national security and foreign policy interests of the United States during commercial launch or reentry activities, and to encourage, facilitate, and promote U.S. commercial space transportation.

The office was established in 1984 as part of the Office of the Secretary of Transportation within the Department of Transportation (DOT). In November 1995, AST was transferred to the FAA as the FAA's only space-related line of business. FAA AST was established to:

- Regulate the U.S. commercial space transportation industry, ensure compliance with international obligations of the United States, and protect the public health and safety, safety of property, and national security and foreign policy interests of the United States;
- Encourage, facilitate, and promote commercial space launches and reentries by the private sector;
- Recommend appropriate changes in federal statutes, treaties, regulations, policies, plans, and procedures; and
- Facilitate the strengthening and expansion of the United States space transportation infrastructure.

AST manages its licensing and regulatory work as well as a variety of programs and initiatives to ensure the health and facilitate the growth of the U.S. commercial space transportation industry through the Office of the Associate Administrator along with its five divisions:

- Space Transportation Development Division
- Licensing and Evaluation Division
- Regulations and Analysis Division
- Safety Inspection Division
- Operations Integration Division

AST issues FAA licenses and permits for commercial launches of orbital and suborbital rockets. The first U.S. licensed launch was a suborbital launch of a Starfire vehicle on March 29, 1989. Since then, AST has licensed over 230 launches. The AST also issues licenses for the operations of non-federal launch sites, or "commercial spaceports." Since 1996, AST has issued site operator licenses for 10 commercial launch and reentry sites.

THE ANNUAL COMPENDIUM

The Annual Compendium is published in January of each year. It represents a consolidation of information designed to provide the reader with a general understanding of the space transportation industry.

General Description

The body of the document is composed of three parts, supplemented by introductory matter and appendices. The first part provides narrative detail on the space transportation industry, covering topics such as launch vehicles, payloads, and launch and reentry sites. The second part is a summary of worldwide space activities during the previous calendar year. It integrates this review with space transportation activities that have taken place during the past five years. The third section covers policies and regulations relevant to commercial space transportation, and highlights activities conducted by the Commercial Space Transportation Advisory Committee (COMSTAC) during the previous calendar year. Future editions of the Compendium will include a fourth section capturing the annually updated 10-year commercial space transportation forecast.

The appendices include definitions and acronyms, a list of tables and figures, and the orbital launch manifest for the previous year. Fact sheets are also included in the appendices. Each two-page sheet covers a particular launch vehicle currently in service and those in an advanced stage of development. Fact sheets contain more detailed information than what is available in the body of the report.

Compendium and Supplemental Fact Sheets

A good deal of technical information is omitted from the body of the Compendium for clarity. This information is carried over into fact sheets, some of which are included in the Compendium Appendix and provided on the FAA AST website.

The fact sheets are related to major sections of the Compendium. Whereas the Compendium will be updated annually and helps provide context, the fact sheets are designed to be updated as necessary to reflect real world developments.

Figure 1 shows how the fact sheets relate to the sections of the Compendium. Future editions will include fact sheets on policy and regulations, as well as a section and supporting fact sheets on the annual 10-year commercial space transportation forecast.

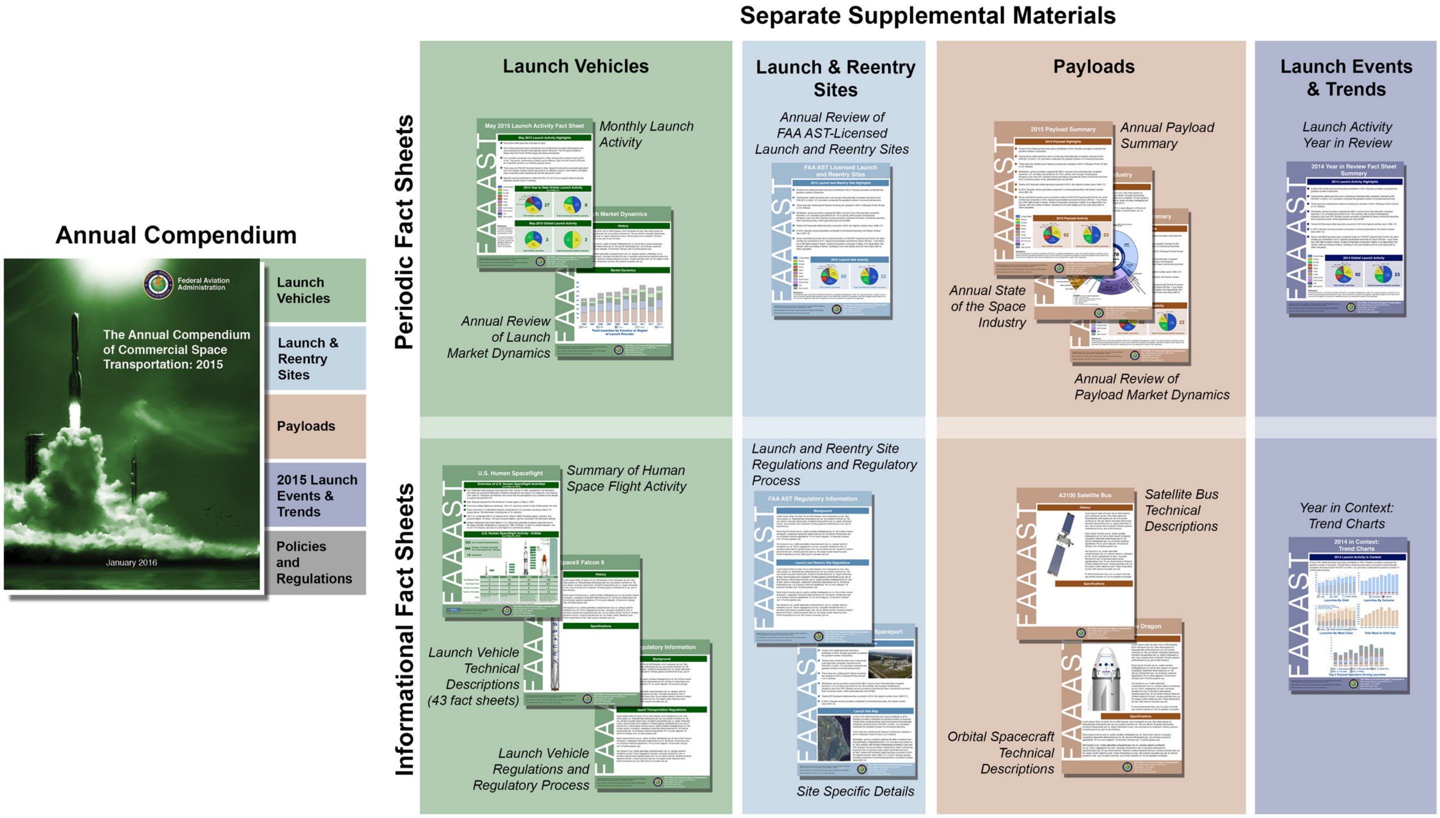


Figure 1. The general structure of the Annual Compendium and its various supporting fact sheets. The fact sheets represented in the graphic are for illustration only.

An Atlas V provided by United Launch Alliance (ULA) sends an Orbital ATK Cygnus module to the International Space Station on December 6, 2015. Source: ULA

THE SPACE TRANSPORTATION INDUSTRY

At $5.9B in revenues in 2014[1], the global space transportation industry is a relatively small part of the overall $323B global space industry. But without it, space-based services would be impossible. It is an enabling capability, one that makes it possible to send national security and commercial satellites into orbit, probes into the solar system, and humans on exploration missions.

THE SPACE INDUSTRY

For context, the global space industry is estimated to have been $323B in 2014. About $203B (63%) of this was revenue generated by companies providing services like television; mobile, fixed, and broadband communications; remote sensing; satellite systems and ground equipment manufacturing and sales; and, of course, launch services. The remaining $120B (37%) constitutes government space budgets and global navigation satellite system (GNSS) chipsets and services.

The U.S. space industry was approximately $125B in 2014. This includes $87B in revenues generated by satellite services, satellite manufacturing, satellite ground equipment, and launch services as well as $38B spent on space programs by the U.S. government. U.S. launch service providers accounted for about $2.4B in total revenues or 41% of global launch services. FAA AST-licensed launches accounted for $617M of the $2.4B.

LAUNCH VEHICLES

The story of space transportation reaches back at least one thousand years ago when the Chinese invented the rocket. At this time, the rocket was essentially a small firework, powered by gunpowder. In 1903, Russian mathematician, Konstantin Tsiolkovsky, published details on his plans for a multi-stage, liquid-fueled rocket. Tsiolkovsky recognized that a combination of stages and liquid fuels was necessary to send a payload into orbit, but never built such a machine. These plans were realized through the work of an American, Robert Goddard, who independently invented a liquid-fueled rocket and launched it in 1926. His work was largely conducted in secret, and his impact on the nascent industry was negligible. Hermann Oberth, of German descent but born in Austria-Hungary, also invented a rocket, unaware of the works of Tsiolkovsky and Goddard. He published his invention in 1923. This work is generally credited with introducing the rocket to the public. Soon after, he and fellow rocket enthusiasts established *Verein für Raumschiffahrt (VfR)*, a rocket club. Similar clubs sprouted elsewhere around the world during the 1920s and 1930s, but it was the cash-strapped *VfR* that received substantial

[1] $5.9B is an estimate that includes all orbital launch contracts in which financial transaction occurred between two or more organizations and revenue estimates for all launches licensed by FAA AST. For example, payload operators typically acquire launches through another organization. The Indian Space Research Organization (ISRO) is an obvious exception, because payloads are built, operated, and launched by ISRO itself. Of the $5.9B, approximately $2.4B was revenue generated by internationally competed launches, in which a customer “shopped around” for a launch. Sources: 2014 State of the Satellite Industry (Satellite Industry Association) and publicly available data.

funding by the German military to scale up the technology. In 1942, *VfR* became the first group to successfully launch a large ballistic missile into suborbital space. Following the end of World War II, many international teams elaborated upon the rocket, most notably in the U.S. and Soviet Union, but also in China, Japan, India, and others. By 2015, the world was launching between 70 and 100 rockets into orbit annually.

Typical Launch Vehicle Subsystems

General Description

A typical launch vehicle system consists of several basic subsystems, including propulsion; power; guidance, navigation, and control (GNC); payload adapters; and fairings. This report focuses more on the propulsion subsystem, specifically rocket engines themselves. Brief descriptions of major rocket engines used on U.S. launch vehicles follow.

Rocket Engines

Rocket engines are generally grouped according to the type of propellant being used: solid or liquid. There are also examples of hybrid engines that feature both solid and liquid propellants.

Rocket engines that burn solid propellant are simpler in construction, relatively inexpensive, and can be stored for long periods of time, making them ideal for missiles in particular. Once ignited, engines burning solid propellant cannot be throttled at will or shut off. These characteristics make it a potentially controversial option for launch systems designed to carry people. The engine, often referred to as a solid motor, consists of a metal or composite casing filled with a viscous propellant that cures and becomes solid. The central axis of the motor is hollow and serves as the combustion volume; combustion takes place along the entire length of the motor. The propellant contains a fuel, such as aluminum powder and an oxidizer, such as ammonium perchlorate. The mixture also contains a binding agent. A catalyst or igniter is used to start the motor. Once ignited, the exhaust is ejected through the nozzle to create thrust.

The following solid motors are used in currently available U.S. launch vehicles. Also included are engines designated for use on vehicles under development.

A 5-segment Solid Rocket Booster being prepared for ground test firing (Orbital ATK)

- **Five-Segment Solid Rocket Boosters (SRB):** The five-segment SRB is derived from the four-segment SRBs used for STS from 1981 to 2011. The boosters were originally designed and manufactured by Thiokol, which was purchased by Alliant Techsystems (ATK) in 2001. The company merged with Orbital Sciences Corporation in 2014 and is now known as Orbital ATK. Two five-segment SRBs will be used to augment the core stage of the Space Launch System (SLS), currently being developed by NASA. The SRBs will burn a polybutadiene acrylonitrile (PBAN)-based ammonium perchlorate composite propellant (APCP). The mixture includes ammonium perchlorate as the oxidizer, aluminum powder as the fuel, PBAN as a binding agent, an iron oxide catalyst, and an epoxy-curing agent. Each booster can produce 16,000 kilonewtons (kN), or 3,600,000 pounds of force (lbf) of thrust. Together, the thrust of both boosters will be about 32,000 kN (7,200,000 lbf). Orbital ATK successfully completed four full-scale, full-duration static fire tests of the five-segment SRB in 2015. The first mission employing SLS will be Exploration Mission-1 (EM-1), scheduled for late 2018.

- **STAR motors:** The STAR line of solid motors, first produced by Thiokol and now manufactured by Orbital ATK, is used for upper stage elements in launch vehicles. The motors are designated by case diameter, so the STAR-37 means the casing diameter is 37 inches (94 centimeters). The most commonly used STAR motors today are the STAR-37 and STAR-48 as upper stages or kick motors designed to insert payloads into their final orbits.
- **GEM Strap-on Booster System:** The Graphite Epoxy Motor (GEM) provided by Orbital ATK was introduced in 1991 to supplement the first stage thrust of the Delta II launch vehicle. This version, called the GEM-40, had a 40-inch diameter. The Delta III, which only flew three times from 1998 to 2000 as a transitional vehicle between the Delta II and Delta IV, used the GEM-46. The GEM-60, with a 60-inch diameter, is currently used for the Delta IV Medium. The vehicle will fly with either two (2,491 kN or 560,000 lbf) or four (5,338 kN or 1.2 million lbf) GEM-60 motors. The GEMs burn a propellant mixture called Hydroxyl-terminated polybutadiene (HTPB) and can feature vectorable nozzles. In 2015, Orbital ATK won a contract to provide the slightly larger GEM-63 motor for use on the Atlas V provided by United Launch Alliance (ULA), replacing the AJ-60A booster provided by Aerojet Rocketdyne in 2018. A longer version of this motor, called the GEM-63XL, will be used on ULA's Vulcan vehicle. Orbital ATK had not released performance data for the GEM-63 by the time of this writing.
- **AJ-60A Solid Rocket Motor:** The AJ-60A solid motors, manufactured by Aerojet Rocketdyne, have been used to supplement first stage thrust for the Atlas V since 2002. The 157-centimeter (62-inch) diameter boosters burn HTPB. One to five boosters can be used, depending on the Atlas V variant. The AJ-60A is being replaced with the Orbital ATK's GEM-63 motors

A STAR-48 motor used for NASA's Low-Density Supersonic Decelerator project (NASA)

A GEM-60 being prepared for integration on a Delta IV (Orbital ATK)

A rocket engine that burns liquid propellants is significantly more complex and expensive than a solid motor. There are two types of liquid rocket engines. Bipropellant engines burn a mixture of liquid fuel and liquid oxidizer using an igniter or, in the case of a hypergolic engine the propellants spontaneously ignite when they come in contact with each other. The former is used for most launch vehicles, while the latter is preferred for on-orbit maneuvering because there are fewer parts involved and combustion is virtually guaranteed. The second type is the monopropellant engine, which uses a liquid fuel that does not require an oxidizer and is ignited using a catalyst. An example would be liquid hydrogen peroxide introduced to a silver mesh catalyst, an interaction that rapidly produces a high-pressure gas. All of these engines rely on a pressurant system using inert gas, combined with pumps, to ensure that propellant is being constantly fed into the engine regardless of the orientation of the vehicle.

An AJ-60A being integrated with an Atlas V (Aerojet Rocketdyne)

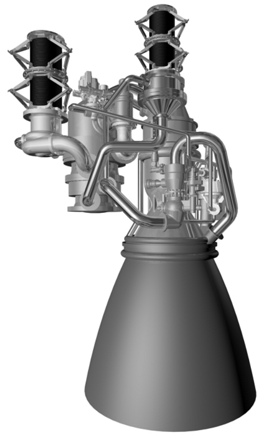
Liquid rocket engines are complex and expensive for a variety of reasons. Often, the propellants used are cryogenic, meaning the liquid is several hundred degrees below zero. The engine can be throttled, necessitating an engine controller and associated hardware. These rocket engines can use bleed-off exhaust products to spin up the turbopumps and often feature recirculating cryogenic propellants to cool the nozzle jacket. They can also employ

A model of the BE-4 engine (Blue Origin)

preburners to warm the cryogenic propellant immediately prior to ignition. In addition, the propellant tanks, pressurant tanks, and plumbing represent added complexity when compared to solid motors. A reusable liquid rocket engine, such as those once employed by the Space Shuttle orbiters, represents another level of complexity because of the need to engineer robustness into a system that experiences very broad temperature extremes and high pressures.

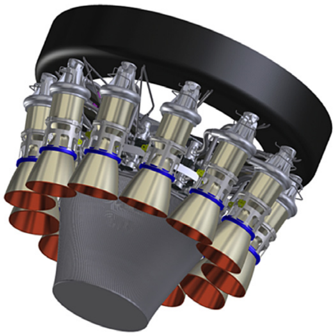
The following liquid rocket engines are used in currently available U.S. launch vehicles. Also included are engines designated for use on vehicles under development.

- **BE-4:** The BE-4 is an engine under development by Blue Origin. It will burn a mixture of liquid oxygen (LOX) and liquefied natural gas (LNG), mostly composed of methane) and produce 2,447 kN (550,000 lbf) of thrust. This is the baseline engine for the company's orbital launch vehicles and the first stage of ULA's Vulcan. Blue Origin is planning to have the BE-4 available for operational flights in 2017. The BE-4 is derived from the LOX-liquid hydrogen BE-3, an engine being used for Blue Origin's *New Shepard* suborbital launch vehicle.
- **AR-1:** The AR-1 is an engine currently under development by Aerojet Rocketdyne. The engine, which will burn a LOX-kerosene mixture, is designed to produce about 2,224 kN (500,000 lbf) of thrust. The AR-1 was proposed as a replacement for the Russian-built RD-180, used by the Atlas V vehicle, but ULA has elected to replace the Atlas V with the new Vulcan vehicle powered by Blue Origin's BE-4. However, ULA has designated the AR-1 is an alternative to the BE-4 in the event the latter engine is delayed.



A 3D model of the AR1 engine (Aerojet Rocketdyne)

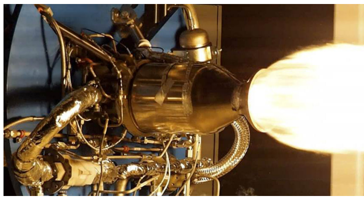
- **FRE-1 and FRE-2:** Fire Fly Space has developed the FRE line of engines to power the first and second stages of its Alpha launch vehicle. The FRE-2 is an aerospike engine that, if successful, may prove to be the first aerospike engine employed in an operational launch system. An aerospike does not feature a traditional bell-shaped nozzle, which reduces weight but also reduces exhaust pressure (specific impulse). Aerodynamic design is used to counter this loss of pressure and increase efficiency. The engine burns LOX and kerosene to produce a thrust of about 443 kN (99,600 lbf). The FRE-1 is a conventional nozzle engine burning the same propellant mixture to produce 28 kN (6,200 lbf) of thrust.
- **Merlin 1D:** The Merlin 1D is the engine used to power both the first and second stages of SpaceX's Falcon 9 and Falcon Heavy launch vehicles. This engine produces about 756 kN (185,500 lbf) of thrust and burns a LOX-kerosene mixture. Nine of these engines power the Falcon 9 first stage (for a total thrust of about 6,806 kN or 1,530,000 lbf) and one is used to power the second stage. The Merlin 1D is a fourth generation SpaceX engine that traces its lineage to the Merlin 1A that powered the Falcon 1 vehicle. The Merlin 1A leveraged technology developed for NASA's Fastrac engine, which used a pintle single-feed injector as opposed to the more typical arrangement of hundreds of injector holes. The Merlin 1C was used for the Falcon 9 v1.0 vehicle, whereas the Merlin 1D powers the Falcon 9 v1.1 vehicle. The more powerful Falcon 9 Full Thrust (Falcon 9 FT) will feature a higher thrust capability, giving the vehicle a 30 percent increase in performance from the Falcon 9 v1.1. This upgraded vehicle will launch in late 2015. As of October 2015, SpaceX does not plan to sell the Merlin engines separately.



The FRE-2 aerospike engine (Firefly Space Systems)

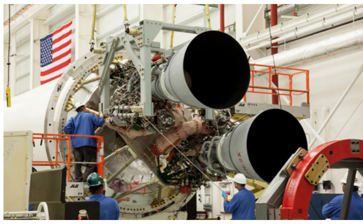
- **Newton:** The Newton series of engines being developed by Virgin Galactic will power the company's air-launched LauncherOne vehicle. These engines use LOX and kerosene as propellants. The NewtonThree, which produces 327 kN (73,500 lbf) of thrust, will power the LauncherOne first stage. A NewtonFour engine, producing 22 kN (5,000 lbf) of thrust, will power the second stage to orbit. First flight of LauncherOne is expected in 2016.
- **RD-180:** The RD-180 is a Russian-built engine that powers the Common Core Booster (CCB) of the Atlas V vehicle using a LOX-kerosene propellant mixture. It produces a thrust of about 3,830 kN (860,000 lbf). The engine is built by RD AMROSS (a joint effort between Aerojet Rocketdyne—previously Pratt & Whitney Rocketdyne—and NPO Energomash). Following the collapse of the Soviet Union, the U.S. government negotiated an agreement whereby Russia would manufacture relatively inexpensive rocket engines to support the Evolved Expendable Launch Vehicle (EELV) program that led to the Atlas V and Delta IV. The original plan called for eventual manufacture of the engine in the United States. However world events and market driven competition has removed the RD-180 from the supply chain. In fact, the National Defense Authorization Act of 2015 limits the use of the RD-180 for national security missions and the government has directed a replacement engine be in operation by 2019.
- **RD-181:** The RD-181 is an engine being developed by NPO Energomash for the Antares vehicle built and offered by Orbital ATK. The original Antares, which was used on four missions, used two AJ26 engines on its first stage. The AJ26 was essentially a significantly modified NK-33 engine. Aerojet purchased 36 of the original 150 NK-33 engines, which were inspected, refurbished, and designated AJ26. Following the loss of the fourth Antares vehicle in October 2014 due to an engine failure, Orbital ATK moved to replace the engines on future Antares vehicles. In 2015, Orbital ATK contracted with NPO Energomash for 20 RD-181 units. The Antares will feature two LOX-kerosene RD-181 engines, each producing about 1,913 kN (430,000 lbf) of thrust. The first launch of the Antares using the new engines is planned for the first half of 2016.
- **RL10:** The first variant of the RL10 engine was designed in 1959 by Pratt & Whitney (now part of Aerojet Rocketdyne). It was first used in 1962 as the engines for the Centaur upper stage of Atlas missiles converted as launch vehicles. The engine burns LOX-liquid hydrogen and produces a thrust of about 110 kN (25,000 lbf). The current model of this engine, the RL10A-4-2, continues to power the Centaur upper stage for the Atlas V. The RL10B-2 is used for the Cryogenic Upper Stage of the Delta IV vehicle. Further development of the RL10 is underway to support ULA's Advanced Cryogenic Evolved Stage (ACES) for the company's Vulcan launch vehicle.
- **RS-25E:** The RS-25E, built by Aerojet Rocketdyne, is an expendable version of the RS-25, also called the Space Shuttle Main Engine (SSME). Four RS-25E engines will be used for each core stage of NASA's upcoming SLS. Sixteen SSMEs from the retired STS Program have been refurbished and stored for use on four SLS missions, which begin in late 2018. The RS-25E will be used on subsequent SLS vehicles. Each RS-25E will burn a LOX-liquid hydrogen propellant mixture and produce about 2,277 kN (512,000 lbf) of thrust. Though the original

A Merlin-1D engine (SpaceX)

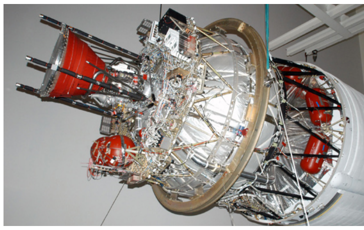


A NewtonOne engine undergoing a test (Virgin Galactic)

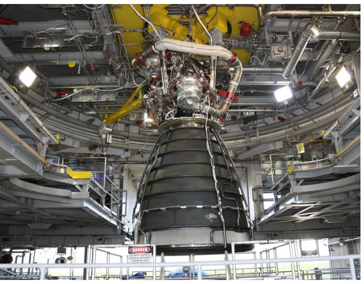
An RD-180 engine installed ont he first stage of an Atlas V (ULA)



Two RD-181 beng integrated with an Antares launch vehicle (NASA)

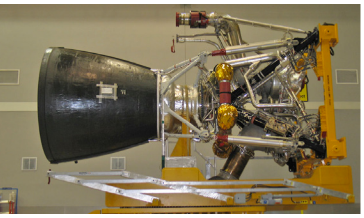


An RL10B-2 powers the Delta IV cryogenic upper stage (ULA)



An RS-25 being prepared for a test firing (Aerojet Rocketdyne)

An RS-27A undergoing ground testing (ULA)



An RS-68A being prepared for installation on a Delta IV CBC (ULA)

SSMEs were expensive, NASA is working with Aerojet Rocketdyne to develop manufacturing methods for the RS-25E designed to increase performance while at the same time reduce the per-unit cost.

- **RS-27A:** The RS-27A is the engine used to power the core stage of the Delta II. Also developed by Aerojet Rocketdyne, the RS-27A burns LOX and kerosene, producing a thrust of about 890 kN (200,100 lbf).
- **RS-68:** Aerojet Rocketdyne also produces the RS-68, a more powerful engine than the RS-27 that burns a LOX-liquid hydrogen propellant mix. From 2002 to 2012, each Common Booster Core (CBC) of the Delta IV was powered by a single RS-68 engine, which produces about 2,950 kN (660,000 lbf) of thrust. An upgraded version of the engine, called the RS-68A, was introduced in 2012 as a replacement to the RS-68. It can produce 3,137 kN (705,000 lbf) of thrust.
- **Rutherford:** Rocket Lab has designed the Rutherford engine for use in the first stage of the company's Electron vehicle. The engine burns a mixture of LOX and kerosene, producing a thrust of about 22 kN (5,000 lbf). Rocket Lab is employing additive manufacturing (3D printing) in the construction of all primary components of the Rutherford, making it a unique example in the industry. 3D printing reduces costs by simplifying the manufacturing process. The first launch of the Electron is expected in 2016 from a site in New Zealand.
- **XR Series:** XCOR Aerospace has been developing engines since 2000, when the company fully integrated the XR-3A2 and XR-4A3 into an EZ-Rocket test aircraft. Currently, XCOR is developing the XR-5K18 engine for the company's Lynx suborbital vehicle. The XR-5K18 burns a LOX and kerosene propellant mixture, producing a thrust of about 13 kN (2,900 lbf). The Lynx will be powered by four XR-5K18 engines. The company is a partner with ULA on the development of a LOX-liquid hydrogen upper stage engine, capable of producing up to 130 kN (30,000 lbf) of thrust. This effort leverages technologies developed for the XR-5K18.

The Rutherford engine (Rocket Lab)

The XR-5K18 being test fired (XCOR Aerospace)

Launch Vehicle Integration and Processing

Since there are many different types of launch vehicles, there are many different ways to integrate and launch them. In general, however, vehicle assemblies and subsystems are manufactured in several locations, then transported via rail, air, or sea to the launch site where the parts come together as a complete launch vehicle. Figure 2 illustrates the basic idea using a generic vehicle as an example.

Once the launch vehicle is fully integrated, it is then joined with its payload. This process is called payload integration. The payload will arrive at the launch site from the manufacturing or checkout site to a specialized facility designed to handle the unique needs of the payload. For example, payloads may require fueling, last-minute integration with components, or final testing and checkout. It is then attached to a payload adapter. The payload adapter is the physical connection between the payload and the launch vehicle, and can be integrated with the launch vehicle either horizontally or vertically depending on the vehicle. Once integrated, the payload fairing is installed. The vehicle and payload then make their way to the launch pad, where the combination continues to be monitored during a technical checklist called a countdown. Fueling of a vehicle using liquid propellants takes place at the pad, usually immediately prior to launch.

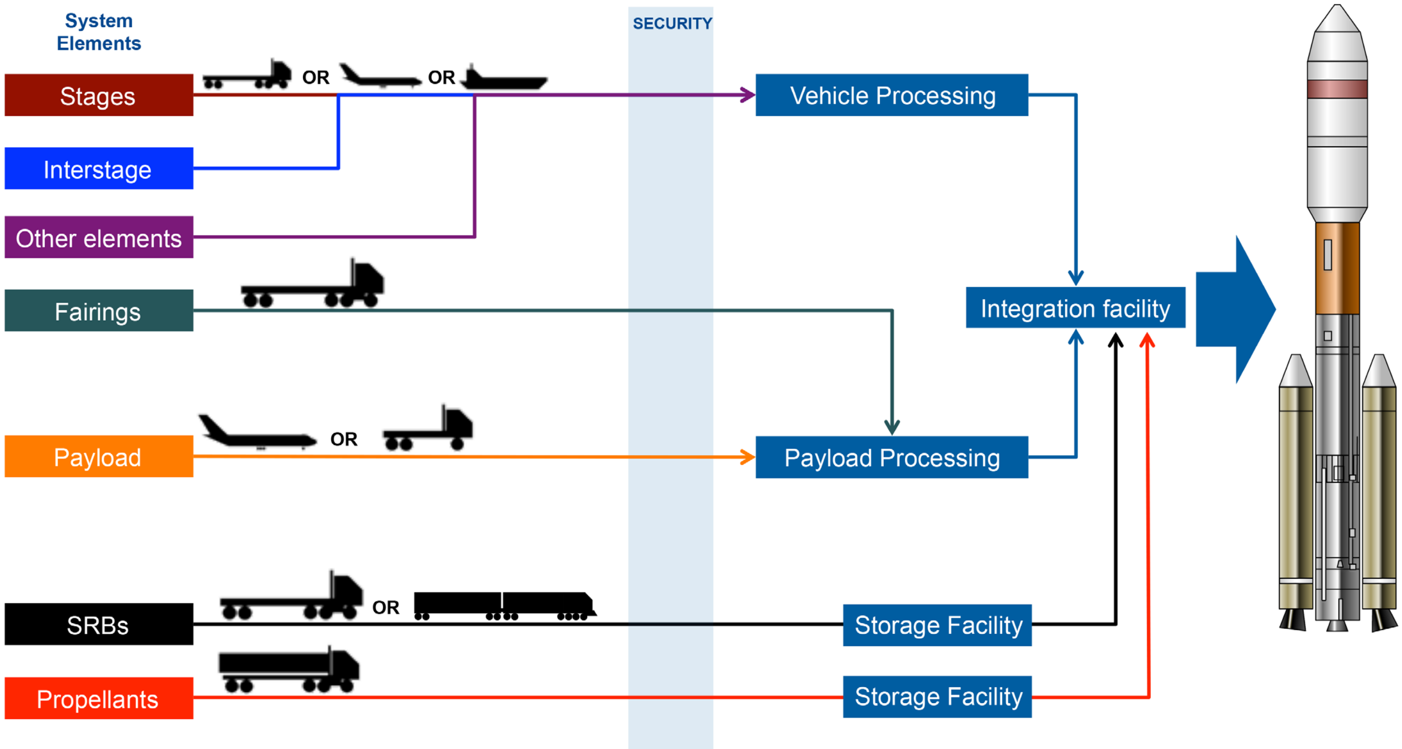


Figure 2. A typical launch vehicle integration and processing scheme.

While the launch vehicle and payload are handled at the launch site, other operations take place to support launch activities. These are handled by a launch range, whose main purpose is to insure that the launch is conducted efficiently and safely. The range manages the airspace around the site, any ground or sea traffic in the vicinity or downrange, and supports launch emergencies should they occur.

Figure 3 describes the typical elements of a launch site and range, using a generic vehicle as an example.

Operational Orbital Launch Vehicles

By the end of 2015, there were 112 different orbital launch vehicles operating around the world. This figure includes variants of a family of vehicles; for example, there are 18 Atlas V variants defined by the number of solid rocket boosters used, type of fairing by diameter, and type of Centaur upper stage (single or dual engine). Not all of these vehicles are available for commercial use, whereby a payload customer can “shop around” for a ride into orbit.

There are six expendable launch vehicle types available for commercial use by launch providers in the United States (see Table 1). The Delta II, which flew once in 2015, is no longer available. U.S. launch service providers include Maryland-based Lockheed Martin, Virginia-based Orbital ATK, California-based SpaceX, and Colorado-based ULA. ULA has historically only served U.S. government customers, but has indicated it plans to open its Atlas V, Delta IV, and future Vulcan vehicles for international competition. Another U.S. vehicle, the Super Strypi, developed and built by the University of Hawaii (UH), Sandia

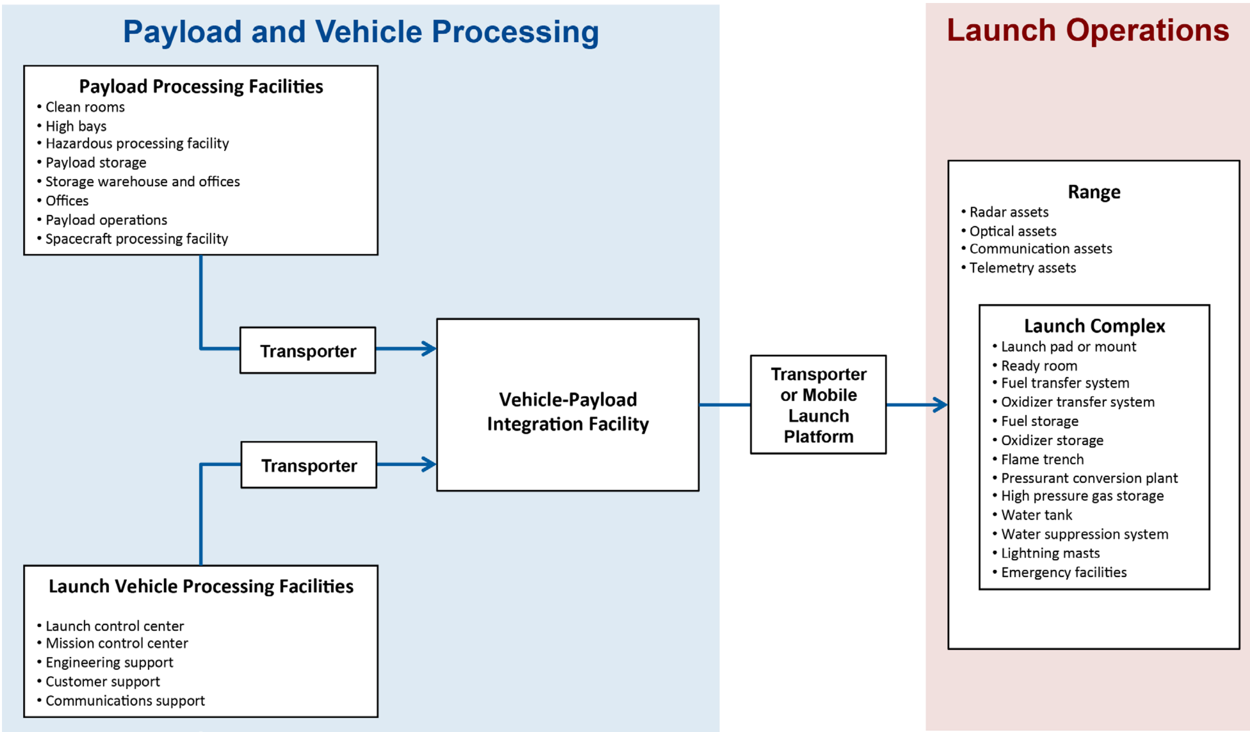


Figure 3. A typical arrangement for a launch site and range.

National Laboratory, and Aerojet Rocketdyne was launched for the first time in 2015; however, the vehicle was destroyed shortly after launch. The availability of this vehicle for commercial use in the future remains uncertain.

Several orbital launch vehicles are under development with inaugural launches planned during the next two to five years. Some of these are operated by non-U.S. companies but are expected to fly from U.S. sites. These are listed in Table 2.

Other U.S. vehicles are under various stages of development, including the air-launched Thunderbolt from Stratolaunch Systems, and several small systems like the Lynx Mark III from XCOR Aerospace, the NEPTUNE from InterOrbital Systems, and others. The Defense Advanced Research Projects Agency (DARPA) is also sponsoring development of vehicles that may be available for commercial use, including the XS-1 and Airborne Launch Assist Space Access (ALASA).

There are 13 expendable launch vehicle types available for commercial use outside the United States: Ariane 5, Dnepr, Epsilon, GSLV, H-IIA/B, Long March 2D, Long March 3A, Proton M, PSLV, Rockot, Soyuz 2, Vega, and Zenit 3SL/SLB.

Operational Suborbital Launch Vehicles

Sounding Rockets

Sounding rockets typically employ solid propellants, making them ideal for storage. They differ from amateur or hobbyist rockets in that they climb to higher altitudes, but do not enter a sustainable orbit, and they carry out missions on behalf of commercial, government, or non-profit clients. Sounding rockets are used for atmospheric research, astronomical observations, and microgravity experiments that do not require human tending.

Vehicle	Operator	Year of First Launch	Total 2015 Launches	Active Launch Sites	Mass to LEO kg (lb)	Mass to SSO kg (lb)	Mass to GTO kg (lb)	Estimated Price per Launch
Antares	Orbital ATK	2013	0	MARS	3,500-7,000 (7,716-15,432)	2,100-3,400 (4,630-7,496)	N/A	$80M-$85M
Atlas V	ULA and LMCLS	2002	9	CCAFS VAFB	**8,123-18,814 (17,908-41,478)**	6,424-15,179 (14,163-33,464)	3,460-8,900 (7,620-19,620)	$110M-$230M
Delta IV	ULA	2002	3	CCAFS VAFB	9,420-28,790 (20,768-63,471)	7,690-23,560 (16,954-51,941)	3,060-14,220 (6,746-31,350)	$164M-$400M
Falcon 9	SpaceX	2010	7	CCAFS VAFB	13,150 (28,991)	Undisclosed	4,850 (10,692)	$61.2M
Minotaur-C	Orbital ATK	2016	0	CCAFS MARS VAFB WFF	1,278-1,458 (2,814-3,214)	912-1,054 (2,008-2,324)	N/A	$40M-$50M
Pegasus XL	Orbital ATK	1994	0	CCAFS Kwajalein VAFB WFF	450 (992)	325 (717)	N/A	$40M

Table 1. Orbital vehicles currently available for commercial use by U.S. providers.

Vehicle	Operator	Year of First Launch	Active Launch Sites	Mass to LEO kg (lb)	Mass to SSO kg (lb)	Mass to GTO kg (lb)	Estimated Price per Launch
Alpha	Fire Fly	2016	KSC	400 (882)	200 (441)	N/A	$8M
Orbital Launch Vehicle	Blue Origin	2020	CCAFS	Undisclosed	Undisclosed	Undisclosed	Undisclosed
Cab-3A	CubeCab	2017	TBD	5 (11)	Undisclosed	N/A	$250K
Electron	Rocket Lab	2016	PSCA Kaitorete	Undisclosed	150 (331)	N/A	$4.9M
Falcon Heavy	SpaceX	2016	KSC VAFB	53,000 (116,845)	Undisclosed	21,200 (46,738)	$270M
GOLauncher-2	Generation Orbit	2017	Cecil Field Spaceport	45.4 (100)	Undisclosed	N/A	$2.5M
LauncherOne	Virgin Galactic	2017	Spaceport America	400 (882)	225 (496)	N/A	$10M
Lynx Mark III	XCOR Aerospace	2018	KSC Midland	10 (22)	Undisclosed	N/A	$545K
SOAR	Swiss Space Systems	2018	KSC	250 (551.2)	Undisclosed	N/A	$10.5M
Stratolaunch	Stratolaunch Systems	2016	Mojave KSC	3,000 (6,614)	1,400 (3,086)	N/A	Undisclosed
Vulcan	ULA	2019	CCAFS VAFB	9,370-18,510 (20,657-40,510)	7,724-15,179 (17,029-33,464)	4,750-8,900 (10,472-19,621)	$85M-$260M

Table 2. Projected orbital launch vehicles that may be available for commercial use in the United States.

Three ELV sounding rocket systems are currently available to U.S. customers, with two that have a long history of providing highly reliable services. Canada-based Bristol Aerospace has provided sounding rockets that have been used in the U.S. for decades. They are available to the U.S. scientific community through the NASA Sounding Rockets Operations Contract (NSROC), managed by the NASA Sounding Rockets Program Office (SRPO), located at Wallops Flight Facility (WFF) in Virginia.

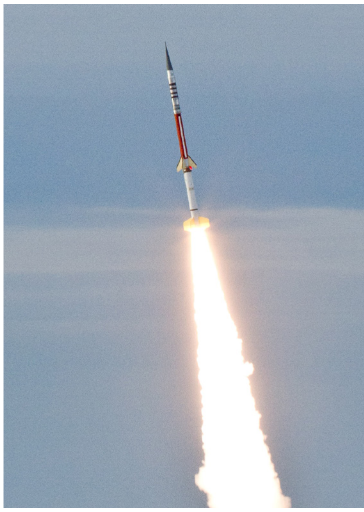
NASA's SRPO conducts sounding rocket launches for NASA, universities, and other customers. Supplied vehicles include Bristol Aerospace's Black Brant series in several vehicle configurations, from a single-stage vehicle to a four-stage vehicle stack (described in a previous section); the Improved Orion; and the Terrier-Improved Orion. WFF provides both engineering and mission operations support to the commercial launch industry. Through NASA Space Act Agreements, WFF engineering personnel and laboratories frequently support commercial space technology development and testing. WFF also provides launch range services to the commercial launch industry, either directly or through partnership with the FAA-licensed MARS. However, NASA cannot offer commercial flights aboard government-owned suborbital vehicles; the agency can support only preparation and mission operations needs for commercial users. NASA's SRPO integrates the subassemblies, which, with the exception of Black Brant, consist of military surplus Orion and Terrier motors. Payloads are typically limited to science and hardware testing. SRPO conducts about 15-20 sounding rocket launches per year from WFF in Virginia, Poker Flat Research Range in Alaska, White Sands Missile Range in New Mexico, and Andoya Rocket Range in Norway.

A description of major U.S. sounding rockets is provided below:

A Black Brant sounding rocket launched in 2011 (NASA)

- **Black Brant:** The Black Brant sounding rocket system is a flexible, multi-configuration family of upper- and exo-atmospheric launch vehicles. Over 1,000 Black Brant rockets have launched since production began in 1962. The Black Brant rocket motor, the related Nihka rocket motor, and supporting hardware are all manufactured in Canada by Bristol Aerospace, a subsidiary of Magellan Aerospace Limited. U.S.-manufactured Terrier, Talos, and Taurus motors are on several Black Brant configurations. The SRPO has made extensive use of the Black Brant vehicles. The Black Brant family of vehicles can launch a 113-kg (250-lb) payload to an altitude of at least 1,400 km (870 mi), a 454-kg (1,000-lb) payload to an altitude of at least 400 km (250 mi), or a 680-kg (1,500-lb) payload to an altitude of at least 260 km (160 mi). These vehicles can provide up to 20 minutes of microgravity time during a flight. Payloads with diameters of up to 56 cm (22 in) have flown successfully. The smallest version of the Black Brant family is the Black Brant V, which is 533 cm (210 in) long and 43.8 cm (17.24 in) in diameter. The rocket produces an average thrust of 75,731 N (17,025 lbf). The Black Brant V motor can be used on its own, as a single-stage vehicle, or used as the second or third stage in larger, multi-stage versions of the Black Brant. The most powerful configuration of the family, the Black Brant XII, is a four-stage vehicle that uses the Black Brant V motor as its third stage and Bristol Aerospace's Nihka motor as its fourth stage. The Black Brant remains in active use today, after nearly 50 years of reliable service. The Black Brant sounding rocket system continues to be the workhorse of the NASA Sounding Rocket Program.

- **Improved Orion and Terrier-Improved Orion:** NASA SRPO The Terrier-Improved Orion consists of a 46-cm (18-in) diameter Terrier first stage and a 36-cm (14-in) diameter Improved Orion second stage. This vehicle, which has a diameter of 36 cm (14 in), can carry a payload of up to 363 kg (800 lb) to an altitude of 75 km (47 mi) or 100 kg (220 lb) to an altitude of 225 km (140 mi). The Terrier-Orion is launched from WFF. SRPO launched three Terrier-Orion vehicles in 2010, with the first launched from Poker Flat Research Range on February 2, 2010. Two others were launched from WFF, on June 24, 2010, and September 21, 2010. A Terrier-Improved Malemute launched on March 27, 2010, to test the Malemute upper stage and carry two student CubeSats. The Malemute is a surplus missile motor, and it is no longer used by SRPO.



A Terrier-Improved Malemute successfully launched in 2012 from the Wallops Flight Facility (NASA)

Suborbital Reusable Vehicles

Suborbital reusable vehicles (SRVs) are part of an emerging industry with the potential to support new markets. SRVs are commercially developed reusable space vehicles that travel just beyond the threshold of space, about 100 km (62 mi) above the Earth. While traveling through space, the vehicles experience between one to five minutes of microgravity and provide relatively clear views of the Earth. Currently planned vehicles can carry up to 770 kg (1,698 lb) of payload, some will carry people, and one (Lynx Mark III) will be able to launch small satellites. The companies developing SRVs typically target a high flight rate and relatively low cost. Current ticket prices for human spaceflight vary from $95,000 to $250,000 per seat. These vehicles have been developed using predominantly private investment as well as some government support. Having gained momentum in 2012, each of the SRV companies has continued its research and development activities. In 2015, Blue Origin's *New Shepard* flew twice under an FAA AST Experimental Permit, with the second flight achieving a historic milestone by becoming the first vehicle to launch vertically, enter space (100.5 km or 62.4 mi), and landing vertically. Table 3 provides a description of SRVs currently under development.

Operator	Vehicle	Seats*	Maximum Payload kg (lb)	Price	Announced Operational Year
Blue Origin	*New Shepard*	6	22.7 (50)***	TBD	2016
Masten Space Systems	Xaero Xombie Xogdor	N/A	12 (26) 20 (44) 25 (55)	TBD	TBD
UP Aerospace	SpaceLoft XL	N/A	36 (79)	$350,000 per launch	2006 (actual)
Virgin Galactic	SpaceShipTwo	6	600 (1,323)	$250,000 per seat	2017
XCOR Aerospace	Lynx Mark I Lynx Mark II Lynx Mark III	1 1 1	120 (265) 120 (265) 770 (1,698)	$105,000 per seat	2016 2017 2018

Table 3. U.S.-based providers of SRVs.
** Spaceflight participants only; several vehicles are piloted.*
*** Net of payload infrastructure*

The first stage of the Falcon 9 Full Thrust vehicle makes a successful landing at Cape Canaveral Air Force Station on December 21, 2015, becoming the first vehicle in history to accomplish the feat after reaching orbital velocity. The vehicle's second stage subsequently deployed 11 ORBCOMM satellites. Source: SpaceX

LAUNCH AND REENTRY SITES

Launch sites are sites dedicated to launching orbital or suborbital vehicles into space. These sites provide the capability to integrate launch vehicle components, fuel and maintain vehicles, and integrate vehicles with payloads. Launch sites can facilitate vertical takeoff, vertical landing (VTVL) or horizontal takeoff, horizontal landing (HTHL) vehicles. From the launch site, a launch vehicle travels through an area called the launch range, which typically includes tracking and telemetry assets. These range assets monitor the vehicle's performance until it safely delivers a payload into orbit or returns to Earth. Tracking and telemetry assets may also facilitate recovery of reusable stages.

FAA AST licenses commercial launch and reentry sites in the United States. As of the end of 2015, FAA AST issued 10 launch site operator licenses. Table 4 lists the FAA AST-licensed launch sites. Table 5 identifies the locations of all federal and non-federal launch sites in United States territory.

Launch Site and State	Operator	License First Issued	Expires	2015 FAA AST-Licensed or Permitted Flights
California Spaceport, CA	Spaceport Systems International	1996	9/18/2016	0
Mid-Atlantic Regional Spaceport, VA	Virginia Commercial Space Flight Authority	1997	12/18/2017	0
Pacific Spaceport Complex Alaska, AK	Alasak Aerospace Corporation	1998	9/23/2018	0
Cape Canaveral Spaceport, FL	Space Florida	1999	6/30/2020	6
Mojave Air and Space Port, CA	East Kern Airport District	2004	6/16/2019	0
Oklahoma Spaceport, OK	Oklahoma Space Industry Development Authority	2006	6/11/2016	0
Spaceport America, NM	New Mexico Spaceport Authority	2008	12/14/2018	0
Cecil Field Spaceport, FL	Jacksonville Aviation Authority	2010	1/10/2020	0
Midland International Airport, TX	Midland International Airport	2014	9/14/2019	0
Ellington Airport, TX	Houston Airport System	2015	6/25/2020	0

Table 4. FAA AST-licensed launch and reentry sites, in order of when it was first issued a site license.

FAA AST-licensed launch and reentry sites are often co-located with federal locations, including Cape Canaveral Air Force Station (CCAFS) in Florida, Vandenberg Air Force Base (VAFB) in California, and WFF in Virginia.

Of the 19 active launch and reentry sites, the U.S. government manages eight, state agencies manage nine FAA AST-licensed commercial sites in partnership with private industry, and a university manages one (Alaska's Poker Flat site, which is not licensed by FAA AST). Four sites are dedicated to orbital launch activity, nine facilitate suborbital launches only, and five can host both types of operations.

In addition to these sites, there are three non-licensed sites where individual companies conduct launches using a licensed or permitted vehicle. Because the companies own and operate these sites using their own vehicles exclusively, a site license is not required. The Odyssey Launch Platform exclusively supports Sea Launch's Zenit 3SL vehicles on the Central Pacific Ocean. SpaceX conducts flight tests of its Falcon 9R vehicle at its McGregor, Texas site. Blue Origin conducts FAA-permitted flight tests from its site near Van Horn, Texas.

Launch Site	Operator	State or Country	Type of Launch Site	Type of Launches Supported	Currently Available for Commercial Operations?
California Spaceport	Spaceport Systems International	CA	Commercial	Orbital	Yes
Cape Canaveral Spaceport	Space Florida	FL	Commercial	Orbital/ Suborbital	Yes
Cape Canaveral Air Force Station	U.S. Air Force	FL	Government	Orbital	SLC-41 (Atlas V) SLC-37B (Delta IV) SLC-40 (Falcon 9) SLC-36 (Blue Origin) Landing Strip
Cecil Field Spaceport	Jacksonville Airport Authority	FL	Commercial	Suborbital	Yes
Edwards Air Force Base	U.S. Air Force	CA	Government	Suborbital	No
Ellington Airport	Houston Airport System	TX	Commercial	Suborbital	Yes
Kennedy Space Center	NASA	FL	Government	Orbital	LC-39A (Falcon Heavy) Shuttle Landing Facility
Mid-Atlantic Regional Spaceport	Virginia Commercial Space Flight Authority	VA	Commercial	Orbital	Yes
Midland International Air and Space Port	Midland International Airport	TX	Commercial	Suborbital	Yes
Mojave Air and Space Port	East Kern Airport District	CA	Commercial	Suborbital	Yes
Oklahoma Spaceport	Oklahoma Space Industry Development Authority	OK	Commercial	Suborbital	Yes
Pacific Missile Range Facility	U.S. Navy	HI	Government	Orbital	No
Pacific Spaceport Complex Alaska	Alaska Aerospace Corporation	AK	Commercial	Orbital/ Suborbital	Yes
Poker Flat Research Range	University of Alaska Fairbanks Geophysical Authority	AK	Non-Profit	Suborbital	Five pads available for suborbital launches
Ronald Reagan Ballistic Missile Defense Test Site	U.S. Army	Republic of the Marshall Islands	Government	Suborbital	Omelek Island launch pad
Spaceport America	New Mexico Spaceport Authority	NM	Commercial	Suborbital	Yes
Vandenberg Air Force Base	U.S. Air Force	CA	Government	Orbital/ Suborbital	SLC-2 (Delta II) SLC-3E (Atlas V) SLC-4E (Falcon 9 and Falcon Heavy) SLC-6 (Delta IV) SLC-8 (Minotaur) SLC-576E (Minotaur-C)
Wallops Flight Facility	NASA	VA	Government	Orbital/ Suborbital	No
White Sands Missile Range	U.S. Army	NM	Government	Suborbital	No

Table 5. Active U.S. government and commercial launch and reentry sites.

U.S. Federal Sites

Cape Canaveral Air Force Station

CCAFS is an installation of Air Force Space Command's 45th Space Wing, and is the primary launch head of America's Eastern Range, with three active launch pads, Space Launch Complexes 37, 40, and 41. It is located on Merritt Island, south of NASA's Kennedy Space Center, and has a 10,000-foot-long runway. CCAFS has been used by the U.S. government since 1949, and has been home to a number of firsts, including launching the first U.S. Earth Satellite in 1958, the first U.S. astronaut in 1961, and the first spacecraft to orbit Mars in 1971 and roam its surface in 1996. SpaceX launched its Dragon spacecraft in April 2014 to resupply the International Space Station from SLC-40 at CCAFS, and unveiled its Crew Dragon, designed to take people into space, in May 2014.

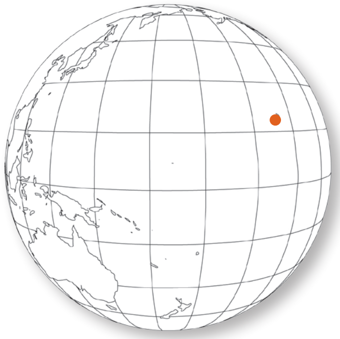
Edwards Air Force Base

Edwards Air Force Base (EAFB) is a U.S. Air Force installation near Rosamond, California. It houses the Air Force Flight Test Center and is the Air Force Materiel Command center for conducting and supporting research and development of flight, as well as testing aerospace systems. EAFB is also home to NASA's Armstrong Flight Research Center (AFRC), and host to commercial aerospace industry testing activities. AFRC began in 1946 when 13 National Advisory Committee for Aeronautics (NACA) Langley Memorial Aeronautical Laboratory engineers began work to support the first supersonic research flights at EAFB. The AFRC's most notable research projects include the Controlled Impact Demonstration and the Linear Aerospike SR-71 Experiment. In addition, the Air Force Research Laboratory (AFRL) Propulsion Directorate maintains a rocket engine test facility on site.

Kennedy Space Center

Kennedy Space Center (KSC) is NASA's Launch Operations Center, supporting Launch Complex 39 (LC-39), originally built for the Saturn V, the largest and most powerful operational launch vehicle in history, for the Apollo program. Since the Apollo program, LC-39 has been used to launch every NASA human spaceflight, including Skylab, the Apollo-Soyuz Test Project, and the Space Shuttle Program. Most recently, SpaceX signed an agreement with NASA to lease Launch Complex 39A for the Falcon Heavy, and the company began modifying the facility in 2014. The Falcon Heavy is currently set to launch in 2016. Beginning in 2014, KSC's

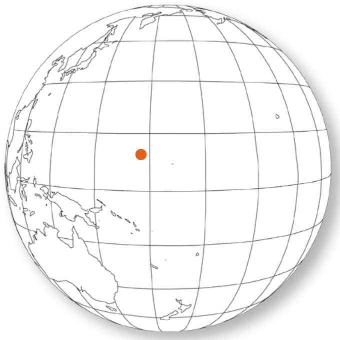
OPF-1 and OPF-2 began the modification process to accommodate the Air Force's X-37B space plane, and Boeing signed a lease agreement with NASA in 2014 to use OPF-3 for the CST-100 Starliner crewed capsule currently in development.



Pacific Missile Range Facility

The Pacific Missile Research Facility (PMRF), Barking Sands, is a U.S. air and naval facility, located in Hawaii. It is the largest instrumented, multi-dimensional testing and training missile range in the world. At this location, submarines, surface ships, aircraft, and space vehicles operate and are tracked simultaneously. PMRF has over 42,000 square miles of controlled airspace, with its base covering nearly 2,400 acres, with a 6,000-foot runway. The U.S. Army acquired Barking Sands from the Kekaha Sugar Company in 1940, expanded in 1941 to over 2,000 acres, and was used as an airport for both private and military aircraft until 1954, when it was designated as Bonham Air Force Base. Naval missile testing operations began two years later with the Regulus I. In 1964, the facility was transferred to the U.S. Navy and became the PMRF, Barking Sands.

Two Missile Defense Agency programs use PMRF currently, the Navy's Aegis Ballistic Missile Defense System, and the Army's Terminal High Altitude Area Defense System (THAAD). In October 2013, the Daniel K. Inouye Technology Center was opened, among other initiatives, it houses the Hawaii Space Flight Laboratory, focusing on space exploration, tracking and controlling satellites launched from PMRF.



Ronald Reagan Ballistic Missile Defense Test Site

The Ronald Reagan Ballistic Missile Defense Test Site (Reagan Test Site), formerly the Kwajalein Missile Range, is a test range in the Pacific Ocean on the Republic of Marshall Islands (RMI). It includes several rocket launch sites spread across the Kwajalein Atoll, Wake Island, and the Aur Atoll. It is a test facility for missile defense and it hosts space research programs. It is also the terminal area for ballistic missile test launches for reentry vehicle testing. Among these programs, the Reagan Test Site serves as a tracking station for manned and unmanned spaceflight. The Reagan Test Site tracks approximately 50,000 objects per year in space, including foreign and domestic satellites and other objects as small as 10 centimeters.

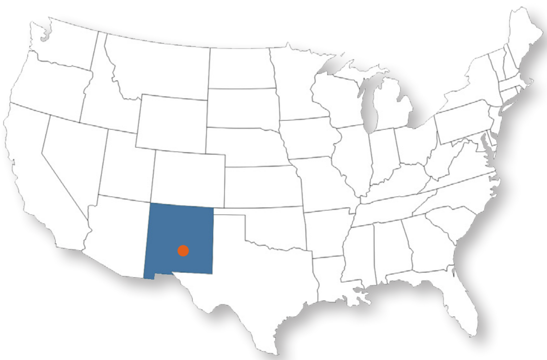
Vandenberg Air Force Base

VAFB is located near the town of Lompoc, California, and is under the jurisdiction of the 30th Space Wing, Air Force Space Command (AFSPC). It is the only location in the United States where both commercial and government polar orbiting satellites are launched. Launches from VAFB are unique in that an entire mission, from launch to orbital insertion, takes place over open water. The Titan IV, Pegasus, Taurus, Delta II, Atlas IIAS, Minotaur, Falcon 1, Atlas V, Delta IV, and SpaceX's Falcon 9 have all been launched from VAFB. VAFB also conducts ballistic missile defense missions. The base started as a U.S. Army training center, Camp Cooke, in 1941, and was officially transferred to the U.S. Air Force in 1957. It has conducted space and missile launches since 1959, launching the world's first polar orbiting satellite, Discoverer

I, on February 28, 1959. VAFB also manages the West Coast Off-shore Operating Area, which controls air space for aircraft testing.

Wallops Flight Facility

WFF is the primary provider of NASA's science suborbital and small orbital flight programs, and is located 100 miles northeast of Norfolk, Virginia. It is owned and operated by the Goddard Space Flight Center in Greenbelt, Maryland. Annually, WFF conducts approximately 30 sounding rocket missions from this and other sites worldwide. It also conducts about 20 high altitude balloon missions per year and several hundred hours of piloted and unpiloted aircraft missions. In addition, WFF manages the Wallops Research Range (WRR), consisting of a launch range, mobile range, and airport. WRR has conducted more than 16,000 launches over its 70-year history and annually supports approximately 20 suborbital launches using its six launch pads.



White Sands Missile Range

White Sands Missile Range (WSMR) is a 3,200-square-mile rocket range in southern New Mexico, operated by the United States Army. It is the largest military operation in the United States, and is the site of the first atomic bomb test, codenamed Trinity, conducted in July 1945. It was also the testing site of the German V-2 rocket in April 1946. The test range, designated WSMR in May 1958, houses the Launch Abort Flight Test Complex for the Orion Project, which had its groundbreaking at LC-32 for the Orion Abort Test Booster in November 2007, NASA's White Sands Test Facility's ground station for Tracking and Data Relay Satellites, and the North Oscura Peak facility of the AFRL, among others.

In September 2015, Orbital ATK completed its 50th and 51st missions of its "Coyote" target vehicle for the U.S. Navy, launching flight tests from WSMR.

FAA AST-Licensed Sites

California Spaceport

Spaceport Systems International, L.P. (SSI), established in 1993, operates The California Spaceport, which came into being just two years later in 1995, when SSI signed a lease with the Air Force. The California Spaceport is a commercial launch and satellite processing facility located on California's central coast at VAFB, near the town of Lompoc, California. SSI signed a 25-year lease with the Air Force to provide commercial launch services from the 100-acre plot it currently occupies. The lease includes an Integrated Processing Facility (IPF), originally built for the STS and designed to process three shuttle-class payloads simultaneously. The Commercial Launch Facility (CLF), known as Space Launch Complex 8 (SLC-8), was also included as part of the lease. In 1996, the FAA AST issued the first Commercial Space Launch Site Operator's License to SLC-8. This launch complex was also the first commercial launch site to become fully operational, in 1999. SLC-8 is currently the only exclusively commercially operated launch site in the United States, receiving no federal or state taxpayer funds to operate.

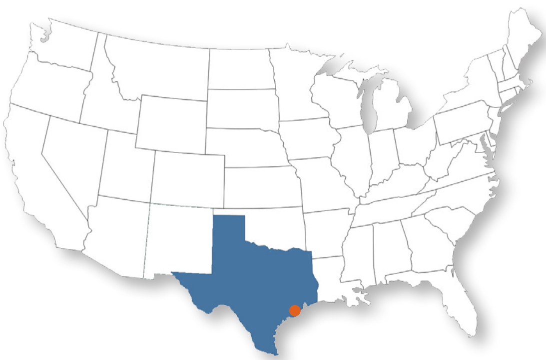
Cecil Field Spaceport

Cecil Field Spaceport (CFS) is the only licensed horizontal launch commercial spaceport on the East Coast, and it is owned and operated by the Jacksonville Aviation Authority (JAA). CFS is positioned on 150 acres of dedicated spaceport development property, adjacent to the runway and taxiway system at Cecil Airport near Jacksonville, Florida. It is specially designed with a 12,500-foot-long runway, 18L-36R, to launch and recover space vehicles that take off and land horizontally. Following four years of feasibility and development studies, JAA was granted a Launch Site Operator License in January 2010. Prompted by a Space Florida resolution, legislation to amend the Florida Statutes to designate Cecil a "Space Territory" was passed, allowing Space Florida to include it in master planning efforts and space-related infrastructure upgrades.

Cape Canaveral Spaceport

Together, the Air Force's CCAFS and NASA's KSC represent the most active orbital launch location in the United States, known as the Cape Canaveral Spaceport (CCS). CCS is co-located at CCAFS, and it is the premier launch complex for sending humans and payloads into space. The CCS has been the departure gate for all U.S. crewed missions, every operational Global Positioning System (GPS) satellite, and thousands of other payloads, including communication satellites, national security surveillance satellites, early warning satellites, and a number of meteorology satellites.

Space Florida is an independent Special District of the State of Florida that advocates for and funds infrastructure projects in Florida's spaceport territory, including the CCS.



Ellington Field

The Ellington Airport, future home to the Houston Spaceport, is a civilian and military use airport in Texas. It is owned by the City of Houston, and operated by the Houston Airport System (HAS). In April 2014, Sierra Nevada Corporation (SNC) ratified an agreement with HAS officials to research Ellington's potential as a commercial Spaceport. SNC hopes to use the site to land its Dream Chaser space plane. The feasibility study estimated costs to properly outfit Ellington as a spaceport to undertake the landing mission was $48 million, and close to $122 million to equip it to handle landing and launching small space vehicles regularly. The FAA granted a launch site license to Ellington Airport in June 2015, becoming the 10th commercial spaceport in the United States.

In October of 2015, the Houston City Council approved the $6.9 million purchase of a building, adjacent to the Ellington Airport, to be used as an incubator for early-stage space industry companies. To date, prospective tenants include Intuitive Machines and United Kingdom-based Catapult Satellite Applications. This 53,000-square-foot facility marks the first dedicated infrastructure project for the Houston Spaceport.

Mid-Atlantic Regional Spaceport

The Mid-Atlantic Regional Spaceport (MARS) is a commercial space launch facility, formerly known as the Virginia Space Flight Center that was developed using a combination of federal, state, and private sector funds from the Virginia Commercial Space Flight Authority (VCSFA). Created in 1995, VCSFA began its lease at Wallops Island in 1997 and expanded the MARS facilities to its present state by 2006 with two active launch facilities (one mid-class and one small-class launch facility). Through agreements with NASA, VCSFA also added access to support infrastructure facilities, such as vehicle and payload processing integration facilities and instrumentation and emergency facilities.

MARS consists mainly of Launch Pads 0A and 0B, as well as supporting facilities. Launch Pad 0A cost about $160 million to support Orbital ATK's Antares vehicle: $90 million was provided by the Commonwealth of Virginia, $60 million from NASA, and $10 million from Orbital ATK. In October 2014, the facility suffered significant damage to LP-0A due to the Antares launch failure. Repairs or replacement to various facilities was completed as scheduled and within the overall budget while keeping a small management reserve for final system performance testing, which started September 25, 2015. MARS was able to begin rebuilding its damaged launch pad, and repairs were completed September 30, 2015 to support a March 2016 launch.

Midland International Air and Space Port

The Midland International Air and Space Port is a city-owned international airport located between the cities of Midland and Odessa, Texas. It is the latest commercial launch site licensed by FAA AST, having been awarded the license in September 2014. The air and space port is located on the same site as Sloan Field, a small airport founded in 1927. The airport was used as a training base during World War II, known as Midland Army Air Field, before reverting back to commercial operations in late 1945. The airfield is owned by the city of Midland, Texas.

In August 2014, XCOR Aerospace, which is moving its headquarters from Mojave Air and Space Port to Midland, kicked off construction of its new hangar. The XCOR hangar will become the home of the first XCOR Lynx suborbital spacecraft, XCOR's corporate headquarters, and its research and development facilities. In October 2014, they were followed by Orbital Outfitters, a company that specializes in space suits and space vehicle mockups. Orbital Outfitters is constructing the Midland Altitude Chamber Complex, a facility that will include three hypobaric chambers for scientific and human high-altitude testing and training. The facility is set for completion by the end of 2015.

Mojave Air and Space Port

The Mojave Air and Space Port is an aerospace test center and launch and reentry site, operated by the East Kern Airport District in the Mojave Desert. Certified by FAA in June 2004, it is the first facility to be licensed in the United States for horizontal launches of reusable spacecraft. Kern County established the airport in 1935, and it became the Marine Corps Auxiliary Air Station (MCAAS) in 1941, following the attack on Pearl Harbor. The base was closed in 1947, and remained so until the outbreak of the Korean War. In 1961, Kern County again obtained the title to the airport, and established the East Kern Airport District (EKAD) in 1972 to administer the airport. EKAD administers the Air and Space Port to this day.

Sixty companies operate out of Mojave, including Scaled Composites, XCOR Aerospace, Masten, Orbital ATK, and Interorbital Systems. Companies are currently designing, building, and testing small suborbital reusable vehicles on site.

In October 2014, Virgin Galactic's SpaceShipTwo VSS Enterprise, which was tested at Mojave Air and Space Port, was destroyed shortly after it was launched from the WhiteKnightTwo carrier aircraft. The pilot survived serious injuries and the copilot was killed. The National Transportation Safety Board (NTSB) has performed an investigation of the accident with the support of FAA AST, and it was determined that the crash was caused by co-pilot error.

Oklahoma Spaceport

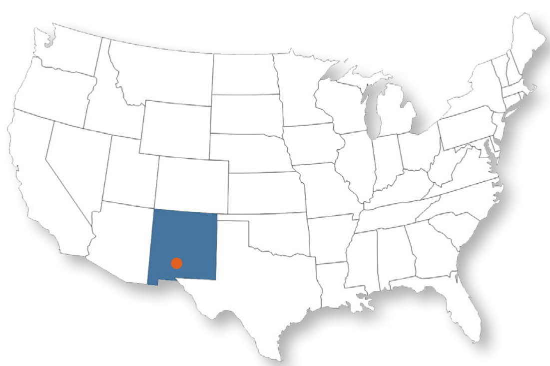
Oklahoma Spaceport is managed by the Oklahoma Space Industry Development Authority (OSIDA), created in 1999, and was granted a license to the site by the FAA in June 2006. The site is located near the community of Burns Flat, Oklahoma. It is part of what is also known as the Clinton-Sherman Industrial Airpark. It is the only spaceport with an FAA-approved spaceflight corridor that is not in restricted airspace or Military Operation Areas (MOAs). The Oklahoma Spaceport has facilities in place for aerospace testing, research and development, flights and launches, with its 13,503-foot by 300-foot concrete runway meant for both civilian and military use. The spaceport has yet to launch any orbital or suborbital flights.

Oklahoma lawmakers voted to give OSIDA $372,887 for 2015 operations costs, in addition to federal funding. While the Oklahoma Spaceport has yet to be used for space travel, its aviation facility conducts approximately 35,000 flight operations annually.

Pacific Spaceport Complex Alaska

The Pacific Spaceport Complex (PSC) Alaska (formerly Kodiak Launch Complex, or KLC) is a commercial rocket launch facility for suborbital and orbital space launch vehicles, located on Kodiak Island, Alaska. It is owned and operated by the Alaska Aerospace Corporation (AAC), created in 1991, which is an independent political and corporate entity located within the Alaska Department of Military and Veterans' Affairs. PSC is the first FAA-licensed launch site not co-located on a federally controlled launch site; however, the majority of the launches it has managed since its inception in 1998 have been U.S. government launches. PSC has one launch pad, Launch Pad 1 (LP-1), which can launch intermediate-class payloads to low Earth orbit (LEO) or polar orbits. The complex also has a suborbital launch pad (LP-2) for missile testing. Development of a third launch pad for the Athena III began in 2012, and this launch pad is intended to allow the facility to support launches of satellites in under 24 hours.

In August 2014, LP-1 was damaged when an Air Force Advanced Hypersonic Weapons test ended in failure, the test vehicle having been destroyed by range control personnel following an anomaly. Soon afterward, Alaska Aerospace made plans to repair and upgrade the facilities to support larger rockets, but state funding priorities prohibited repairs to PSC.



Spaceport America

Spaceport America, formerly the Southwest Regional Airport, is the world's first purpose-built, commercial spaceport. The site is located in Sierra County, near the city of Truth or Consequences, New Mexico, and is operated by the New Mexico Spaceport Authority. The spaceport was officially opened for business in October 2011, and its first FAA-licensed launch took place in October 2012.

The New Mexico Spaceport Authority received its license for horizontal and vertical launch from FAA AST in December 2008. Virgin Galactic, the anchor tenant, signed a 20-year lease agreement immediately after issuance of the license. The main terminal hangar is capable of housing two WhiteKnightTwo aircraft and five Virgin Galactic SpaceShipTwo spacecraft.

Delays experienced by launch service providers like Virgin Galactic have inspired the New Mexico Spaceport Authority to explore alternative means of generating revenue at the spaceport until flight operations begin. Negotiations with several potential tenants took place in 2014. The Spaceport hired a marketing firm to solicit sponsors, and was unsuccessful. At the moment, Spaceport America is mostly vacant. The spaceport is entirely financed by the taxpayers of New Mexico, and is substantially complete at a cost of $209 million. In early 2015, a bill was introduced to the New Mexico Legislature that the State of New Mexico sell the public spaceport to commercial interests to begin recouping some of the state's investment. If the bill passes, the spaceport will be required to put together a marketing plan before the end of 2015.

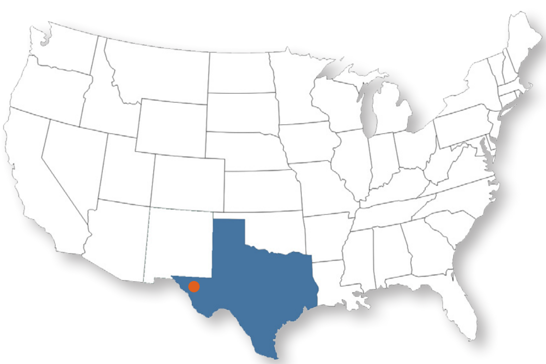
SpaceX signed a three-year lease with Spaceport America in 2013, and to date has spent over $2 million in infrastructure improvements. SpaceX hopes to use the site to launch, recover, and reuse its Falcon 9 v1.1 booster. Thus far, several tests have been performed in preparation for launch and recovery. SpaceX successfully tested flyback and landing of an operational Falcon 9 first stage in December 2015. The vehicle was used to deploy 11 ORBCOMM satellites.

Non-Licensed U.S. Sites

SpaceX McGregor Rocket Development and Test Facility

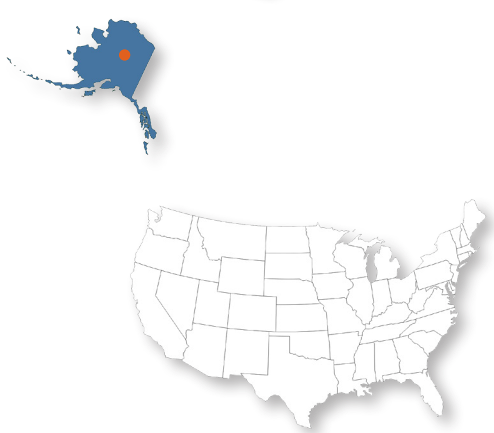
SpaceX purchased the testing facilities of defunct Beal Aerospace in McGregor, Texas, announcing plans in 2011 to upgrade the former bomb manufacturing plant to allow for launch testing of a VTVL rocket. The next year, SpaceX constructed a half-acre concrete launch facility on the property to support the Grasshopper test flight program. The total facility comprises 900 acres, and is currently being used for research and development of new rocket engines and thrusters, as well as for testing final manufactured engines and their various components, and testing potential reusable boosters. The facility currently has 11 test stands that operate 18 hours per day, six days per week. Thus far, SpaceX has used the site to test the Merlin 1D engine, and the Falcon 9 v1.1, as well as high-altitude, high-velocity flight testing of Grasshopper v1.1, which was permitted by the FAA until October 2014. Recovered SpaceX Dragon spacecraft are also sent to McGregor to be refurbished for potential reuse.

Blue Origin West Texas Rocket Flight Facility



Blue Origin, LLC is an American-owned, privately funded aerospace development and manufacturing company, established by Amazon.com founder Jeff Bezos. The company is currently developing technologies to enable commercial spaceflight with lower costs and increased reliability. Blue Origin's West Texas high-altitude rocket flight facility is located near the town of Van Horn, Texas. It is currently permitted by the FAA for flights up to a maximum altitude of 66 miles, with no more than one flight per week.

Poker Flat Rocket Range



The Poker Flat Rocket Range (PFRR) serves as a launch facility and sounding rocket range near Fairbanks, Alaska. It is the only U.S. launch facility owned and operated by a non-profit, the University of Alaska, Fairbanks (UAF), which has owned the site since 1948, and is currently under contract to NASA WFF. PFRR is home to five launch pads, two of which are optimized for extreme weather conditions. The 5,000-acre facility has performed more than 1,700 launches to study the Earth's atmosphere and its interaction with the space environment.

Non-U.S. Sites

There are many active orbital and suborbital launch sites across 10 different countries and territories. The most significant of these sites are described briefly in the following paragraphs.

Russian service providers launch vehicles from three primary sites: Baikonur Cosmodrome, located in Kazakhstan as a byproduct of the collapse of the Soviet Union in 1991; Plestesk Cosmodrome, in the western part of the country; and Dombarovsky Air Base near the western Kazakh border. Virtually all Russian vehicles launch from Baikonur, including the Angara, Dnepr, Proton M, Rockot, Soyuz (including missions to ISS), and Zenit, among others. The Soyuz and Rockot vehicles launch from Plestesk, and only the Dnepr launches from Dombarovsky. The Russian government is also constructing a new site in the East called Vostochny Cosmodrome, which is expected to open some time before 2020. This site is expected to launch Soyuz and possibly Angara vehicles.

China is home to three launch sites. The Jiuquan Satellite Launch Center is located in Inner Mongolia and is the most active site, with launches of the Long March 2C, 2D, and 2F typically taking place. Taiyuan Satellite Launch Center is located in the northeast of the country, with Xichang Satellite Launch Center located further south. Polar-bound Long March 4 vehicles tend to launch from Taiyuan, whereas GEO-bound Long March 3B vehicles launch from Xichang. The Chinese government is building a site on Hainan Island called Wencheng Satellite Launch Center, and this is expected to open by 2018.

The French space agency Centre National d'Études Spatiales (CNES), together with the European Space Agency (ESA), operates the Guiana Space Center in French Guiana. This site is used to launch the Ariane 5, Soyuz 2, and Vega, provided by Arianespace.

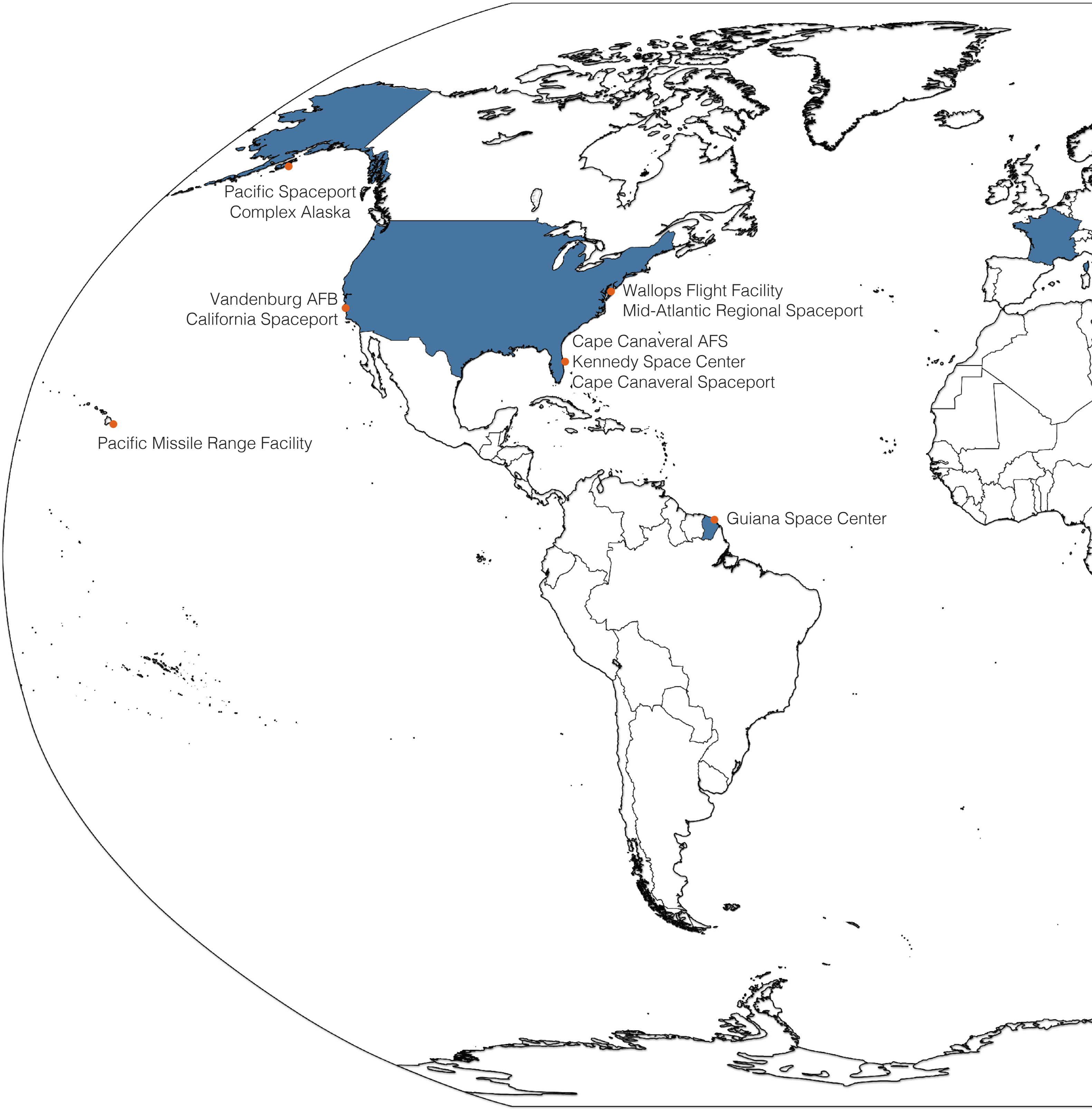
Japan has two active launch sites. The Tanegashima Space Center is the larger of the two, and it is from this location that the H-IIA and H-IIB vehicles are launched. Previously known as Kagoshima Space Center, the Uchinoura Space Center is the launch site for the newly introduced small-class vehicle called Epsilon.

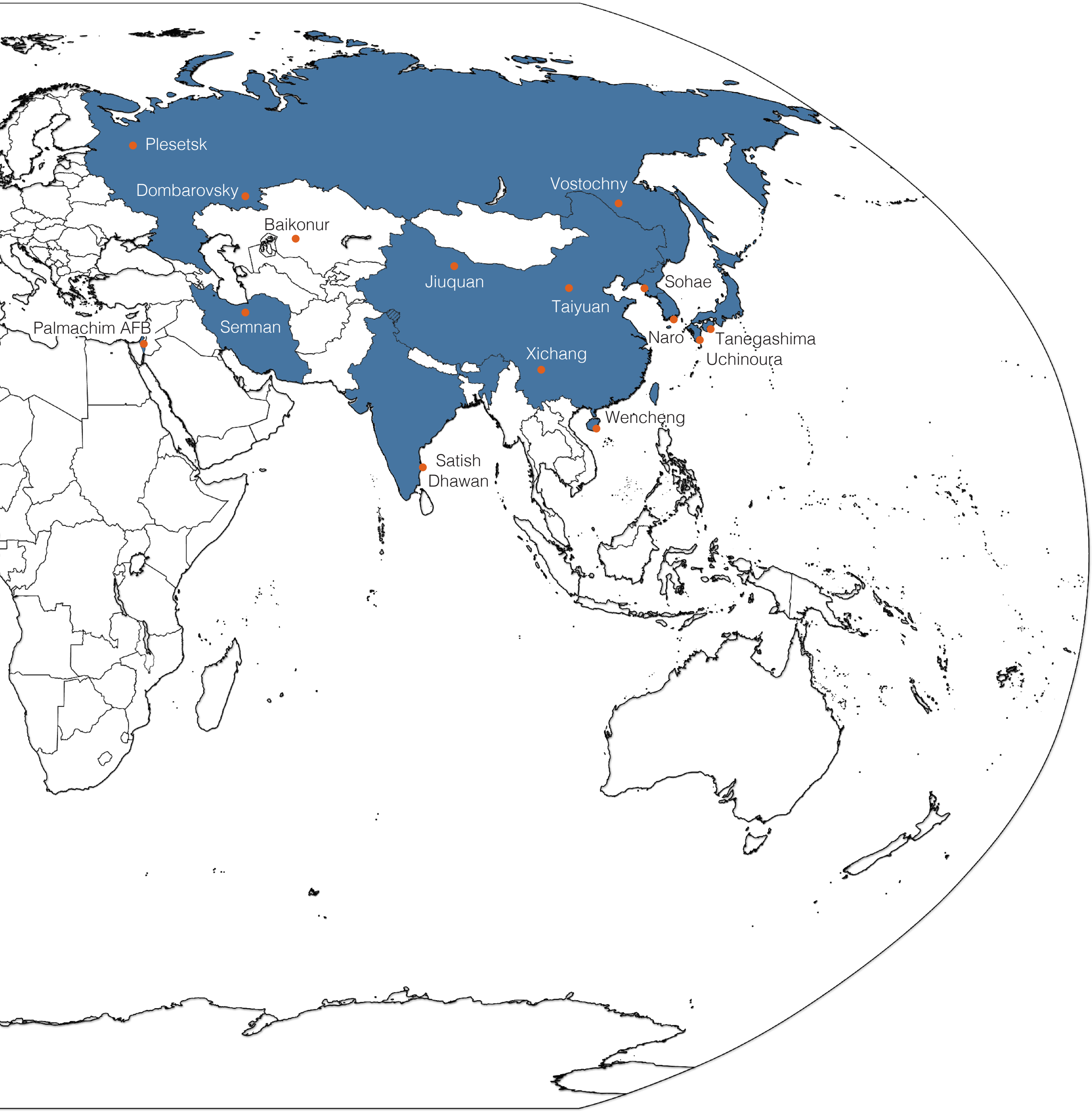
The Indian Space Research Organization (ISRO) operates India's sole launch site, the Satish Dhawan Space Center located near Sriharikota. Inaugurated in 1971, this is the launch site for ISRO's Polar Satellite Launch Vehicle (PSLV) and the Geosynchronous Satellite Launch Vehicle (GSLV). ISRO's next vehicle, the more powerful LMV-3, will also launch from this site.

The Israeli Defense Force operates an orbital launch pad from Palmachim Air Force Base. It is from here that the country's Shavit vehicle is launched. Iran launches its Safir orbital vehicle from Semnan located in the north of the country near the Caspian Sea. North Korea's Unha launch vehicle is launched from the Sohae Satellite Launching Station located in the country's northeast. Finally, South Korea's launch site for the Naro-1 vehicle is located at the Naro Space Center.

Figure 4 on the next two pages shows the locations of these launch sites as well as active suborbital sites.

Figure 4. The location of orbital launch sites worldwide.




Plesetsk
Dombarovsky
Baikonur
Vostochny
Jiuquan
Taiyuan
Sohae
Palmachim AFB
Semnan
Naro
Tanegashima
Uchinoura
Xichang
Wencheng
Satish
Dhawan

A SpaceX Dragon orbits the Earth on the Spx-5 mission to the ISS, launched on January 10, 2015. Source: NASA

PAYLOADS

In the case of an orbital launch, the payload can be a satellite, a space probe, an on-orbit vehicle, or a platform that carries humans, animals, or cargo. Such satellites, probes, or on-orbit vehicles and platforms, often generally referred to as spacecraft, are usually separated from a launch vehicle (or its upper stage) to continue their spaceflight independently, in an Earth orbit, or beyond it.

Suborbital reusable vehicles can carry various types of payloads, including but not limited to humans, scientific instruments, or hardware and materials subject to microgravity and other space environment testing that are subsequently returned to the ground inside or on the suborbital vehicles that launched them. In cases when a suborbital vehicle would be used to launch a satellite or, possibly, another type of spacecraft, it would be separated from it, often combined with an upper stage or a booster, similar to an orbital payload launch described above.

State of the Payload Industry

The first orbital payloads were satellites launched into LEO. They were followed by on-orbit vehicles and platforms, including space stations, carrying humans, Earth observation, communications, and scientific satellites carrying sensors, telescopes, and transponders, launched into other types of orbits, including sun-synchronous (SSO), highly elliptical, and geosynchronous orbit (GEO), and scientific probes sent to such destinations as the Moon, planets, and other destinations within and beyond our solar system.

Space industry companies and organizations worldwide, sometimes the same as launch vehicle manufacturers but also those specifically dedicated to spacecraft manufacturing, produce these spacecraft. Commercially launched payloads are typically used for the following mission types:

- Commercial communications satellites;
- Commercial remote sensing or Earth observation satellites;
- Commercial crew and cargo missions, including on-orbit vehicles and platforms;
- Technology test and demonstration missions, usually new types of payloads undergoing test or used to test new launch vehicle technology; and
- Other commercially launched payloads, usually satellites launched for various purposes by governments of countries not having indigenous orbital launch capability.

All orbital payloads are divided into mass classes, described in Appendix 1 on Page 58.

Global Payload Industry

Countries and jurisdictions worldwide that possess functional and operating indigenous payload manufacturing sectors are China, the European Union, India, Japan, Russia, and the United States. Countries that have developed and built their own spacecraft include Argentina, Iran, Israel, North Korea, South

Korea, and Ukraine. A total of over 30 countries have developed and built at least one orbital payload, usually a satellite. The payload building capability of more than half of these countries is limited to CubeSats, built from pre-fabricated kits by universities and government and non-profit organizations.

Table 6 presents civil, military, and commercial orbital payloads, by country of manufacturer, in 2015. In 2015, 42 CubeSats, most of them commercial, were launched as cargo for subsequent deployment from the ISS. Sixteen CubeSats for commercial remote sensing operator Planet Labs were launched aboard Spx-6 mission in April. Eighteen CubeSats were launched in August aboard the HTV cargo spacecraft, 14 of them for Planet Labs and 4 more CubeSats for research and development purposes. Eight Planet Labs' CubeSats were lost in the Spx-7 launch incident in June. These satellites are counted separately because they are not deployed in their respective orbits at the time of the separation from the launch vehicle and are stored inside an on-orbit cargo vehicle.

Country of Manufacturer	Civil	Military	Non-Profit	Commercial	Total
Argentina	0	0	0	1	***1***
Canada	0	0	0	1	***1***
China	7	8	24	6	***45***
Europe	11	1	1	10	***23***
India	4	0	0	0	***4***
Indonesia	1	0	0	0	***1***
Iran	1	0	0	0	***1***
Japan	1	2	0	1	***4***
Russia	12	13	0	0	***25***
Singapore	1	0	4	1	***6***
South Korea	1	0	0	0	***1***
USA	18	14	19	33	***84***
TOTALS	***57***	***38***	***48***	***53***	***196***

Table 6. Number of civil, military, non-profit, and commercial, payloads launched in 2015 by country of manufacturer.

U.S. Payload Industry

The backbone of the United States payload industry consists of the established aerospace companies and major U.S. government space and defense prime contractors developing and manufacturing spacecraft, launched commercially:

- Ball Aerospace
- The Boeing Company
- Lockheed Martin Corporation
- Orbital ATK
- Space Systems Loral (SSL)

These companies build spacecraft, mostly of large- and medium- but also small-mass class, for civil, military and commercial uses. Three of the five companies, Boeing, Lockheed Martin, and Orbital ATK are also launch vehicle manufacturers. Ball Aerospace and SSL are strictly payload (spacecraft) companies.

Companies, such as Harris, Northrop Grumman, and Raytheon, develop and produce specialized payload components, including antennas, electronics, and other subsystems.

Other U.S. companies, many established in the last 15 years, manufacture spacecraft of all mass classes, for civil, military, and commercial use.

Commercial On-orbit Vehicle and Platforms

NASA started the commercial crew and cargo program to help commercial companies develop new capabilities for transporting crew and cargo to the International Space Station (ISS). These services are intended to replace some of the ISS resupply services performed by the Space Shuttle. The first of these vehicles, SpaceX's Dragon, became operational in 2012, restoring NASA's ability to deliver and retrieve cargo in LEO. Crewed vehicles made many advances in 2015 but are not expected to become operational before 2017.

On-orbit vehicle and platform development by commercial companies conducted in 2015 included:

- Four cargo missions were conducted as part of NASA's ISS CRS contracts with SpaceX. The Orbital ATK OA-4 mission was conducted using an Atlas V launch vehicle provided by ULA following the 2014 launch failure of Orbital's Antares vehicle. Antares is currently undergoing upgrades, including new RD-181 engines, provided by NPO Energomash. Its return to flight is not expected until the Spring of 2016.
- SpaceX conducted three cargo missions: Two were successful while the Spx-7 mission was lost following a launch failure. The next SpaceX cargo mission is expected not earlier than in January 2016, following the Falcon 9 vehicle return to flight, launching satellites for commercial clients in December 2015.

Boeing continues to develop the CST-100 Starliner and SpaceX is developing the Crewed Dragon for the NASA Commercial Crew Transportation Capability (CCtCap) program. Sierra Nevada Corp., which is developing the *Dream Chaser*, vows to continue working on its winged vehicle. Blue Origin continues work on its New Shepard suborbital vehicle, and announced in 2015 more detailed plans to develop its orbital spacecraft and launch vehicle.

Table 7 lists on-orbit vehicles and platforms currently offered or being developed in the U.S.

Operator	Vehicle	Launch Vehicle	Maximum Cargo kg (lb)	Maximum Crew Size	First Flight
SpaceX	Dragon	Falcon 9	6,000 (13,228)	0	2010
SpaceX	Crewed Dragon	Falcon 9	TBD	7	2017
Orbital ATK	Cygnus	Antares	3,500 (7,716)	0	2013
Boeing	CST-100 Starliner	Atlas V Falcon 9	TBD	7	2017
Sierra Nevada Corp.	Dream Chaser	Atlas V	TBD	TBD	TBD
Blue Origin	Space Vehicle	Atlas V Blue Origin	TBD	7	TBD

Table 7. On-orbit vehicles in service or under development.

One of the last Delta II vehicles, provided by ULA, stands poised to launch NASA's Soil Moisture Active Passive (SMAP) mission on January 31, 2015 from Vandenberg AFB, California. Source: NASA

2015 LAUNCH EVENTS

Space launch activity worldwide is carried out by the civil, military, and commercial sectors. This section summarizes U.S. and international orbital launch activities for calendar year 2015, including launches licensed by the Federal Aviation Administration's Office of Commercial Space Transportation (FAA AST).

Countries and jurisdictions worldwide that possess functional and operating indigenous launch industries are the United States, Russia, China, European Union, India, Japan, Israel, Iran, North Korea, and South Korea. Several other countries, including Argentina, Brazil, and Indonesia, are developing launch vehicle technologies.

Table 8 presents civil, military, and commercial orbital launches by country in 2015.

Country/Region	Civil	Military	Commercial	Total
Russia	14	7	5	**26**
USA	4	8	8	**20**
China	12	7	0	**19**
Europe	5	0	6	**11**
India	3	0	2	**5**
Japan	1	2	1	**4**
Iran	1	0	0	**1**
TOTALS	***40***	***24***	***22***	***86***

Table 8. Total orbital launches in 2015 by country and type.

In 2015, the United States, Russia, Europe, China, Japan, India, and Iran conducted a total of 86 orbital launches, 22 of which were commercial (See Figure 5). In 2014 there were 92 launches, including 23 commercial launches.

Three of the 86 launches failed; these included two commercial launches, one provided by International Launch Services of a Proton M carrying Mexsat-1 communications satellite and one provided by SpaceX of a Falcon 9 launch

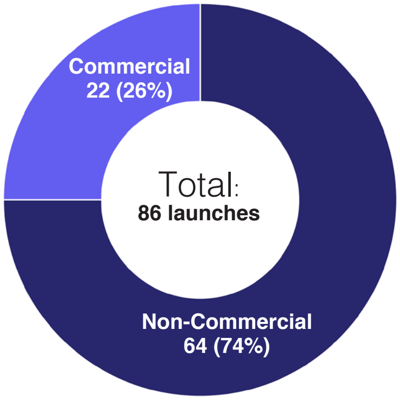


Figure 5. 2015 total worldwide launch activity.

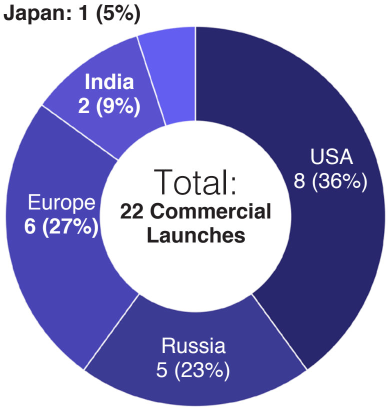


Figure 6. 2015 total worldwide commercial launch activity.

carrying a Dragon cargo spacecraft (Spx-7) to the ISS under a Commercial Resupply Services (CRS) with NASA. The third was of a U.S. Air Force sponsored Super Strypi vehicle launched from Hawaii.

Highlights of 2015 in the orbital space launch industry:

- The United States performed 8 commercial orbital launches.
- NASA continued its ISS CRS program, with the launch of five resupply missions. However, the Spx-7 mission of a Dragon cargo spacecraft launched by a Falcon 9 vehicle resulted in a launch failure. It was the second failure of a CRS mission, following an Antares vehicle failure in October 2014;
- SpaceX continued to launch payloads for commercial clients, including three commercial launches to geosynchronous transfer orbit (GTO) and one to LEO. Falcon 9 successfully returned to flight launching 11 ORCOMM satellites in December 2015;
- United Launch Alliance (ULA) performed 13 missions, launching nine Atlas V, three Delta IV, and one Delta II; and
- Two new orbital launch vehicles were successfully tested. The Chinese Long March 6 and Long March 11 launch vehicles were introduced, successfully deploying a large number of small satellites. The inaugural launch of the U.S. Super Strypi vehicle ended in failure shortly after launch from Hawaii.

Revenues from the 22 commercial orbital launches in 2015 were estimated to be $2.15 billion. These revenues are only slightly lower than in 2014 and consistent with commercial launch revenue in 2009, 2010, and 2012. The estimated commercial orbital launch revenues of $617 million for U.S. providers was about half a billion dollars lower than in 2014, due to the delays in commercial launch schedule following the last and this years' accidents with the Antares and Falcon 9 launch vehicles (See Figure 7).

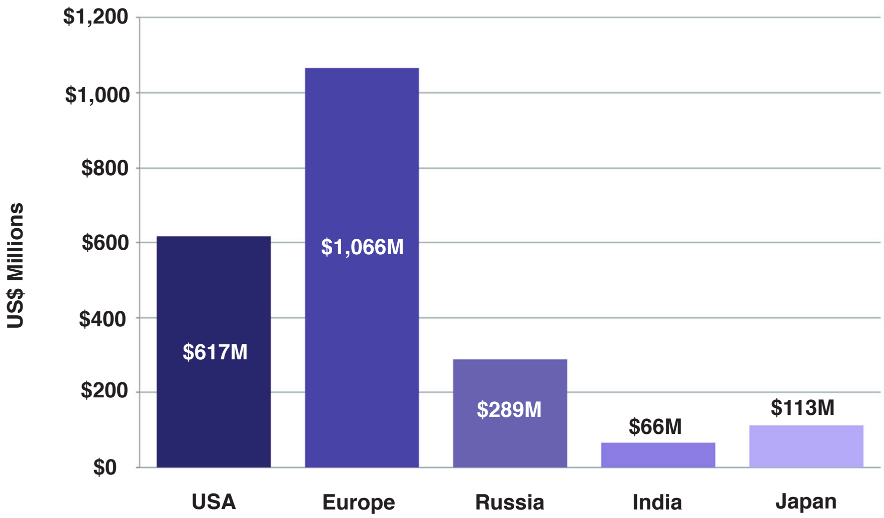


Figure 7. 2015 estimated revenues for commercial launches by country of service provider.

FAA AST 2015 ORBITAL LAUNCH ACTIVITY

FAA AST licensed eight commercial orbital launches in 2015, compared to 12 licensed launches in 2014 (Table 9). SpaceX's Falcon 9 vehicle was used in six licensed launches: three in January, April, and June under NASA's CRS program, and three for commercial satellite operators Eutelsat and ORBCOMM, and for the government of Turkmenistan. ULA's Atlas V vehicles successfully launched a communications satellite for Mexico and a Cygnus cargo module to ISS on behalf of Orbital ATK.

Figure 8 shows that the number of FAA AST-licensed orbital launches in 2015 was slightly less than the number in 2014. The drop is due to a delay in Falcon 9 launches following the June 2015 accident.

Table 10 on the next page provides specifications for the four vehicle types that were launched during 2015 under an FAA license. Note that the Falcon 9 was introduced in 2010, and that this early variant flew successfully five times from 2010 to 2013. The Falcon 9 v1.1 has flown 14 times, with one failure, since its introduction in 2013. SpaceX is introduced a more powerful version in 2015 called Falcon 9 Full Thrust.

Date	Vehicle	Primary Payload	Orbit	Launch Outcome
1/10/2015	Falcon 9	Spx-5	LEO	Success
3/1/2015	Falcon 9	Eutelsat 115 West B	GEO	Success
4/14/2015	Falcon 9	Spx-6	LEO	Success
4/27/2015	Falcon 9	TurkmenAlem52E	GEO	Success
6/28/2015	Falcon 9	Spx-7	LEO	Failure
10/2/2015	Atlas V	Morelos 3	GEO	Success
12/6/2015	Atlas V	OA-4	LEO	Success
12/21/2015	Falcon 9	ORBCOMM	LEO	Success

Table 9. 2015 FAA AST-licensed orbital launch events.

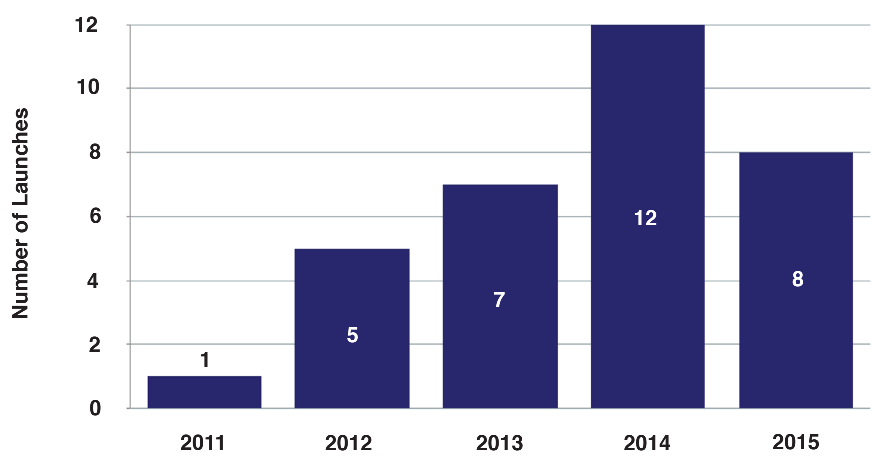
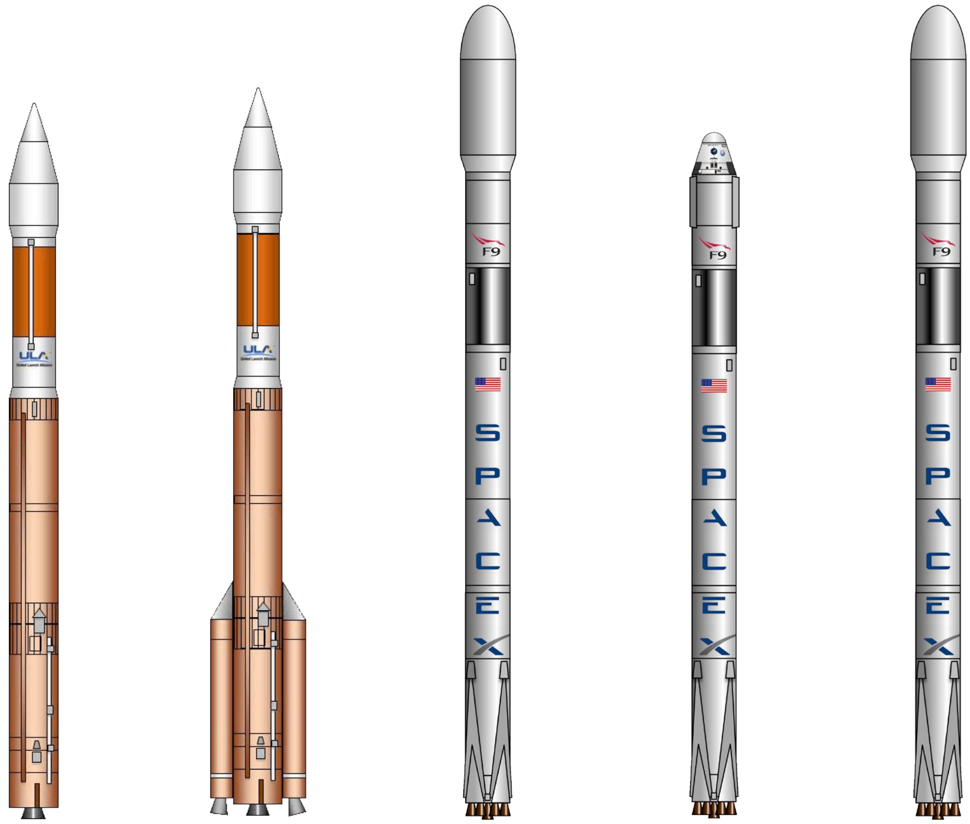


Figure 8. FAA AST-licensed orbital launch events, 2011-2015.



Vehicle	Atlas V 401	Atlas V 421	Falcon 9 v1.1	Falcon 9 (Dragon)	Falcon 9 Full Thrust
2015 Total Launches	4	2	3	3	1
2015 Licensed Launches	1	1	2	3	1
Launch Reliability (2015)	4/4 100%	2/2 100%	3/3 100%	2/3 67%	2/2 100%
Launch Reliability (Last 10 Years)	30/30 100%	5/5 100%	11/11 100%	4/5 80%	2/2 100%
Year of First Launch*	2002	2007	2013	2014	2015
Active Launch Sites	CCAFS, VAFB	CCAFS, VAFB	CCAFS, VAFB	CCAFS	CCAFS, VAFB
LEO kg (lbs)	9,797 (21,598)	14,067 (31,012)	13,150 (28,991)	9,000 (19,842)	17,095 *est* (37,688)
GTO kg (lbs)	4,750 (10,470)	6,890 (15,190)	4,850 (10,692)	--	6,305 *est* (13,900)

Table 10. U.S. and FAA AST-licensed launch vehicles active in 2015.

FAA AST 2015 REENTRY LICENSE SUMMARY

There were three reentries conducted under an FAA reentry license in 2015. Two SpaceX's Dragon spacecraft performed the licensed reentries, in January and May, completing its fifth and sixth CRS missions to the ISS.

FAA AST 2015 SUBORBITAL LAUNCH SUMMARY

Suborbital launches carried out in 2015 under FAA licenses or experimental permits:

- SpaceX conducted a successful pad abort test of its Dragon crewed capsule on May 6 under an FAA license;
- Two flights were conducted under an FAA Experimental Permit by Blue Origin-built New Shepard vehicle.

Blue Origin's New Shepard booster as it appeared shortly after landing following a test launch on November 23, 2015. The vehicle, which flew under an FAA AST Experimental Permit, was the first in history to launch vertically, enter space at a suborbital velocity, and land vertically. Source: Blue Origin

U.S. COMMERCIAL SPACE TRANSPORTATION LAW AND POLICY

National governments, acting both independently and cooperatively, develop laws and guidelines to assign responsibility and to provide direction and accountability for space activities, including space transportation. The U.S. government also works with other countries to develop and advance cooperation and best practices for space transportation operations.

This section briefly describes the international treaties that provide a global framework for the space activities of signatories, as well as U.S. law and policy that specifically govern U.S. space activities. FAA AST also receives public input in support of regulatory development via the Commercial Space Transportation Advisory Committee (COMSTAC), so this section includes a description of that body and its activities during the calendar year.

CURRENT LAW AND POLICY

International Treaties

The foundational instrument of the outer space legal regime is the 1967 *Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies* (referred to as the "Outer Space Treaty" or OST). The treaty, drafted by the United Nations Committee on the Peaceful Uses of Outer Space (UNCOPUOS), entered into force on October 10, 1967. As of December 31, 2015, there are 104 state signatories to the treaty.

The OST established a series of broad principles that have been elaborated upon and implemented in a series of subsequent international treaties and national laws. These principles include:

- The exploration and use of outer space shall be carried on for the benefit and in the interests of all mankind;
- Outer space and celestial bodies are free for exploration and use by all States;
- Outer space and celestial bodies are not subject to national appropriation;
- No weapons of mass destruction are permitted in outer space;
- The Moon and other celestial bodies shall be used exclusively for peaceful purposes;
- States shall be responsible for their national activities in outer space, whether carried on by governmental or non-governmental entities;
- The activities of non-governmental entities in outer space shall require the authorization and continuing supervision by the appropriate State;
- States shall retain jurisdiction and control over their space objects and any personnel thereon;
- States shall be liable for damage caused by their space objects; and
- States shall avoid the harmful contamination of outer space.

The OST was followed by the 1968 *Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space*, the 1972 *Convention on International Liability for Damage Caused by Space Objects*, the 1975 *Convention on Registration of Objects Launched into Outer Space*, and the 1979 *Agreement Governing the Activities of States on the Moon and Other Celestial Bodies*, the latter of which has not been ratified by the United States.

The U.S. government carries out its space-related responsibilities through several different agencies. FAA AST regulates the U.S. commercial space transportation industry; encourages, facilitates, and promotes commercial space launches and reentries by the U.S. private sector; recommends appropriate changes in federal statutes, treaties, regulations, policies, plans, and procedures; and facilitates the strengthening and expansion of the U.S. space transportation infrastructure. The National Oceanic and Atmospheric Administration (NOAA) is responsible for issuing licenses to U.S-based non-federal organizations that intend to operate remote sensing satellites (under the 1992 Land Remote Sensing Policy Act). The Federal Communications Commission (FCC) requires operators of non-federal satellites that employ radio communications to be licensed. The provisions of the 1976 Arms Export Control Act are implemented under the International Traffic in Arms Regulations (ITAR), which control the export and import of defense-related technologies and services identified on the United States Munitions List (USML) managed by the Department of State, which includes some space hardware. In addition to ITAR, there is the Export Administration Regulations (EAR), which contains the Commercial Control List (CCL) managed by the Department of Commerce. The CCL also captures various space-related technologies.

U.S. Law and Policy

Commercial Space Launch Act of 1984

The Commercial Space Launch Act of 1984, as amended and re-codified at 51 U.S.C. 50901-50923, authorizes DOT and, through delegation, FAA AST, to oversee, authorize, and regulate both launches and reentries of launch and reentry vehicles, and the operation of launch and reentry sites when carried out by U.S. citizens or within the United States. The act directs the FAA to exercise this responsibility consistent with public health and safety, safety of property, and the national security and foreign policy interests of the United States. The act also directs FAA AST to encourage, facilitate, and promote commercial space launches and reentries by the private sector, including those involving spaceflight participants.

Spurring Private Aerospace Competitiveness and Entrepreneurship (SPACE) Act of 2015

During FY 2015, both houses of the U.S. Congress passed bills exclusively focused on commercial space activities. A compromise bill, the SPACE Act, was passed by the Senate on November 10, the House of Representatives on November 16, and signed by President Barack Obama on November 25. This act supercedes the Commercial Space Launch Amendments Act of 2004 (CSLAA) signed into law on December 23, 2004 by President George W. Bush. The full text of the act is available on the FAA AST website.

Generally, the SPACE Act covers responsibilities under the Department of Transportation and Department of Commerce as they relate to commercial space activities. The act also includes sections on space resource exploration and utilization by U.S.-based private entities.

The SPACE Act continues FAA AST responsibilities previously outlined under CSLAA, but does include an extension of indemnification for U.S. launch providers for extraordinary catastrophic third-party losses of a failed launch through 2025, while the previous indemnification law was scheduled to expire in 2016. The Act also extends, through 2025, the "learning period" restrictions which limit the ability of FAA AST to enact regulations regarding the safety of spaceflight participants.

FAA AST Advisory Circulars, Guidelines, and Handbooks

Guidance documents provide information to aid understanding and compliance with specific FAA regulations. They include Advisory Circulars, guidelines, handbooks, and sample applications about commercial space transportation safety and other regulatory matters. Although not guidance, per se, legal interpretations from the FAA's Office of the Chief Counsel address specific legal issues that have precedential effect. FAA AST has issued legal interpretations on subjects, such as the regulation of spacecraft that produce sonic booms, launch site-licensing requirements, delivery of regulations to mobile devices, and legal definitions. These documents are available on the FAA AST website.

2010 National Space Policy

The National Space Policy expresses the President's direction for the nation's space activities. Broadly, it recognizes the rights of all nations to access, use, and explore space for peaceful purposes; promotes international cooperation in space science and exploration, Earth sciences, and space surveillance; and emphasizes openness and transparency. Specific to U.S. activities in space, the policy recommends that the U.S. government use commercial space products and services in fulfilling governmental needs, and emphasizes the need for partnerships between NASA and the private sector. It highlights the need to invest in space situational awareness capabilities, orbital debris mitigation, and launch vehicle technologies, among other issues relating to national security in particular. Finally, it states that the U.S. will accelerate the development of satellites to observe and study the Earth's environment, and conduct research programs to study the Earth's lands, oceans, and atmosphere.

2013 National Space Transportation Policy

On November 21, 2013, the White House issued the 2013 National Space Transportation Policy, which updates and replaces the 2004 U.S. Space Transportation Policy. It provides guidance to federal departments and agencies on the development and use of commercial and governmental space transportation systems. The policy provides comprehensive guidance to all federal departments and agencies on U.S. priorities and on roles and responsibilities with respect to space transportation issues and programs.

The overarching goal of the policy is to have assured access to diverse regions of space in support of civil and national security missions. To further this goal, the policy prescribes actions aimed at improving U.S. launch industry robustness, cost effectiveness, innovation, entrepreneurship, and international competitiveness.

Under the policy, the U.S. government will use commercial space transportation products and services to help fulfill government needs, invest in new and advanced technologies and concepts, and use a broad array of partnerships with industry to promote innovation. The policy is also designed to encourage partnerships with private industry to put U.S. government instruments on non-governmental spacecraft, which will increase scientific and other capabilities, facilitate access to space, and save taxpayer dollars using arrangements known as "hosted payloads." It also aims to foster cooperation with industry to develop guidelines for the development and expansion of current and future U.S. space transportation systems and directs further research and development to improve the reliability, responsiveness, performance, and cost effectiveness of the U.S. commercial human spaceflight market.

COMMERCIAL SPACE TRANSPORTATION ADVISORY COMMITTEE

Commercial Space Transportation Advisory Committee (COMSTAC) was established in 1984 to provide information, advice, and recommendations to the FAA Administrator on critical matters concerning the U.S. commercial space transportation industry.

The economic, technical, and institutional expertise provided by COMSTAC members has been invaluable to FAA AST in developing effective regulations that ensure safety during commercial launch operations and policies that support international competitiveness for the industry.

Purpose, Scope, and 2015 Membership

COMSTAC provides information, advice, and recommendations to the FAA Administrator on all matters relating to U.S. commercial space transportation industry activities. It does not exercise program management responsibilities and makes no decisions directly affecting the programs on which it provides advice; it only provides a forum for the development, consideration, and communication of information from a knowledgeable, independent perspective.

COMSTAC's charter allows it to:

- Undertake such information-gathering activities as necessary to address issues identified by the FAA for consideration by the committee, develop recommendations on those issues, and present the committee's recommendations to the Administrator.
- Evaluate economic, technological, and institutional developments relating to commercial space transportation and submit to the Administrator recommendations on promising new ideas and approaches for federal policies and programs.
- Provide the FAA with direct, first-hand information and insight from the substantially affected interests by exchanging ideas about FAA regulations and rulemakings that may require changes or elimination. The committee's activities must satisfy the normal rulemaking and

public comment process. The FAA will disclose in the public docket any committee communication on any particular issue in a rulemaking. The FAA will include an assessment of how the communication affects the development of proposed rules in the docket or preamble of any proposed rule. The committee will undertake only those tasks assigned by the FAA. Neither the committee nor any of its working groups may assign a task without prior approval by the FAA.
- Serve as a forum for the discussion of problems involving the relationship between industry activities and federal government requirements.

The following individuals served as members of COMSTAC during 2015:

- **Michael Gold (Chair), Bigelow Aerospace**
- **Michael Lopez-Alegria (Vice-Chair), MLA Space**
- Bretton Alexander, Blue Origin
- Christine Anderson, New Mexico Spaceport Authority
- Chuck Beams, Vulcan
- Mark Campbell, Aerospace Medical Association
- Daniel Collins, United Launch Alliance
- Patricia Cooper, Intelsat
- Richard DalBello, Virgin Galactic
- Debra Facktor Lepore, Ball Aerospace
- Peter Fahrenhold, Northrop Grumman Corporation
- Oscar Garcia, InterFlight Global Corporation
- Jeff Greason, XCOR Aerospace
- Michael Griffin, Schafer Corporation
- Wayne Hale, Special Aerospace Services
- Dan Hendrickson, Astrobotic Technology
- Timothy Hughes, SpaceX
- Livingston Holder, Holder Aerospace
- Ray Johnson, The Aerospace Corporation
- Janet Karika, Interagency Launch Programs
- Bill Khourie, Oklahoma Space Industry Development Authority
- Christopher Kunstadter, XL Insurance
- Samantha Marquart, George Washington University
- James McMurry, Boeing
- Will Pomeranz, Virgin Galactic
- Charles Precourt, Orbital ATK
- Frank Slazer, Aerospace Industries Association
- Mark Sundhahl, Cleveland State University
- Wilbur Trafton, Will Trafton and Associates, Inc.
- Jennifer Warren, Lockheed Martin

2015 Activities

Standards Working Group

The Working Group was formed at the last COMSTAC meeting in September 2014. It met via teleconference in December 2014 and February 2015. The focus of the Working Group has been on U.S. industry consensus standards, specifically on the space industry's prioritization rationale in making standards, and the process by which they are developed with FAA AST. The current leader in developing standards is the Commercial Spaceflight Federation (CSF): Its top prioritization rationale is human spaceflight occupancy safety. The Standards Working Group found the industry benefits from the rigorous prioritization and subsequent selection and adoption of consensus standards. COMSTAC agreed with this finding.

The working group recommended that COMSTAC meet occasionally with FAA AST to discuss the standards making process. It further recommended that FAA AST should reach out to industry in helping develop a breathable atmosphere standard, and start to create a hub where the two groups can jointly work together to catalog, prioritize, and adopt new standards.

Operations Working Group

During the April 2015 COMSTAC meeting, Janet Karika, Chair of the Operations Working Group, introduced Lieutenant Colonel Robert Jertberg, the Chief of the Launch and Range Branch at Air Force Space Command (AFSPC) Headquarters. Lt. Col. Jertberg said AFSPC is committed to maintaining the Eastern and Western ranges of the U.S. civil and national space lift, and to continue to provide the instrumentation to support test and space lift users. Due to recent sequestration, AFSPC had to put many instrumentation assets into standby status, which, along with aging infrastructure, meant that several launches were scrubbed. However, recently, AFSPC has begun to restore these assets. AFSPC is also in the process of rewriting requirement documents for range assets. The Working Group recommended that FAA AST should continue to advocate for commercial user range requirements in the 30SW and 45SW forums, as well as advocate for AFSPC to continue open communications with stakeholders concerning major changes to the ranges before decisions are finalized.

The Operations Working Group also found that creating an FAA AST spaceport directory would be a useful tool. There are currently 10 licensed spaceports and a directory would give general information and information about launch capability for each location. It would provide potential customers useful data for initial screening and establishing direct contact with a potential spaceport, and would be updated as new spaceports come online. The working group recommended that FAA AST develop a spaceport directory, distribute an information template to spaceports for completion, and identify the mechanism for publication, distribution and maintenance of the directory.

Business/Legal Working Group

The Business/Legal Working Group met in the morning session of the April 2015 COMSTAC meeting and group chair Christopher Kunstadter presented the group's deliberations and recommendations. The working group observed that FAA AST is authorized to promulgate safety regulations to promote safety of crew and spaceflight participants, and that while industry standards are a key part of producing a culture of continuous safety improvement, industry is not always willing to develop these standards.

The Business/Legal Working Group recommended that FAA AST identify three specific recommendations for potential standards for commercial human spaceflight each year, and should continue to ensure that the safety experience of all vehicles and operators is made known publicly. It also recommended that the current safety regime as described in the CSLA as amended should be extended until October 1, 2020, during which time FAA AST should inform industry when it becomes aware of safety-related incidents and work with industry and COMSTAC to develop practices and/or standards to reduce the likelihood of similar future incidents.

The working group further recommended that FAA AST convey COMSTAC support to Congress for granting FAA AST the authority to establish a process for issuing a Mission License for any space-based activity that is not under the jurisdiction of an existing government agency. Under this proposed arrangement, the White House should identify an agency to maintain a registry of Mission Licenses and FAA AST should be authorized to require any Mission License to provide updated information.

International Space Policy Working Group

During the April 2015 COMSTAC meeting, the International Space Policy Working Group found that FAA AST has an important role and opportunity to provide input on matters, such as export control, and should advocate for modernized regulations and practices. The U.S. space industry will benefit from placing human spaceflight systems under the auspices of the Export Administration Regulations (EAR). The working group observed that an important concern articulated by the Department of Defense (DoD) considering the transition of technologies from the United States Munitions List (USML) to the Commerce Control List (CCL) is the control of systems and technologies that could provide anti-satellite (ASAT) capabilities. As such, the working group recommended that FAA AST convene with industry to identify characteristics relevant to ASAT capabilities that can inform export control reform.

The International Space Policy Working Group also recommended that FAA AST advocate for unarmed, commercial suborbital spacecraft, particularly if controlled by an onboard pilot, be transferred to the CCL if such spacecraft is covered by an FAA AST license or permit.

The working group further observed that past COMSTAC recommendations and Congressional report language have stressed the importance of providing noninterference for private sector activities on celestial bodies. A recommendation was advanced that FAA AST provide more detail about the definition of "non-interference" through a dialogue with industry and COMSTAC.

DEFINITIONS

Commercial Suborbital or Orbital Launch

A commercial suborbital or orbital launch has one or more of these characteristics:

- The launch is licensed by FAA AST.
- The primary payload's launch contract was internationally competed (see definition of internationally competed below). A primary payload is generally defined as the payload with the greatest mass on a launch vehicle for a given launch.
- The launch is privately financed without government support.

Launch Failure

A launch failure happens when the payload does not reach a usable orbit (an orbit where some portion of the mission can be salvaged) or is destroyed as the result of a launch vehicle malfunction.

Internationally Competed

An internationally competed launch contract is one in which the launch opportunity was available in principle to any capable launch service provider. Such a launch is considered commercial.

Commercial Payload

A commercial payload has one or both of these characteristics:

- The payload is operated by a private company.
- The payload is funded by the government, but provides satellite service partially or totally through a private or semi-private company. This distinction is usually applied to certain telecommunications satellites whose transponders are partially or totally leased to a variety of organizations, some or all of which generate revenues. Examples include Russia's Express and Ekran series of spacecraft.

All other payloads are classified as non-commercial (government civil, government military, or non-profit).

Orbits

A spacecraft in geostationary Earth orbit (GSO) 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. Geosynchronous (GEO) is a broader category used for any circular orbit at an altitude of 35,852 kilometers (22,277 miles) with a low inclination (i.e., near or on the equator).

Non-geosynchronous orbit (NGSO) satellites are those in orbits other than GEO.

They are located in low Earth orbit (LEO, lowest achievable orbit to about 2,400 kilometers, or 1,491 miles), medium Earth orbit (MEO, 2,400 kilometers to GEO), SSO (Sun Synchronous Orbit), and all other orbits or trajectories. ELI ("elliptical") describes a highly elliptical orbit (such as those used for Russian Molniya satellites), and EXT ("external") describes trajectories beyond GEO (such as interplanetary trajectories).

Vehicle Mass Class

Small launch vehicles are defined as those with a payload capacity of less than 2,268 kilograms (5,000 pounds) at 185 kilometers (100 nautical miles) altitude and a 28.5-degree inclination. Medium to heavy launch vehicles are capable of carrying more than 2,269 kilograms at 185 kilometers altitude and a 28.5-degree inclination.

Payload Mass Class

Table 11 provides the payload mass classes used by the FAA AST.

Class Name	Kilograms (kg)	Pounds (lb)
Femto	0.01 - 0.1	0.02 - 0.2
Pico	0.09 - 1	0.19 - 2
Nano	1.1 - 10	3 - 22
Micro	11 - 200	23 - 441
Mini	201 - 600	442 - 1,323
Small	601 - 1,200	1,324 - 2,646
Medium	1,201 - 2,500	2,647 - 5,512
Intermediate	2,501 - 4,200	5,513 - 9,259
Large	4,201 - 5,400	9,260 - 11,905
Heavy	5,401 - 7,000	11,906 - 15,432
Extra Heavy	>7,001	>15,433

Table 11. Payload mass classes.

ACRONYMS

21AT	Twenty First Century Aerospace Technology Company Ltd.
ABS	Asia Broadcast Satellite
AIS	Automatic Identification System
ADF	Australian Defense Force
ATK	Alliant Technologies
ATV	Automated Transfer Vehicle
BEAM	Bigelow Expandable Activity Module
BMBF	Federal Ministry of Education and Research
BPA	Blok Perspektivnoy Avioniki
CASSIOPE	Cascade, Smallsat, and Ionospheric Polar Explorer
CAST	Chinese Academy of Space Technology
CCAFS	Cape Canaveral Air Force Station
CCDev	Commercial Crew Development
CCiCAP	Commercial Crew Integrated Capacity
CEO	Chief Executive Officer
CHIRP	Commercially Hosted Infrared Payload Flight Demonstration Program
COMSTAC	Commercial Space Transportation Advisory Committee
COTS	Commercial Orbital Transportation Services
CPC	Certification Product Contract
CRS	Commercial Resupply Services
CSA	Canadian Space Agency
CSSWE	Colorado Student Space Weather Experiment
CST-100	Crew Space Transportation-100 (CST-100 Starliner)
CXBN	Cosmic X-Ray Background
DARS	Digital Audio Radio Service
DBS	Direct Broadcasting Services
DEM	Digital Elevation Model
DLR	Deutsches Zentrum für Luft- und Raumfahrt (German space agency)
DMC	Disaster Monitoring Constellation
DMCii	DMC International Imaging, Ltd.
DTH	Direct-to-Home
EADS	European Aeronautic Defence and Space Company
EAL	Excalibur Almaz, Ltd.
ECA	Export Credit Agency
EDRS	European Data Relay System

EGNOS	European Geostationary Navigation Overlay Service
ELaNa	Educational Launch of Nanosatellites
ELI	Highly Elliptical Orbit (also refered to as HEO)
EROS	Earth Remote Observation Satellite
ESA	European Space Agency
EXIM	Export-Import Band
EXT	External or Non-Geocentric Orbit
FAA AST	Federal Aviation Administration, Office of Commercial SpaceTransportation
FCC	Federal Communications Commission
FY	Fiscal Year
FSS	Fixed Satellite Services
GEO	Geosynchronous Orbit
GIS	Geographic Information Systems
GMW	GeoMetWatch
GPS	Global Positioning System
GSLV	Geosynchronous Satellite Launch Vehicle
GSO	Geostationary Orbit
GTO	Geosynchronous Transfer Orbit
HDTV	High Definition Television Services
HPA	Hosted Payload Alliance
ICL	Imperial College London
ILS	International Launch Services
IPO	Initial Public Offering
ISRO	Indian Space Research Organization
ISS	International Space Station
ITAR	International Traffic in Arms Regulations
ITT	International Telephone & Telegraph
ITU	International Telecommunications Union
KARI	Korea Aerospace Research Institute
KSLV	Korean Space Launch Vehicle
LEO	Low Earth Orbit
LCRD	Laser Communications Relay Demonstration
LLC	Limited Liability Company
MEO	Medium Earth Orbit
MHI	Mitsubishi Heavy Industries, Ltd.

MPCV	Multi Purpose Crew Vehicle
MSS	Mobile Satellite Services
NASA	National Aeronautics and Space Administration
NEC	Nippon Electric Company
NGA	National Geospatial-Intelligence Agency
NGSO	Non-Geosynchronous Orbits
NOAA	National Oceanic and Atmospheric Administration
O3b	Other Three Billion Networks, Ltd.
OHB	Orbitale Hochtechnologie Bremen
Orbital	Orbital Sciences Corporation
PSLV	Polar Satellite Launch Vehicle
RCM	RADARSAT Constellation Mission
RRV	Reusable Return Vehicle
SAA	Space Act Agreement
SAR	Synthetic Aperture Radar
SBAS	Satellite-Based Augmentation Systems
SNC	Sierra Nevada Corporation
SpaceX	Space Exploration Technologies Corporation
SPOT	Satellite Pour l'Observation de la Terre
SSL	Space Systems Loral
SSO	Sun-Synchronous Orbit
SSTL	Surrey Satellite Technology Limited
TBD	To Be Determined
TSX	TerraSAR X-band
UAE	United Arab Emirates
UCISAT	University of California, Irvine Satellite
UHF	Ultra-High Frequency
ULA	United Launch Alliance
USLM	United States Munitions List
USAF	United States Air Force
WAAS	Wide Area Augmentation System

LIST OF TABLES

LIST OF FIGURES

2015 Worldwide Orbital Launch Events

Date			Vehicle	Site		Payload(s)	Orbit	Operator	Manufacturer	Use	Comm'l Price	L	M
10-Jan-15	√	+	Falcon 9 v1.1	CCAFS	*	Spx-5	LEO	SpaceX	SpaceX	Cargo	$61.2M	S	S
20-Jan-15			Atlas V 551	CCAFS		MUOS-3	GEO	U.S. Navy	Lockheed Martin	Communications		S	S
31-Jan-15			Delta II 7320-10	VAFB		SMAP	SSO	NASA	NASA/JPL	Scientific		S	S
						FIREBIRD-IIA	SSO	Montana State University	Montana State University	Development			S
						FIREBIRD-IIB	SSO	Montana State University	Montana State University	Development			S
						GRIFEX	SSO	NASA/JPL	NASA/JPL	Development			S
						ExoCube	SSO	California Polytechnic State University	California Polytechnic State University	Development			S
1-Feb-15			H-IIA 202	Tanegashima		IGS Radar Spare	SSO	Japan Self-Defense Forces	MELCO	IMINT		S	S
1-Feb-15	√		Proton M	Baikonur		Inmarsat-5F2	GEO	Inmarsat	Boeing	Communications	$65M	S	S
2-Feb-15			Safir 2	Semnan		Fajr	LEO	Iranian Department for Science and Technology	Iranian Space Agency	Development		S	S
11-Feb-15			Falcon 9 v1.1	CCAFS		DSCOVR	SSO	NOAA	Orbital ATK	Remote Sensing		S	S
17-Feb-15			Soyuz	Baikonur		Progress M-26M	LEO	Roscosmos	RKK Energia	Cargo		S	S
27-Feb-15			Soyuz 2.1a	Plesetsk		Cosmos 2503 (Bars -M)	SSO	Russian Ministry of Defense	TsSKB Progress	IMINT		S	S
1-Mar-15	√	+	Falcon 9 v1.1	CCAFS	*	Eutelsat-115 West B	GEO	Eutelsat	Boeing	Communications	$61.2M	S	S
					*	ABS-3A	GEO	Asia Broadcast Satellite	Boeing	Communications			S
12-Mar-15			Atlas V 421	CCAFS		MMS 1-4	ELI	NASA	NASA/GSFC	Scientific		S	S
19-Mar-15			Proton M	Baikonur		Express-AM7	GEO	Russian Satellite Communication Company (RSCC)	Airbus	Communications		S	S
25-Mar-15			Delta IV Medium+ (4,2)	CCAFS		USA 260 (Navstar GPS 2F-09)	MEO	U.S. Air Force	Boeing	Navigation		S	S
25-Mar-15	√		Dnepr	Dombarovsky		KOMPSat-3A	SSO	Korea Aerospace Research Institute (KARI)	KARI	Remote Sensing	$29M	S	S
26-Mar-15			H-IIA 202	Tanegashima		IGS Optical-5	SSO	Japan Self-Defense Forces	MELCO	IMINT		S	S
27-Mar-15			Soyuz	Baikonur		Soyuz TMA-16M	LEO	Roscosmos	RKK Energia	Crew		S	S
27-Mar-15			Soyuz 2.1b	Guiana Space Center		Galileo FOC-3 (Adam)	MEO	SpaceOpal	OHB System	Navigation		S	S
						Galileo FOC-4 (Anastasia)	MEO	SpaceOpal	OHB System	Navigation			S
28-Mar-15			PSLV XL	Satish Dhawan		IRNSS-1D	GEO	Indian Space Research Organization (ISRO)	ISRO	Navigation		S	S
30-Mar-15			Long March 3C/ YZ-1	Xichang		BDS I1-S	GEO	China National Space Administration (CNSA)	China Academy of Space Technology (CAST)	Navigation		S	S
31-Mar-15			Rockot	Plesetsk		Gonets-M21	LEO	Gonets Satcom	NPO Prikladnoi Mekhaniki (NPO PM)	Communications		S	S
						Gonets-M22	LEO	Gonets Satcom	NPO PM	Communications			S
						Gonets-M23	LEO	Gonets Satcom	NPO PM	Communications			S
						Cosmos 2504	LEO	Russian Ministry of Defense	Classified	Development			S
14-Apr-15	√	+	Falcon 9 v1.1	CCAFS	*	Spx-6	LEO	SpaceX	SpaceX	Cargo	$61.2M	S	S
26-Apr-15	√		Ariane 5 ECA	Guiana Space Center	*	Thor-7	GEO	Telenor	Space Systems Loral	Communication	$178M	S	S
						SICRAL-2 (Syracuse-3C)	GEO	Italian Ministry of Defense/French Defense Procurement Agency	Thales Alenia Space	Communication			S
27-Apr-15	√	+	Falcon 9 v1.1	CCAFS		TurkmenAlem52E/ MonacoSat-1	GEO	Turkmenistan National Space Agency	Thales Alenia Space	Communication	$61.2M	S	S

Date			Vehicle	Site		Payload(s)	Orbit	Operator	Manufacturer	Use	Comm'l Price	L	M
28-Apr-15			Soyuz	Baikonur		Progress M-27M	LEO	Roscosmos	RKK Energia	Cargo		S	F
16-May-15	√		Proton M	Baikonur		MexSat-1	GEO	Secretariat of Communications and Transportation	Boeing	Communication	$65M	F	F
20-May-15			Atlas V 501	CCAFS		X-37B OTV-4	LEO	U.S. Air Force	Boeing	Development		S	S
						AeroCube-8A	LEO	The Aerospace Corporation	The Aerospace Corporation	Development			S
						AeroCube-8B	LEO	The Aerospace Corporation	The Aerospace Corporation	Development			S
						BRICSat-P	LEO	U.S. Naval Academy	U.S. Naval Academy	Development			S
						GEARRS-2	LEO	Taylor University	Taylor University	Development			S
						LightSail-A	LEO	The Planetary Society	The Planetary Society	Development			S
						OptiCube-1	LEO	California Polytechnic State University	California Polytechnic State University	Development			S
						OptiCube-2	LEO	California Polytechnic State University	California Polytechnic State University	Development			S
						OptiCube-3	LEO	California Polytechnic State University	California Polytechnic State University	Development			S
						ParkinsonSat	LEO	U.S. Naval Academy	U.S. Naval Academy	Development			S
						ULTRASat	LEO	NASA	NASA	Development			S
						USS Langley	LEO	U.S. Naval Academy	U.S. Naval Academy	Development			S
27-May-15	√		Ariane 5 ECA	Guiana Space Center	*	DirecTV-15	GEO	DirecTV	Airbus	Communications	$178M	S	S
					*	Sky Mexico-1	GEO	SKY México	Orbital ATK	Communications			S
5-Jun-15			Soyuz 2.1a	Plestesk		Cosmos 2505 (Kobalt-M)	LEO	Russian Ministry of Defense	TsSKB Progress	IMINT		S	S
22-Jun-15			Vega	Guiana Space Center		Sentinel-2A	SSO	European Space Agency (ESA)	Airbus	Remote Sensing		S	S
23-Jun-15			Soyuz 1.2b	Plestesk		Cosmos 2506 (Persona)	SSO	Russian Ministry of Defense	TsSKB Progress	IMINT		S	S
27-Jun-15			Long March 4B	Taiyuan		Gaofen-8	SSO	CNSA	CAST	Remote Sensing		S	S
28-Jun-15	√	+	Falcon 9 v1.1	CCAFS	*	Spx-7	LEO	SpaceX	SpaceX	Cargo	$61.2M	F	F
3-Jul-15			Soyuz	Baikonur		Progress M-28M	LEO	Roscosmos	RKK Energia	Cargo		S	S
10-Jul-15	√		PSLV XL	Satish Dhawan	*	DMC3-A	SSO	DMCii	Surrey Satellite Technology Limited (SSTL)	Remote Sensing	$34M	S	S
					*	DMC3-B	SSO	DMCii	SSTL	Remote Sensing			S
					*	DMC3-C	SSO	DMCii	SSTL	Remote Sensing			S
						CBNT-1	SSO	SSTL	SSTL	Development			S
						DeOrbitSail	SSO	Surrey Space Center	SSTL	Development			S
15-Jul-15			Atlas V 401	CCAFS		USA 262 (Navstar GPS 2F-10)	MEO	U.S. Air Force	Boeing	Navigation		S	S
15-Jul-15	√		Ariane 5 ECA	Guiana Space Center	*	Star One C4	GEO	Star One	Space Systems Loral	Communications	$178M	S	S
						MSG-4	GEO	Eumetsat	Thales Alenia Space	Meteorology			S
22-Jul-15			Soyuz	Baikonur		Soyuz TMA-17M	LEO	Roscosmos	RKK Energia	Crew		S	S
23-Jul-15			Delta IV Medium+ (5,4)	CCAFS		USA 263 WGS-7	GEO	U.S. Air Force	Boeing	Communications		S	S
25-Jul-15			Long March 3B/ YZ-1	Xichang		BDS M1-S	MEO	CNSA	CAST	Navigation		S	S
						BDS M2-S	MEO	CNSA	CAST	Navigation			S
19-Aug-15			H-IIB	Tanegashima		HTV-5	LEO	Japan Aerospace Exploration Agency (JAXA)	Mitsubishi Heavy Industries	Cargo		S	S
20-Aug-15	√		Ariane 5 ECA	Guiana Space Center	*	Eutelsat-8 West B	GEO	Eutelsat	Thales Alenia Space	Communications	$178M	S	S
					*	Intelsat-34	GEO	Intelsat	Space Systems Loral	Communications			S
27-Aug-15			Long March 4C	Taiyuan		Yaogan-27	SSO	People's Liberation Army (PLA)	Shanghai Academy of Spaceflight Technology (SAST)	IMINT		S	S
27-Aug-15			GSLV Mk II	Satish Dhawan		GSAT-6	GEO	ISRO	ISRO	Communications		S	S
28-Aug-15	√		Proton M	Baikonur	*	Inmarsat-5F3	GEO	Inmarsat	Boeing	Communications	$65M	S	S
2-Sep-15			Soyuz	Baikonur		Soyuz TMA-18M	LEO	Roscosmos	RKK Energia	Crew		S	S

Date	Vehicle	Site	Payload(s)	Orbit	Operator	Manufacturer	Use	Comm'l Price	L	M
2-Sep-15	Atlas V 551	CCAFS	MUOS-4	GEO	U.S. Navy	Lockheed Martin	Communications		S	S
10-Sep-15	Soyuz 2.1b	Guiana Space Center	Galileo FOC-5 (Alba)	MEO	SpaceOpal	OHB System	Navigation		S	S
			Galileo FOC-6 (Oriana)	MEO	SpaceOpal	OHB System	Navigation			S
12-Sep-15	Long March 3B	Xichang	TJSSW-1	GEO	PLA	Classified	Development		S	S
14-Sep-15	Proton M	Baikonur	Express-AM8	GEO	RSCC	ISS Reshetnev	Communication		S	S
14-Sep-15	Long March 2D	Jiuquan	Gaofen-9	SSO	CNSA	CAST	Remote Sensing		S	S
19-Sep-15	Long March 6	Taiyuan	DCBB	SSO	China Amateur Satellite Group (CAMSAT)	CAMSAT	Other		S	S
			LilacSat-2	SSO	Harbin Institute of Technology (HIT)	HIT	Development			S
			NS-2	SSO	Tsinghua University	Tsinghua University	Development			S
			NUDT-Phone-Sat	SSO	National University of Defense Technology (NUDT)	NUDT	Development			S
			Tiantuo-3	SSO	NUDT	NUDT	Development			S
			Xingchen-1	SSO	NUDT	NUDT	Development			S
			Xingchen-2	SSO	NUDT	NUDT	Development			S
			Xingchen-3	SSO	NUDT	NUDT	Development			S
			Xingchen-4	SSO	NUDT	NUDT	Development			S
			Xiwang-2A	SSO	CAMSAT	CAMSAT	Communications			S
			Xiwang-2B	SSO	CAMSAT	CAMSAT	Communications			S
			Xiwang-2C	SSO	CAMSAT	CAMSAT	Communications			S
			Xiwang-2D	SSO	CAMSAT	CAMSAT	Communications			S
			Xiwang-2E	SSO	CAMSAT	CAMSAT	Communications			S
			Xiwang-2F	SSO	CAMSAT	CAMSAT	Communications			S
			XY-2	SSO	China Aerospace Science and Technology Corporation (CASC)	CASC	Development			S
			ZDPS-2A	SSO	Zhejiang University	Zhejiang University	Development			S
			ZDPS-2B	SSO	Zhejiang University	Zhejiang University	Development			S
			ZJ-1	SSO	Tsinghua University	Tsinghua University	Development			S
			ZJ-2	SSO	Tsinghua University	Tsinghua University	Development			S
24-Sep-15	Rockot	Plesetsk	Cosmos 2507 (Strela-3M)	LEO	Russian Ministry of Defense	NPO PM	Communications		S	S
			Cosmos 2508 (Strela-3M)	LEO	Russian Ministry of Defense	NPO PM	Communications			S
			Cosmos 2509 (Strela-3M)	LEO	Russian Ministry of Defense	NPO PM	Communications			S
25-Sep-15	Long March 11	Jiuquan	Pujiang-1	SSO	SAST	SAST	Development		S	S
			Tianwang-1A	SSO	ShanghaiTech	ShanghaiTech	Development			S
			Tianwang-1B	SSO	ShanghaiTech	ShanghaiTech	Development			S
			Tianwang-1C	SSO	ShanghaiTech	ShanghaiTech	Development			S
28-Sep-15	PSLV XL	Satish Dhawan	Astrosat	LEO	ISRO	ISRO	Scientific		S	S
			* ExactView-9	LEO	exactEarth	COM DEV International	Communications			S
			LAPAN-A2	LEO	National Institute of Aeronautics and Space (LAPAN)	LAPAN	Remote Sensing			S
			* Lemur-2 1	LEO	Spire Global	Spire Global	Remote Sensing			S
			* Lemur-2 2	LEO	Spire Global	Spire Global	Remote Sensing			S
			* Lemur-2 3	LEO	Spire Global	Spire Global	Remote Sensing			S
			* Lemur-2 4	LEO	Spire Global	Spire Global	Remote Sensing			S
29-Sep-15	Long March 3B/E		BDS I2-S	GEO	CNSA	CAST	Navigation		S	S

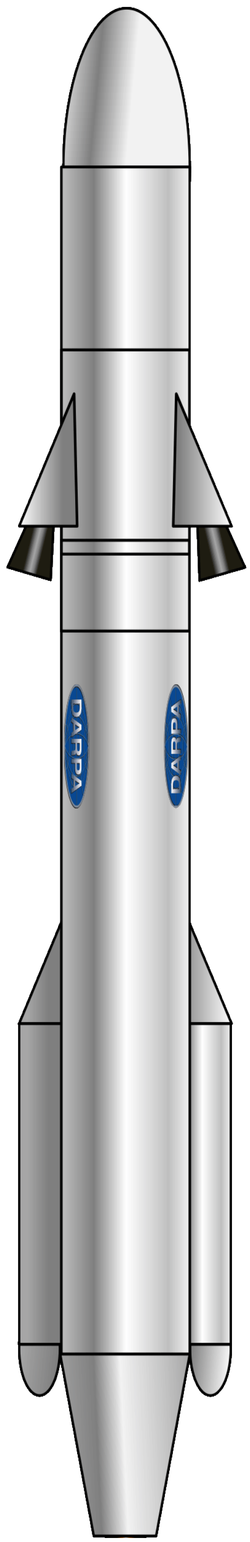
Date			Vehicle	Site		Payload(s)	Orbit	Operator	Manufacturer	Use	Comm'l Price	L	M
30-Sep-15	√		Ariane 5 ECA	Guiana Space Center	*	NBN Co. 1A	GEO	NBN Co. Ltd.	Space Systems Loral	Communications	$178M	S	S
					*	Arsat-2	GEO	Nahuelsat	INVAP	Communications			S
1-Oct-15			Soyuz	Baikonur		Progress M-29M	LEO	Roscosmos	RKK Energia	Cargo		S	S
2-Oct-15	√	+	Atlas V 421	CCAFS		Mexsat-3/Morelos-3	GEO	Ministry of Communications and Transportation	Boeing	Communications	$180M	S	S
7-Oct-15			Long March 2D	Jiuquan		Jilin-1A	SSO	Changchun Institute of Optics and Fine Mechanics and Physics (CIOMP)	CIOMP	Remote Sensing		S	S
						Jilin-1B	SSO	CIOMP	CIOMP	Remote Sensing			S
						Jilin-1C	SSO	CIOMP	CIOMP	Remote Sensing			S
						Jilin-1D	SSO	CIOMP	CIOMP	Remote Sensing			S
8-Oct-15			Atlas V 401	VAFB		USA 264 (NOSS)	LEO	National Reconnaissance Office (NRO)	Classified	ELINT		S	S
						AeroCube-5C	LEO	The Aerospace Corporation	The Aerospace Corporation	Development			S
						AeroCube-7	LEO	The Aerospace Corporation	The Aerospace Corporation	Development			S
						AMSAT Fox-1	LEO	Radio Amateur Satellite Corporation (AMSAT)	AMSAT	Communications			S
						ARC-1	LEO	University of Alaska Fairbanks	University of Alaska Fairbanks	Development			S
						BisonSat	LEO	Salish Kootenai College	Salish Kootenai College	Remote Sensing			S
						LMRST-Sat	LEO	NASA/JPL	NASA/JPL	Development			S
					*	PropCube-1	LEO	Tyvak Nano-Satellite Systems	Tyvak Nano-Satellite Systems	Development			S
					*	PropCube-2	LEO	Tyvak Nano-Satellite Systems	Tyvak Nano-Satellite Systems	Development			S
						SINOD-D 1	LEO	SRI International	SRI International	Development			S
						SINOD-D 2	LEO	SRI International	SRI International	Development			S
						SNaP-3A	LEO	U.S. Army	U.S. Army	Development			S
						SNaP-3B	LEO	U.S. Army	U.S. Army	Development			S
						SNaP-3C	LEO	U.S. Army	U.S. Army	Development			S
16-Oct-15			Long March 3B/E	Xichang		APStar-9	GEO	APT Satellite Holdings	CASC	Communications		S	S
16-Oct-15	√		Proton M	Baikonur	*	Türksat-4B	GEO	Türksat	MELCO	Communications	$65M	S	S
26-Oct-15			Long March 2D	Jiuquan		Tianhui-1C	SSO	PLA	CASC	Remote Sensing		S	S
31-Oct-15			Atlas V 401	CCAFS		USA 265 (Navstar GPS 2F-11)	MEO	U.S. Air Force	Boeing	Navigation		S	S
3-Nov-15			Long March 3B/E	Xichang		ChinaSat-2C	GEO	PLA	CAST	Communications		S	S
3-Nov-15			Super Strypi	Pacific Missile Range Facility		HiakaSat	LEO	Operationally Responsive Space (ORS) Office	ORS Office	Development		F	F
						Argus	LEO	St. Louis University/ Vanderbilt University	St. Louis University/ Vanderbilt University	Development			F
						EDSN (8)	LEO	NASA	NASA	Development			F
						PrintSat	LEO	Montana State University	Montana State University	Development			F
						STACEM	LEO	Utah State University	Utah State University	Development			F
					*	Supernova-Beta	LEO	Pumpkin, Inc.	Pumpkin, Inc.	Development			F
8-Nov-15			Long March 4B	Taiyuan		Yaogan 28	SSO	PLA	SAST	IMINT		S	S
10-Nov-15	√		Ariane 5 ECA	Guiana Space Center	*	Arabsat-6B	GEO	Arabsat	Airbus	Communications	$178M	S	S
						GSAT-15	GEO	ISRO	ISRO	Communications			S
17-Nov-15			Soyuz 2.1b	Plesetsk		Cosmos 2510 (Tundra)	ELI	Russian Ministry of Defense	RKK Energia	Early Warning		S	S
20-Nov-15			Long March 3B/E	Xichang		LaoSat-1	GEO	Laos National Authority for Science and Technology	CAST	Communications		S	S

Date			Vehicle	Site		Payload(s)	Orbit	Operator	Manufacturer	Use	Comm'l Price	L	M
24-Nov-15	√		H-IIA 204	Tanegashima		Telstar-12V	GEO	Telesat	Airbus	Communications	$113M	S	S
26-Nov-15			Long March 4C	Taiyuan		Yaogan-29	SSO	PLA	SAST	IMINT		S	S
3-Dec-15			Vega	Guiana Space Center		LISA Pathfinder	EXT	ESA/NASA	Airbus	Scientific		S	S
5-Dec-15			Soyuz 2.1v	Plesetsk		Cosmos 2511 (Kanopus-ST)	SSO	Russian Ministry of Defense	VNIIEM Corporation	IMINT		S	F
						Cosmos 2512 (KYuA-1)	SSO	Russian Ministry of Defense	Almaz-Antey	Other			S
6-Dec-15	√	+	Atlas V 401	CCAFS	*	OA-4	LEO	Orbital ATK	Orbital ATK	Cargo	$110M	S	S
9-Dec-15			Long March 3B/E	Xichang		Chinasat-1C	GEO	PLA	CAST	Communications		S	S
11-Dec-15			Zenit 3F	Baikonur		Elektro-L No. 2	GEO	Roscosmos	NPO Lavotchkin	Meteorology		S	S
13-Dec-15			Proton M	Baikonur		Cosmos 2513 (Garpun No. 12L)	GEO	Russian Ministry of Defense	ISS Reshetnev	Communications		S	S
15-Dec-15			Soyuz	Baikonur		Soyuz TMA-19M	LEO	Roscosmos	RKK Energia	Crew		S	S
16-Dec-15	√		PSLV CA	Satish Dhawan	*	TeLEOS-1	LEO	AgilSpace	AgilSpace	Remote Sensing	$33M	S	S
						Athenoxat-1	LEO	Nanyang Technological University	Nanyang Technological University	Remote Sensing			S
						Galassia	LEO	National University of Singapore	National University of Singapore	Scientific			S
						Kent Ridge-1	LEO	National University of Singapore	National University of Singapore	Remote Sensing			S
						VELOX-C1	LEO	Nanyang Technological University	Nanyang Technological University	Scientific			S
						VELOX-2	LEO	Nanyang Technological University	Nanyang Technological University	Development			S
17-Dec-15			Long March 2D	Jiuquan		DAMPE	SSO	Chinese Academy of Sciences	Chinese Academy of Sciences	Scientific		S	S
17-Dec-15			Soyuz 2.1b	Guiana Space Center		Galileo FOC 8 (Andriana)	MEO	SpaceOpal	OHB System	Navigation		S	S
						Galileo FOC 9 (Liene)	MEO	SpaceOpal	OHB System	Navigation			S
21-Dec-15			Soyuz 2.1a	Baikonur		Progress MS-1	LEO	Roscosmos	RKK Energia	Cargo		S	S
22-Dec-15	√	+	Falcon 9 FT	CCAFS	*	ORBCOMM-2 F2	LEO	ORBCOMM	Sierra Nevada Corp. (SNC)	Communications	$61.2M	S	S
					*	ORBCOMM-2 F5	LEO	ORBCOMM	SNC	Communications			S
					*	ORBCOMM-2 F8	LEO	ORBCOMM	SNC	Communications			S
					*	ORBCOMM-2 F10	LEO	ORBCOMM	SNC	Communications			S
					*	ORBCOMM-2 F12	LEO	ORBCOMM	SNC	Communications			S
					*	ORBCOMM-2 F13	LEO	ORBCOMM	SNC	Communications			S
					*	ORBCOMM-2 F14	LEO	ORBCOMM	SNC	Communications			S
					*	ORBCOMM-2 F15	LEO	ORBCOMM	SNC	Communications			S
					*	ORBCOMM-2 F16	LEO	ORBCOMM	SNC	Communications			S
					*	ORBCOMM-2 F17	LEO	ORBCOMM	SNC	Communications			S
					*	ORBCOMM-2 F18	LEO	ORBCOMM	SNC	Communications			S
24-Dec-15			Proton M	Baikonur		Express-AMU1	GEO	RSCC	ISS Reshetnev	Communications		S	S
28-Dec-15			Long March 3B/E	Xichang		Gaofen-4	GEO	CNSA	CAST	Remote Sensing		S	S

√ Denotes commercial launch, defined as a launch that is internationally competed or FAA-licensed, or privately financed launch activity. For multiple manifested launches, certain secondary payloads whose launches were commercially procured may also constitute a commercial launch.
\+ Denotes FAA-licensed launch.
* Denotes a commercial payload, defined as a spacecraft that serves a commercial function or is operated by a commercial entity.
L and M refer to the outcome of the Launch and Mission: S=Success, P=Partial Success, F=Failure.
Notes: All prices are estimates.
All launch dates are based on local time at the launch site.

Launch Vehicle Fact Sheet

Airborne Launch Assist Space Access (ALASA)



ALASA is designed to be a significantly less expensive approach for routinely launching small satellites. DARPA plans at least a threefold reduction in launch costs compared to current military and US commercial launch vehicles. DARPA seeks a system that can launch 45-kilogram (100-pound) payloads to LEO for less than $1M, including range support costs. To achieve this goal, the ALASA program is employing new technologies to provide increased specific impulse propellants, stable propellant formulations, hybrid propellant systems, potential "infrastructure free" cryogen production, new motor case materials, new flight controls and mission planning techniques, new nozzle designs, improved thrust vectoring methods, and new throttling approaches.

ALASA is designed for launch from an aircraft to improve performance, reduce range costs and enable more frequent missions, all of which combine to reduce cost. The baseline aircraft for the program is an F-15E Strike Eagle. The ability to relocate and launch quickly from virtually any major runway around the world substantially reduces the time needed to launch a mission. Launching from an aircraft also maximizes the number of potential orbits, as there are no major concerns for launch direction limits imposed by geography at fixed-base launch facilities.

A pathfinder program called the Small Air Launch Vehicle to Orbit (SALVO) is already underway. SALVO, built by Ventions under the ALASA program, is designed to test technologies expected to be used for ALASA.

The nitrous oxide and acetylene propellant mix was selecred because it is very powerful, but difficult to handle safely. As a result of two ground accidents relating to propellant handling, launches of ALASA have been delayed from an expected introduction in 2016.

Launch service provider
DARPA

Organization Headquarters
USA

Manufacturer
Boeing

Mass, kg (lb)
36,786 (81,100)

Length, m (ft)
19.4 (63.8)

Wingspan, m (ft)
13 (42.8)

Year of Planned First Launch
TBD

Launch sites
Various

GTO capacity, kg (lb)
N/A

LEO capacity, kg (lb)
45 (100)

Estimated Price per Launch
$1M

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

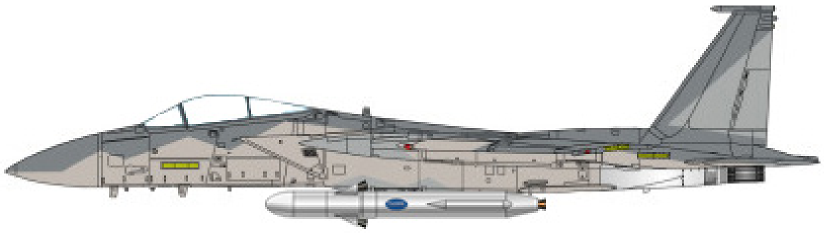
Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

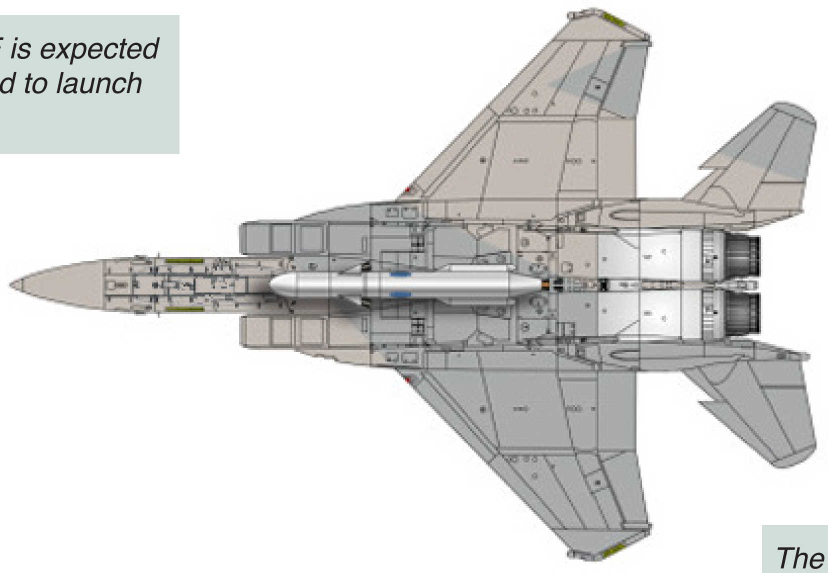
FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

FAA AST

Launch Vehicle Fact Sheet
Airborne Launch Assist Space Access (ALASA)



An F-15E is expected to be used to launch ALASA



The same aircraft type was reportedly used to launch SALVO in 2015

Fairing	Length, m (ft)	Diameter, m (ft)
Standard Fairing	0.6 (2) *est*	0.6 (2) *est*

	1st Stage	2nd Stage	3rd Stage
Stage designation	F-15E	1st Stage	2nd Stage
Length, m (ft)	19.4 (63.8)	3.7 (12.1) *est, tank only*	1.8 (5.9) est, tank only
Diameter/Wingspan, m (ft)	13 (42.8)	0.6 (2) *est*	0.6 (2) *est*
Manufacturer	Boeing	Boeing	Boeing
Propellant	Kerosene (JP-4)	N_2O/Acetylene (NA-7)	N_2O/Acetylene (NA-7)
Propellant mass, kg (lb)	16,125 (35,550)	Undisclosed	Undisclosed
Total thrust, kN (lbf)	258 (58,000)	Undisclosed	Undisclosed
Engine(s)	2 x F100-PW-220/229	4 x TBD	4 x TBD
Engine manufacturer	Pratt & Whitney	Boeing	Boeing
Engine thrust, kN (lbf)	129 (29,000)	Undisclosed	Undisclosed

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

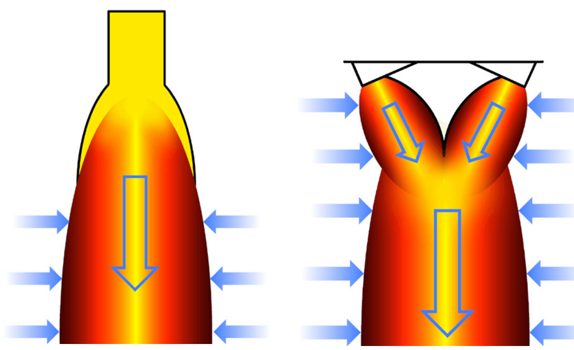
FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

Alpha 1.0

U.S.-based Firefly Space Systems was founded in 2014 to provide launch services catering to operators of microsatellites.

The company offers the Alpha launch vehicle, the first vehicle since Lockheed Martin's X-33 and *VentureStar* to feature an aerospike engine. If successful, it will be the first operational vehicle to employ an aerospike engine. A conventional rocket engine uses a nozzle to direct exhaust in one direction, maximing the output pressure needed to impart thrust (left diagram). An aerospike differs by directing the exhaust along two paths that exit at the base of a linear spike and merge at the tip (right diagram). The spike serves as one edge of a "virtual nozzle" while the ambient air pressure (solid blue arrows) serves as the other edge. This means an aerospike engine is lighter, more aerodynamic, and more efficient through all altitudes, particularly at lower altitudes where the air is denser. An aerospike is 30% more efficient than a nozzle at sea level.



The Alpha is expected to launch for the first time in 2017 from LC-39C.

Firefly was selected in 2015 by NASA to conduct a demonstration CubeSat launch by March 2018. The Venture Class Launch Services (VCLS) contract to Firefly is valued at $5.5M.

Launch service provider
Firefly Space Systems

Organization Headquarters
USA

Manufacturer
Firefly Space Systems

Mass, kg (lb)
Undisclosed

Length, m (ft)
23.6 (77.3)

Diameter, m (ft)
1.5 (4.8)

Year of Planned First Launch
2017

Launch site
KSC (LC-39C)

GTO capacity, kg (lb)
N/A

LEO capacity, kg (lb)
400 (882)

SSO capacity, kg (lb)
200 (441)

Estimated Price per Launch
$8M

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

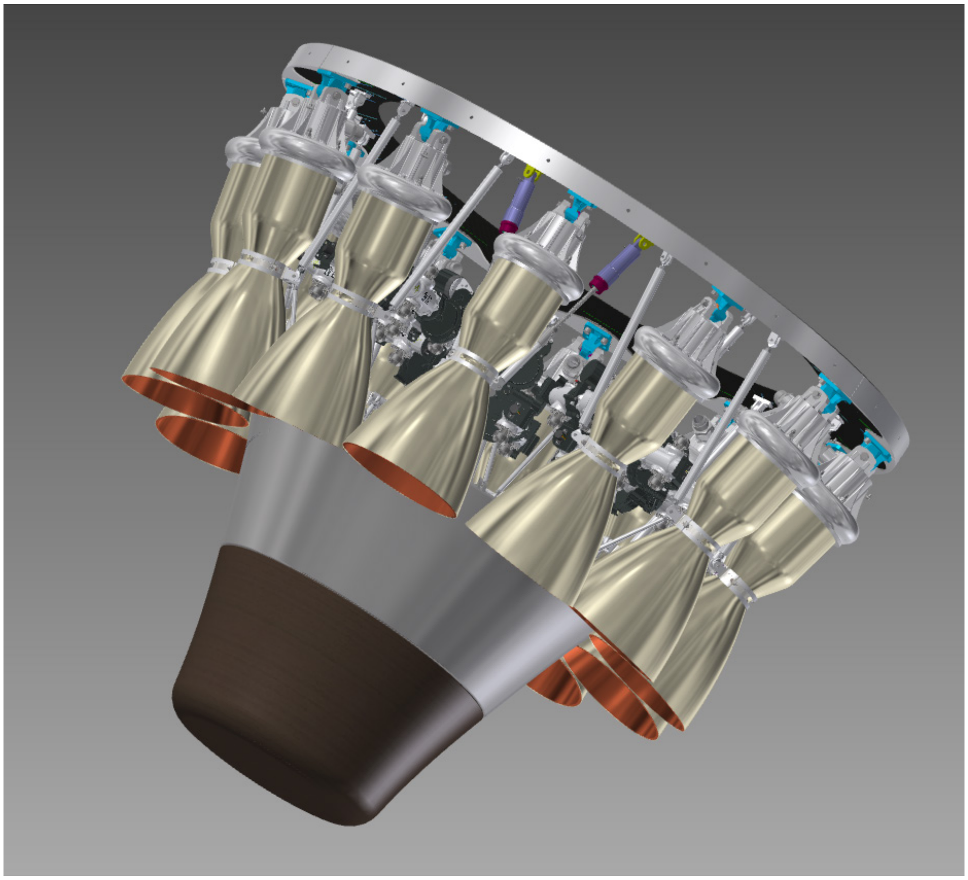
Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet
Alpha 1.0

FAA AST



A 3D diagram of the FRE-2 aerospike engine that will be used to power the Alpha's first stage. Source: Firefly Space Systems.

Fairing	Length, m (ft)	Diameter, m (ft)
Standard Fairing	1.8 (5.8)	1.5 (4.8)

	1st Stage	2nd Stage
Stage designation	1st Stage	2nd Stage
Length, m (ft)	16.7 (54.8)	4.6 (15)
Diameter, m (ft)	2 (6.6)	1.5 (4.8)
Manufacturer	Firefly Space Systems	Firefly Space Systems
Propellant	LOX/Kerosene	LOX/Kerosene
Propellant mass, kg (lb)	Undisclosed	Undisclosed
Total thrust, kN (lbf)	443 (99,600)	27.6 (6,200)
Engine(s)	1 x FRE-2	1 x FRE-1
Engine manufacturer	Firefly Space Systems	Firefly Space Systems
Engine thrust, kN (lbf)	443 (99,600)	27.6 (6,200)

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

Antares

In 2013, Orbital Sciences Corporation (now Orbital ATK) began offering its Antares, a two-stage vehicle designed to launch government and commercial satellites to low Earth orbit (LEO), Cygnus cargo modules to the International Space Station (ISS), and missions requiring Earth escape trajectories. The Antares is also available under the NASA Launch Services (NLS) II contract for future science missions.

The Antares is the first cryogenically fueled vehicle produced by Orbital ATK. The first version of the vehicle family, the Antares 100 series powered by AJ26 engines, has been discontinued in favor of the Antares 200 series powered by RD-181 engines.

The Antares 200 series consists of a first stage produced by Ukrainian Yuzhnoye Design Office (Yuzhnoye) powered by twin NPO Energomash RD-181 engines, each of which produces about 400 kN more thrust than a single AJ26. A customer can select from two different second stages, the Castor-30B or the Castor-30XL. Orbital ATK also offers an optional Bi-Propellant Third Stage (BTS) for high-energy performance needs. The vehicle is topped off with a payload adapter and a 4-meter (13-foot) diameter fairing. In 2008, NASA selected the Antares (originally named Taurus II) to receive funding under the COTS program. NASA ultimately selected Orbital and its competitor SpaceX to provide cargo transportation to the ISS under a CRS contract.

The fifth launch of Antares, which took place in October 2014, ended in a launch failure. Following the accident, Orbital ATK preceded with development of the 200 series, which is schedule to fly for the first time in 2016.

Launch service provider
Orbital ATK

Organization Headquarters
USA

Manufacturer
Orbital ATK

Mass, kg (lb)
530,000 (1,168,450)

Length, m (ft)
40.5 (132.9)

Diameter, m (ft)
3.9 (12.8)

Year of First Launch
2013

Number of Launches
5

Reliability
80%

Launch site
MARS (Pad 0-A)

GTO capacity, kg (lb)
N/A

LEO capacity, kg (lb)
3,500-7,000 (7,716-15,432)

SSO capacity, kg (lb)
2,100-3,400 (4,630-7,496)

Estimated Price per Launch
$80M-$85M

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

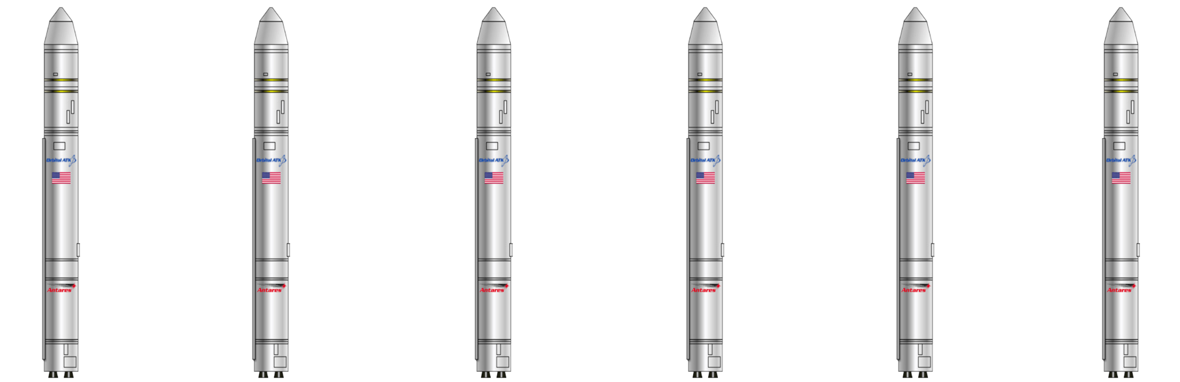
FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

FAA AST

Launch Vehicle Fact Sheet

Antares

The Antares family consists of six variants. The first stage, which is common to all six variants, can be outfitted with either a Castor 30B or Castor 30XL solid motor upper stage. The vehicle can have no third stage, or an option between a Bi-Propellant Third Stage (BTS) or a STAR 48. The same fairing is used for all six versions.



Antares 220 | Antares 221 | Antares 222 | Antares 230 | Antares 231 | Antares 232

Fairing	Length, m (ft)	Diameter, m (ft)
Standard Fairing	9.9 (32.5)	3.9 (12.8)

	1st Stage	2nd Stage	3rd Stage Option	3rd Stage Option
Stage designation	N/A	Castor-30B/30XL	STAR-48V	Bi-Propellant Third Stage (BTS)
Length, m (ft)	25 (82)	30B: 4.17 (13.7) 30XL: 5.99 (19.7)	2 (6.6)	1.8 (5.9)
Diameter, m (ft)	3.9 (12.8)	2.34 (7.7)	1.2 (3.9)	1.7 (5.6)
Manufacturer	KB Yuzhnoye	Orbital ATK	Orbital ATK	Orbital ATK
Propellant	LOX/Kerosene	Solid	Solid	N_2O_4/UDMH
Propellant mass, kg (lb)	240,000 (529,109)	30B: 12,887 (28,411) 30XL: 24,196 (53,343)	2,010 (4,431)	--
Total thrust, kN (lbf)	3,648 (820,000)	396.3 (89,092)	77.8 (17,490)	--
Engine(s)	2 x RD-181	--	--	--
Engine manufacturer	NPO Energomash	--	--	Orbital ATK
Engine thrust, kN (lbf)	1,824 (410,000)	396.3 (89,092)	77.8 (17.490)	--

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

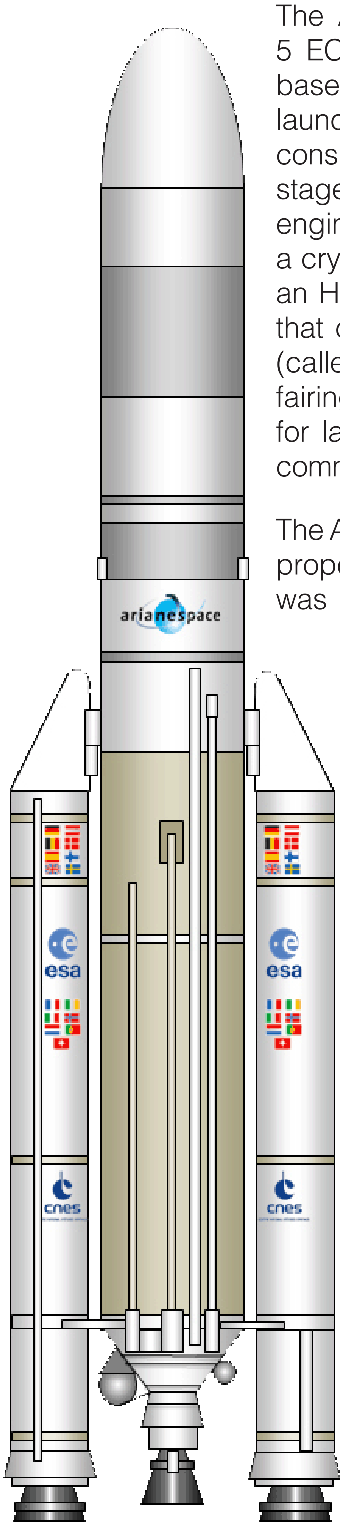
Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

Ariane 5 ECA

FAA AST



The Ariane 5, technically the Ariane 5 ECA, is the workhorse of France-based Arianespace, a European launch consortium. The Ariane 5 consists of a liquid-fueled core stage powered by a single Vulcain 2 engine, two strap-on solid boosters, a cryogenic upper stage powered by an HM7B engine, a payload adapter that can accommodate two satellites (called SYLDA), and a payload fairing. The Ariane 5 ECA is optimized for launches of two geosynchronous communications satellites.

The Ariane 5 ES version with a storable propellant upper stage engine was used to launch the Automated Transfer Vehicle (ATV) to the International Space Station (ISS) and very large satellites like Envisat. This vehicle will also be used for some launches of the Galileo global navigation satellite system.

Arianespace oversees the procurement, quality control, launch operations, and marketing of the Ariane 5. A new joint venture, called Airbus Safran Launchers and established in late 2014, is the prime contractor for Ariane 5 manufacturing. The Ariane 5 has launched 83 times since its introduction in 1996, with 69 consecutive successes since 2003. The Ariane 5 ECA variant has flown 53 times.

In December 2014, the European Space Agency (ESA) authorized development of the Ariane 6 vehicle as an eventual replacement for the Ariane 5. The new vehicle will be offered in two variants beginning in 2020. The Ariane 5 ECA will be phased out by 2023.

Launch service provider
Arianespace

Organization Headquarters
France

Manufacturer
Airbus Safran Launchers

Mass, kg (lb)
780,000 (1,719,606)

Length, m (ft)
54.8 (179.8)

Diameter, m (ft)
5.4 (17.7)

Year of First Launch
2002 (ECA version)

Number of Launches
83

Reliability
98%

Launch site
Guiana Space Center (ELA-3)

GTO capacity, kg (lb)
9,500 (20,944)

LEO capacity, kg (lb)
21,000 (46,297)

SSO capacity, kg (lb)
10,000 (22,046)

Estimated Price per Launch
$178M

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

Ariane 5 ECA

FAA AST

An Ariane 5 ECA launches from the Guiana Space Center on August 20, 2015 carrying Eutelsat 8 West B and Intelsat 34. Source: Arianespace.

Fairing	Length, m (ft)	Diameter, m (ft)
Standard Fairing	17 (55.8)	5.4 (17.7)

	SRB*	1st Stage	2nd Stage
Stage designation	EAP	EPC	ESC-A
Length, m (ft)	31.6 (103.7)	30.5 (100.1)	4.7 (15.4)
Diameter, m (ft)	3.1 (10.2)	5.4 (17.7)	5.4 (17.7)
Manufacturer	Airbus Safran Launchers	Airbus Safran Launchers	Airbus Safran Launchers
Propellant	Solid	LOX/LH_2	LOX/LH_2
Propellant mass, kg (lb)	240,000 (529,109)	170,000 (374,786)	14,900 (32,849)
Total thrust, kN (lbf)	7,080 (1,591,647)	960 (215,817)	67 (15,062)
Engine(s)	--	1 x Vulcain 2	1 x HM-7B
Engine manufacturer	--	Airbus Safran Launchers	Airbus Safran Launchers
Engine thrust, kN (lbf)	--	960 (215,817)	67 (15,062)

** Figures are for each booster. Total thrust is sum of all boosters.*

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

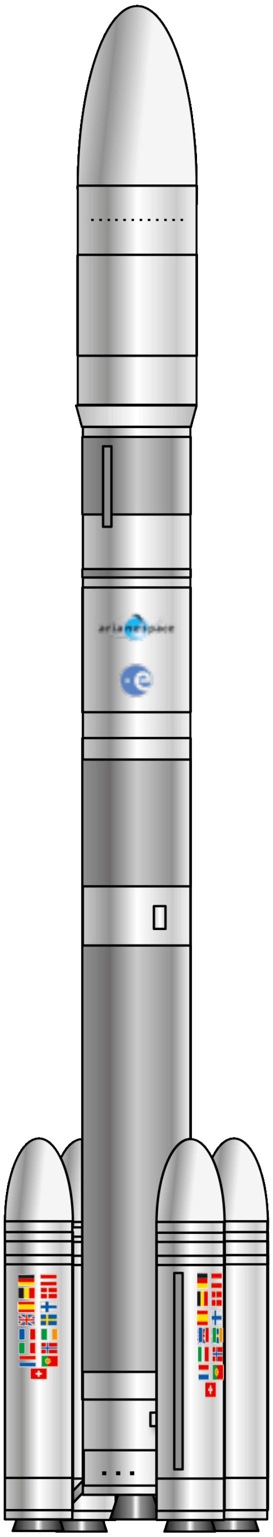
Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

Ariane 6



The Ariane 6 family currently under development is expected to replace the Ariane 5 ECA by 2023. The family will be composed of two variants, the Ariane 62 and the Ariane 64, with the main differentiator being the use of two or four solid boosters, respectively. The vehicle will be manufactured by a newly established consortium called Aribus Safran Launchers (ASL). ASL was formed to streamline launch vehicle manufacturing and reduce costs. The maximum throughput planned is 12 Ariane 6 launches per year, an operational tempo also expected to reduce launch costs.

The Ariane 62 will primarily be used for single launches to geosynchronous transfer orbit (GTO) and for some payloads destined for deep space exploration. The Ariane 64 will primarily be used for dual-manifested payloads to GTO. Small and medium payloads destined for low Earth orbit (LEO) or Sun-synchronous orbits (SSO) will be handled using the Soyuz 2 or Vega vehicles also offered by Arianespace.

The decision to move forward on the Ariane 6 was made in December 2014. In August 2015, the European Space Agency (ESA) signed contracts for the development of the Ariane 6, its launch infrastructure, and a new variant of the Vega called Vega C. The Vega C is a related development program because the first stage of that vehicle, the P120C, will serve as the solid booster for Ariane 6.

Launch service provider
Arianespace

Organization Headquarters
France

Manufacturer
Airbus Safran Launchers

Mass, kg (lb)
800,000 (1,763,698)

Length, m (ft)
70 (230)

Diameter, m (ft)
4.6 (15.1)

Year of Planned First Launch
2020

Launch site
Guiana Space Center (ELA-3)

GTO capacity, kg (lb)
5,000-11,000 (11,023-24,251)

LEO capacity, kg (lb)
10,000-21,000 (22,046-46,297)

SSO capacity, kg (lb)
N/A

Estimated Price per Launch
$94M-$117M

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

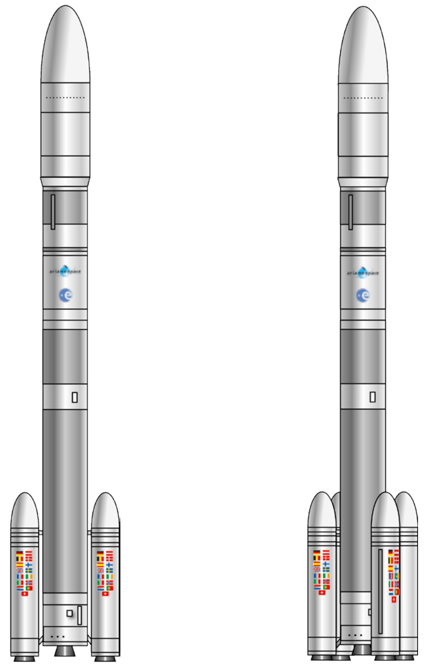
Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

FAA AST

Launch Vehicle Fact Sheet
Ariane 6



Ariane 62 Ariane 64

Two variants of the Ariane 6 will be available. The Ariane 62 will primarily be used for singular missions to GTO, whereas the Ariane 64 will be used for dual-manifested payloads to GTO.

Fairing	Length, m (ft)	Diameter, m (ft)
Standard Fairing	15 (49) *est*	5 (16.4) *est*

	SRB*	1st Stage	2nd Stage
Stage designation	P120C	2nd Stage	3rd Stage
Length, m (ft)	11.5 (37.7)	40 (131) *est*	15 (49) *est*
Diameter, m (ft)	3.3 (10.8)	4.6 (15.1)	4.6 (15.1)
Manufacturer	Airbus Safran Launchers	Airbus Safran Launchers	Airbus Safran Launchers
Propellant	Solid	LOX/H_2	LOX/H_2
Propellant mass, kg (lb)	120,000 (264,555)	149,000 (328,489)	30,000 (66,139)
Total thrust, kN (lbf)	3,500 (786,831)	350 (78,683)	180 (40,466)
Engine(s)	--	1 x Vulcain 2.1	1 x Vinci
Engine manufacturer	--	Airbus Safran Launchers	Airbus Safran Launchers
Engine thrust, kN (lbf)	--	350 (78,683)	180 (40,466)

** Figures are for each booster. Total thrust is sum of all boosters.*

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

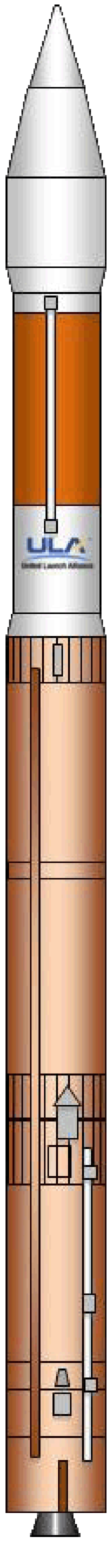
Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

Atlas V



The Atlas V family is a product of the U.S. Air Force's Evolved Expendable Launch Vehicle Program (EELV), begun in 1995. Lockheed Martin originally developed the Atlas V, but manufacturing and operations are now conducted by United Launch Alliance (ULA), a joint company between Lockheed Martin and Boeing. ULA markets the vehicle to the U.S. Government and Lockheed Martin Commercial Launch Services markets to commercial clients worldwide. In 2010, ULA began the process of certifying Atlas V for human missions, to launch NASA astronauts to low Earth orbit (LEO). ULA has an agreement to launch Boeing's CST-100 Starliner, a crewed vehicle designed to service the International Space Station (ISS).

Atlas V consists of the Common Core Booster (CCB) powered by a Russian RD-180 engine, a combination of up to five solid rocket boosters, a Centaur upper stage powered by either one or two Pratt & Whitney Rocketdyne (PWR) RL10A-4-2 engines, a payload adapter, and a payload fairing. The vehicle variants are described in two groups: Atlas V 400 series and Atlas V 500 series. The first number of the three-digit designator indicates the diameter of the fairing in meters, the second number indicates the number of Aerojet solid rocket boosters used (zero to five), and the third number indicates the number of RL10A-4-2 engines employed by the Centaur upper stage (one or two).

The Atlas V family debuted in 2002 with the successful launch of an Atlas V 401 from Cape Canaveral Air Force Station (CCAFS) and can launch payloads to any desired orbit. It will be replaced with ULA's Vulcan family beginning in 2019, with full replacement expected shortly after 2023.

In 2015, ULA selected Orbital ATK is the provider of solid motors for the Atlas V, replacing the AJ-60A motors. First flight of an Atlas V with the new GEM-63 motors is expected in 2018.

Launch service provider
ULA/LMCLS

Organization Headquarters
USA

Manufacturer
ULA

Mass, kg (lb)
401: 333,731 (734,208)
551: 568,878 (1,251,532)

Length, m (ft)
60.6-75.5 (198.7-247.5)

Diameter, m (ft)
3.8 (12.5)

Year of First Launch
2002

Number of Launches
59

Reliability
100%

Launch sites
CCAFS (SLC-40)
VAFB (SLC-3E)

GTO capacity, kg (lb)
3,460-8,900 (7,620-19,620)

LEO capacity, kg (lb)
8,123-18,814 (17,908-41,478)

SSO capacity, kg (lb)
6,424-15,179 (14,163-33,464)

Estimated Price per Launch
$110M-$230M

FAA AST

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

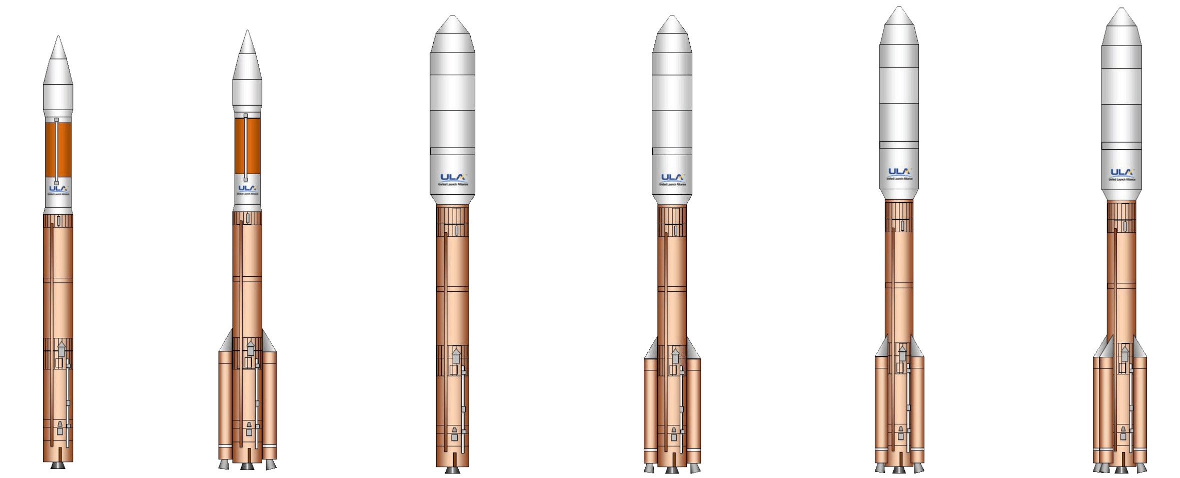
FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

FAA AST

Launch Vehicle Fact Sheet

Atlas V

The Atlas V family consists of 18 variants, though only nine variants have flown to date. The Atlas V variants are defined by the number of solid rocket boosters attached to the CCB (between zero and 5), the type of Centaur upper stage employed (either a single or dual engine), and the type of fairing (4-meter or 5-meter diameter).



Atlas V 401/402 411/412 — Atlas V 421/431 — Atlas V 501/502 511/512 — Atlas V 521/522 531/532 — Atlas V 541/542 — Atlas V 551/552

Fairing	Length, m (ft)	Diameter, m (ft)
4m Large Payload Fairing	12 (39.3)	4 (13)
4m Extended Payload Fairing	12.9 (42.3)	4 (13)
4m Extra Extended Payload Fairing	13.8 (45.3)	4 (13)
5m Large Payload Fairing	20.7 (68)	5 (16.4)
5m Extended Payload Fairing	23.5 (77)	5 (16.4)
5m Extra Extended Payload Fairing	26.5 (87)	5 (16.4)

	1st Stage	SRB*	2nd Stage Option	2nd Stage Option
Stage designation	Common Core Booster	AJ-60A	Single Engine Centaur	Dual Engine Centaur
Length, m (ft)	32.5 (106.6)	20 (65.6)	12.7 (41.7)	12.7 (41.7)
Diameter, m (ft)	3.8 (12.5)	1.6 (5.2)	3.1 (10.2)	3.1 (10.2)
Manufacturer	ULA	Aerojet Rocketdyne	ULA	ULA
Propellant	LOX/Kerosene	Solid	LOX/LH_2	LOX/LH_2
Propellant mass, kg (lb)	284,089 (626,309)	46,697 (102,949)	20,830 (45,922)	20,830 (45,922)
Total thrust, kN (lbf)	3,827 (860,309)	1,688 (379,550)	99.2 (22,300)	198.4 (44,600)
Engine(s)	1 x RD-180	--	1 x RL10A-4-2	2 x RL10A-4-2
Engine manufacturer	RD AMROSS	--	Aerojet Rocketdyne	Aerojet Rocketdyne
Engine thrust, kN (lbf)	3,827 (860,309)	1,688 (379,550)	99.2 (22,300)	99.2 (22,300)

** Figures are for each booster. Total thrust is sum of all boosters.*

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

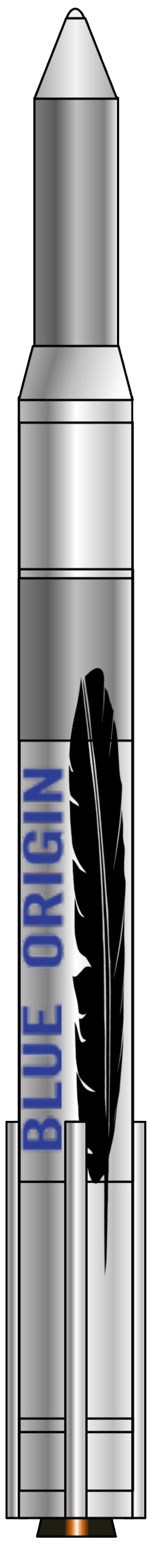
Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

Blue Origin Vehicle



In the summer of 2015, Blue Origin publicly announced its plan to develop an orbital launch vehicle. Details regarding the vehicle's design remain close-hold, but a some information is known.

The launch vehicle, which has yet to be named, will launch from SLC-36 located at Cape Canaveral Air Force Station (CCAFS), Florida. The reusable first stage will be powered by the company's BE-4 engine, the same engine being developed for the first stage of the Vulcan, which will be provided by United Launch Alliance (ULA) beginning in 2019. This stage also appears to feature four extendable landing struts. The expendable second stage will be powered by the BE-3, a smaller engine that will also be used to power Blue Origin's reusable *New Shepard* crewed suborbital vehicle.

The BE-4, which will be flight ready by 2017, is fed a LOX-liquified natural gas (LNG) mix. The LNG, essentially methane, is considered by Blue Origin and ULA to be a an affordable and efficient propellant on par with rocket grade kerosene (RP-1). The key difference is that LNG is a cleaner burning fuel, ideal for a reueable engine.

SLC-36 was once used by NASA to launch Mariner, Surveyor, and Pioneer probes during the 1960s and 1970s, as well as national security payloads for the Department of Defense (DoD). The last mission from this pad took place in 2005 with the launch of an Atlas III. Blue Origin is leasing the pad from Space Florida and is currently developing the facility in preparation for an inaugural launch around 2020.

Launch service provider
Blue Origin

Organization Headquarters
USA

Manufacturer
Blue Origin

Mass, kg (lb)
Undisclosed

Length, m (ft)
46.9 (154) *est*

Diameter, m (ft)
3 (10) *est*

Year of Planned First Launch
2020

Launch site
CCAFS (SLC-36)

GTO capacity, kg (lb)
Undisclosed

LEO capacity, kg (lb)
Undisclosed

Estimated Price per Launch
Undisclosed

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

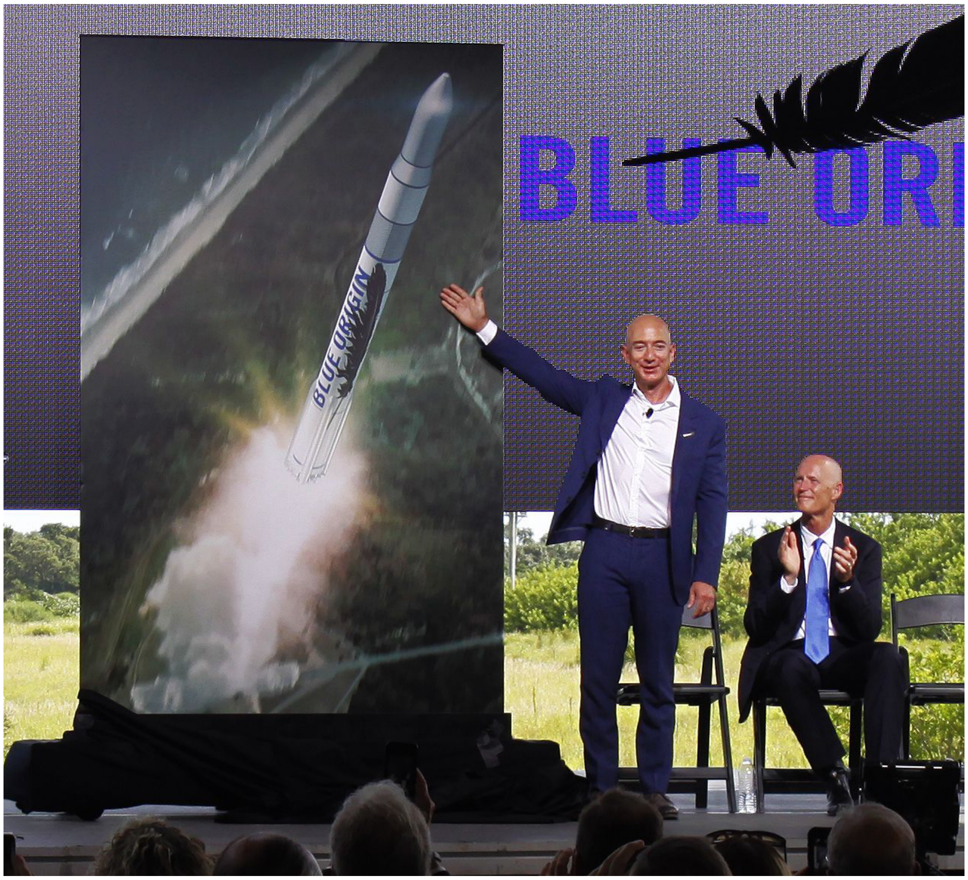
Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

Blue Origin Vehicle

FAA AST



Blue Origin CEO Jeff Bezos reveals the company's new orbital launch vehicle at Cape Canaveral Air Force Station (CCAFS), Florida, in 2015. Source: Blue Origin

Fairing	Length, m (ft)	Diameter, m (ft)
Standard Fairing	3 (10) *est*	2.4 (8) *est*

	1st Stage	2nd Stage
Stage designation	1st Stage	2nd Stage
Length, m (ft)	36.6 (120) *est*	7.3 (24) *est*
Diameter, m (ft)	3 (10) *est*	2.4 (8) *est*
Manufacturer	Blue Origin	Blue Origin
Propellant	LOX/CH_4	LOX/H_2
Propellant mass, kg (lb)	Undisclosed	Undisclosed
Total thrust, kN (lbf)	Undisclosed	Undisclosed
Engine(s)	1 x BE-4	1 x BE-3
Engine manufacturer	Blue Origin	Blue Origin
Engine thrust, kN (lbf)	2,447 (550,000)	489 (110,000)

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

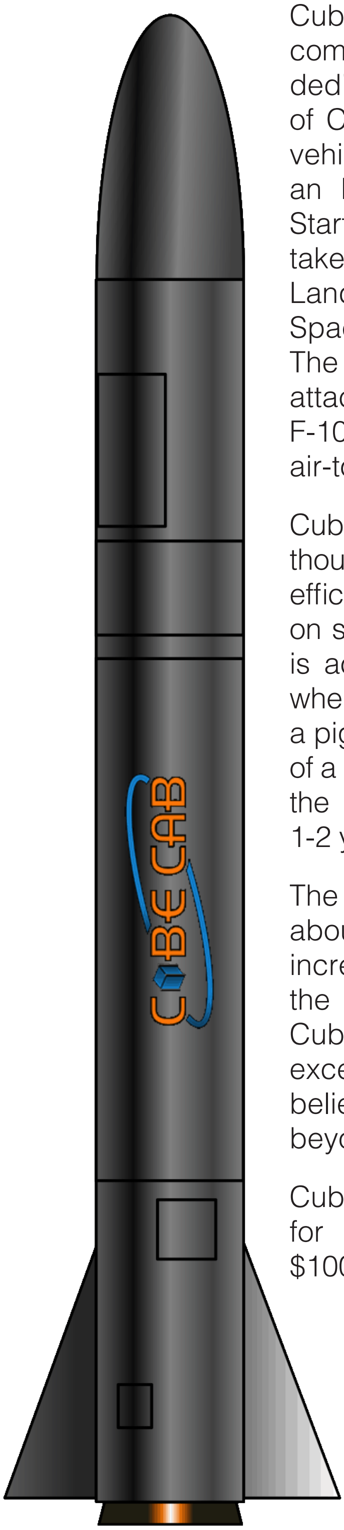
Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

Cab-3A



CubeCab is a U.S.-based company seeking to provide dedicated launches for operators of CubeSats. The relatively small vehicle will be launched from an F-104 Starfighter offered by Starfighters Aerospace that will take off from NASA's Shuttle Landing Facility at Kennedy Space Center (KSC) in Florida. The CubeCab vehicle will be attached below the wing of the F-104 in a similar manner to an air-to-air missile.

CubeCab believes that the even though it is technically less efficient to launch small payloads on small launch vehicles, the cost is actually less than experienced when arranging for a rideshare as a piggyback payload. An example of a cost-saving benefit is trimming the launch scheduling time from 1-2 years to just a few months.

The company expects to launch about 100 times per year, further increasing efficiencies. Though the number of 1U and 3U CubeSats launched per year first exceeded 100 in 2014, CubeCab believes this market will grow beyond that number per year.

CubeCab is targeting $250,000 for a 3U CubeSat launch, or $100,000 for a 1U CubeSat.

Launch service provider
CubeCab

Organization Headquarters
USA

Manufacturer
CubeCab

Mass, kg (lb)
13,000 (28,660) *est*

Length, m (ft)
16.8 (55)

Wingspan, m (ft)
6.6 (21.8)

Year of Planned First Launch
2017

Launch site
KSC (Runway)

GTO capacity, kg (lb)
N/A

LEO capacity, kg (lb)
5 (11)

Estimated Price per Launch
$250,000

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

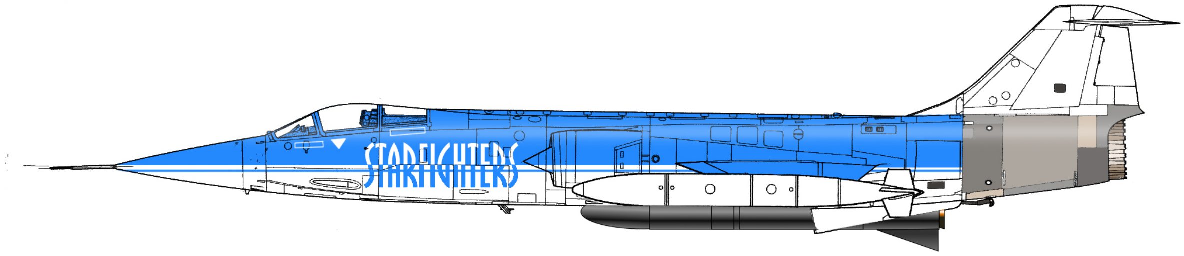
Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

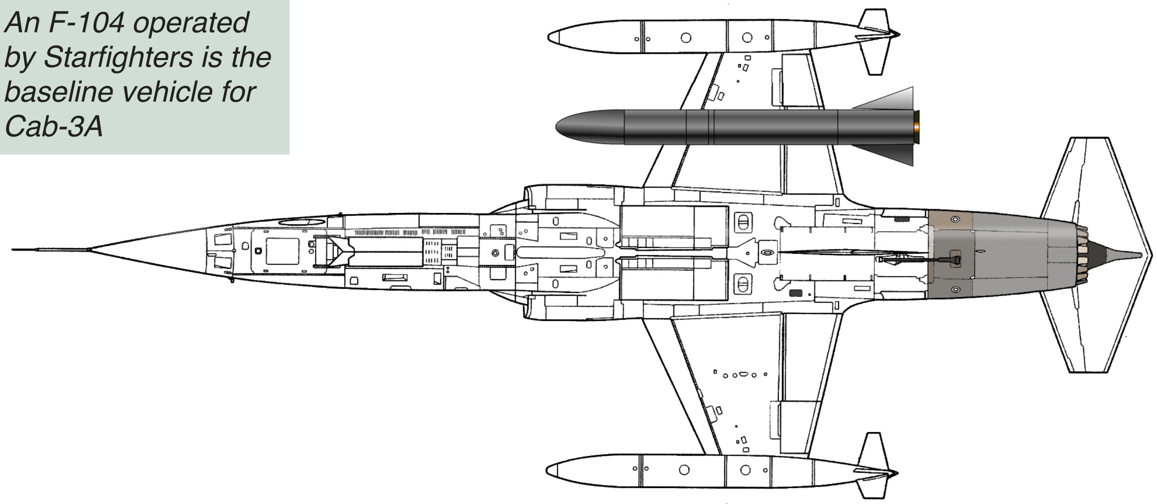
Launch Vehicle Fact Sheet

Cab-3A

FAA AST



An F-104 operated by Starfighters is the baseline vehicle for Cab-3A



Fairing	Length, m (ft)	Diameter, m (ft)
Standard Fairing	0.5 (1.7) *est*	0.5 (1.7) est

	1st Stage	2nd Stage
Stage designation	F-104	CubeCab
Length, m (ft)	16.8 (55)	5.3 (17.4) *est*
Diameter/Wingspan, m (ft)	6.6 (21.8)	0.5 (1.7) *est*
Manufacturer	Lockheed	CubeCab
Propellant	Kerosene (JP-4)	Undisclosed
Propellant mass, kg (lb)	8,727 (19,240)	Undisclosed
Total thrust, kN (lbf)	79.3 (17,835)	Undisclosed
Engine(s)	1 x J79-GE-11A	Undisclosed
Engine manufacturer	General Electric	CubeCab
Engine thrust, kN (lbf)	79.3 (17,835)	Undisclosed

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

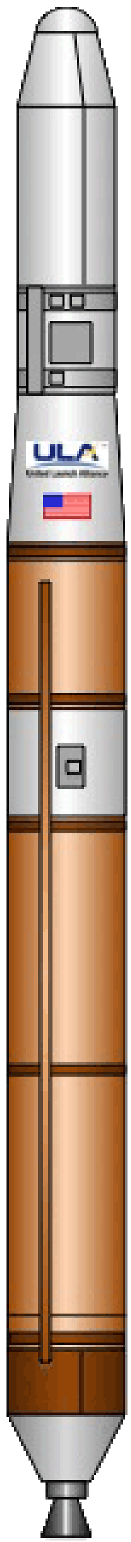
Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

Delta IV



The Delta IV family is a product of the U.S. Air Force's Evolved Expendable Launch Vehicle Program (EELV), begun in 1995. Boeing originally developed the Delta IV, but manufacturing and operations are now conducted by United Launch Alliance (ULA), a joint company between Lockheed Martin and Boeing. ULA markets the vehicle to the U.S. Government, though Boeing can make the Delta IV available to commercial customers worldwide.

The Delta IV is composed of a Common Booster Core (CBC) powered by an Aerojet Rocketdyne RS-68A main engine, one of two different types of cryogenic upper stages (varying in propellant tank volume and diameter) powered by a single Aerojet Rocketdyne RL10B-2 engine, a payload adapter, and a choice between three fairings. The vehicle may also feature between two and four Orbital ATK GEM-60 motors. The Delta IV is available in five variants.

The Delta IV family debuted in 2002 with the successful launch of a Delta IV Medium+ (4,2) from Cape Canaveral Air Force Station (CCAFS).

With the exception of the Delta IV Heavy, the Delta IV has been slated for retirement in 2018 as ULA prepares to introduce the Vulcan launch vehicle family in 2019. The Delta IV Heavy will continue to fly until the Vulcan's Centaur upper stage is replaced with the Advanced Cryogenic Evolved Stage (ACES), boosting the Vulcan's payload capacity dramatically, effectively making the Delta IV Heavy obsolete. The Delta IV Heavy is expected to be retired by 2023.

Launch service provider
ULA

Organization Headquarters
USA

Manufacturer
ULA

Mass, kg (lb)
D-IVM: 249,500 (549,559)
D-IVH: 733,000 (1,615,416))

Length, m (ft)
62.8-71.6 (206-234.9)

Diameter, m (ft)
5 (16.4)

Year of First Launch
2002

Number of Launches
30

Reliability*
100%

Launch sites
CCAFS (SLC-40)
VAFB (SLC-3E)

GTO capacity, kg (lb)
3,060-14,220 (6,746-31,350)

LEO capacity, kg (lb)
9,420-28,790 (20,768-63,471)

SSO capacity, kg (lb)
7,690-23,560 (16,954-51,941)

Estimated Price per Launch
$164M-$400M

** The December 21, 2004 partial launch success of a Delta IV Heavy is counted as a success in this reliability calculation*

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

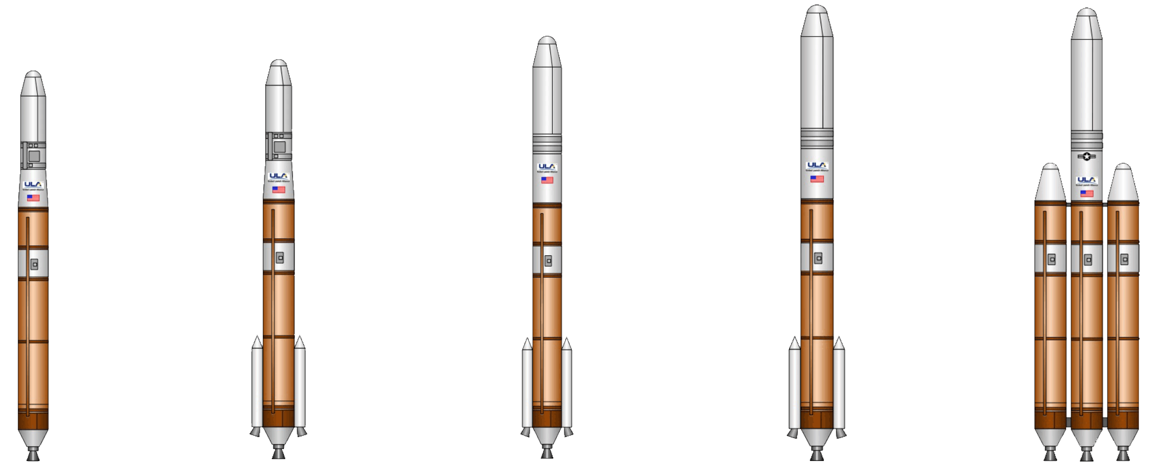
Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet
Delta IV

FAA AST

The Delta IV family consists of five variants. The Delta IV Medium features a CBC and a 4-meter fairing, but no solid motors. Three versions of the Delta IV Medium+ are available, using either a 4-meter or 5-meter fairing, and a combination of solid motors. Finally, the Delta IV Heavy is composed of three CBCs and a 5-meter fairing.



Fairing	Length, m (ft)	Diameter, m (ft)
11.7-Meter Fairing	11.7 (38.5)	4 (13)
14.3-Meter Fairing	14.3 (47)	5 (16.4)
19.1-Meter Fairing	19.1 (62.7)	5 (16.4)
Metallic Fairing	19.8 (65)	5 (16.4)

	1st Stage*	SRB**	2nd Stage Option	2nd Stage Option
Stage designation	Common Booster Core	GEM-60	4-Meter Cryogenic Upper Stage	5-Meter Cryogenic Upper Stage
Length, m (ft)	46.7 (153.2)	15. 8 (52)	10.4 (34)	12.2 (40)
Diameter, m (ft)	5 (16.4)	1.6 (5.3)	4 (13.1)	5 (16.4)
Manufacturer	ULA	Orbital ATK	ULA	ULA
Propellant	LOX/LH_2	Solid	LOX/LH_2	LOX/LH_2
Propellant mass, kg (lb)	199,640 (439,735)	59,520 (130,944)	20,410 (45,000)	27,200 (60,000)
Total thrust, kN (lbf)	2,891 (650,000)	1,245.5 (280,000)	110 (24,750)	110 (24,750)
Engine(s)	1 x RS-68A	--	1 x RL10B-2	1 x RL10B-2
Engine manufacturer	Aerojet Rocketdyne	--	Aerojet Rocketdyne	Aerojet Rocketdyne
Engine thrust, kN (lbf)	2,891 (650,000)	1,245.5 (280,000)	110 (24,750)	110 (24,750)

** Delta IV Heavy uses 3 CBC units*

*** Figures are for each booster. Total thrust is sum of all boosters.*

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

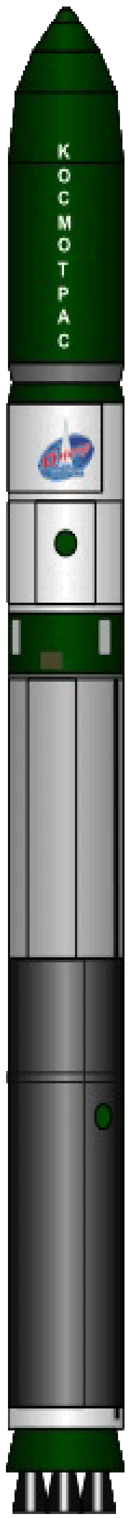
Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

Dnepr



The Dnepr, introduced in 1999, is developed from surplus Soviet R-36 (SS-18) intercontinental ballistic missiles (ICBM). About 150 missiles were made available for conversion into launch vehicles. The missiles, with components built during the Soviet era, are refurbished by PA Yuzhmash located in Ukraine. The three-stage, liquid fueled vehicle is designed to address medium-class payloads or clusters of small- and micro-class satellites. It is marketed by the Russian-based company ISC Kosmotras.

The Dnepr has launched 21 times, with one failure. The Dnepr is launched from Pad 109 and Pad 95 at the Baikonur Kosmodrome in Kazakhstan and the Dombarovsky missile base in Western Russia.

Due to increasing political tensions between Russia and Ukraine during 2014, and the resulting international sanctions against Russia, PA Yushmash, a key supplier of missiles and other hardware to the Russian military, has experienced considerable financial difficulties that may impact its product line. Despite this, ISC Kosmotras has reassured existing and potential customers that the Dnepr will be available.

Launch service provider
ISC Kosmotras

Organization Headquarters
Russia

Manufacturer
PA Yuzhmash

Mass, kg (lb)
201,000 (462,971)

Length, m (ft)
34.3 (112.5)

Diameter, m (ft)
3 (9.8)

Year of First Launch
1999

Number of Launches
22

Reliability
95%

Launch sites
Baikonur (LC-109, LC-95)
Dombarovsky (LC-13)

GTO capacity, kg (lb)
N/A

LEO capacity, kg (lb)
3,200 (7,055)

SSO capacity, kg (lb)
2,300 (5,071)

Estimated Price per Launch
$29M

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

Dnepr

Satellites integrated on the Dnepr vehicle prior to launch in June 2004 (Source: GAUSS)

Fairing	Length, m (ft)	Diameter, m (ft)
Sandard Fairing	5.3 (17.4)	3 (9.8)
Extended Fairing	6.1 (20)	3 (9.8)

	1st Stage	2nd Stage	3rd Stage
Stage designation	1st Stage	2nd Stage	3rd Stage
Length, m (ft)	22 (72.2)	6 (19.7)	1.5 (4.9)
Diameter, m (ft)	3 (9.8)	3 (9.8)	3 (9.8)
Manufacturer	PA Yuzhmash	PA Yuzhmash	PA Yuzhmash
Propellant	N_2O_4/UDMH	N_2O_4/UDMH	N_2O_4/UDMH
Propellant mass, kg (lb)	147,900 (326,064)	36,740 (80,998)	1,910 (4,211)
Total thrust, kN (lbf)	4,520 (1,016,136)	755 (169,731)	18.6 (4,181)
Engine(s)	4 x RD-264	1 x RD-0255	1 x RD-869
Engine manufacturer	OKB-456 (NPO Energomash)	OKB-154 (KB Khimavtomatika)	OKB-586 (Yuzhnoye)
Engine thrust, kN (lbf)	1,130 (254,034)	755 (169,731)	18.6 (4,181)

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet
Electron

Founded in New Zealand in 2007 by entrepreneur Peter Beck, Rocket Lab is now headquartered in the United States with a subsidiary in New Zealand.

Rocket Lab aims to provide its Electron vehicle to tap the microsatellite market, offering rapid scheduling and dedicated launch services to operators that have historically been dependent on piggyback rides with primary payloads. These piggyback rides mean the microsatellite operator does not have much say in scheduling or orbital trajectory.

The two-stage Electron features a simple construction using low-mass composite materials capable of handling cryogeni liquids like liquid oxygen (LOX). In addition, the company's Rutherford engine is designed to be produced quickly, as ten total engines are used for each Electron and Rocket Labs plans to launch the vehicle frequently. To enable this, and to keep costs down, all primary components of the Rutherford are produced using additive manufacturing, commonly refered to as 3D printing.

The Electron will be marketed primarilly for customers whose satellites are pound for Sun-synchronous orbits (SSO).

In 2015, Rocket Lab was awarded a NASA Venture Class Launch Services contract. The $6.95M ontract is for the launch of a NASA payload to low-Earth orbit (LEO) between 2016 and 2017. Moon Express announced in 2015 that it will purchase three Rocket Lab launches for its lunar lander spacecraft as part of the former's bid to win the Google Lunar X Prize competition. Rocket Lab has indicated it has other customers in the queue, but has not released their names publicly. Also in 2015, Rocket Lab announced it selected Alaska Aerospace Corporation to provide range safety support for their upcoming Electron launches in 2016 from the Pacific Spaceport Complex – Alaska (PSCA).

Launch service provider
Rocket Lab

Organization Headquarters
USA

Manufacturer
Rocket Lab

Mass, kg (lb)
10,500 (23,149)

Length, m (ft)
16 (52.5)

Diameter, m (ft)
1.2 (3.9)

Year of Planned First Launch
2016

Launch sites
PSCA
Kaitorete (New Zealand)

GTO capacity, kg (lb)
N/A

SSO capacity, kg (lb)
150 (331)

Estimated Price per Launch
$4.9M

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

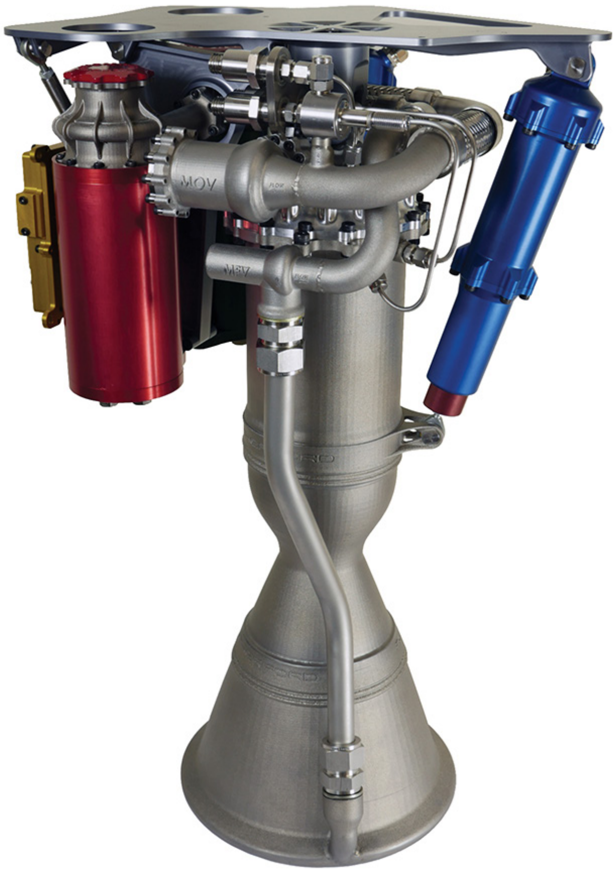
Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

Electron

FAA AST



Rocket Lab's Rutherford engine. All its primary components are produced using additive manufacturing, or 3D printing. Source: Rocket Lab

Rocket Lab's launch price for a 1U CubeSat is $50,000. For a 3U, it is $180,000.

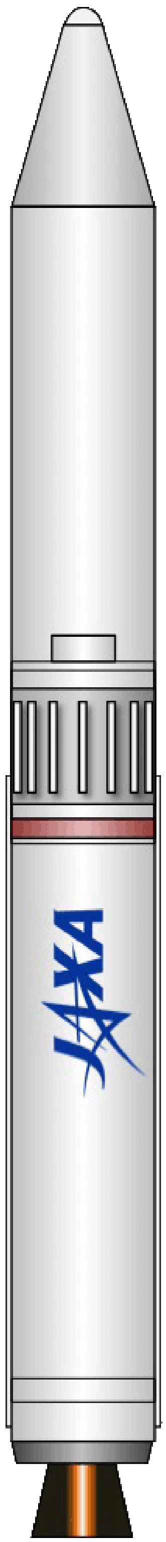
Fairing	Length, m (ft)	Diameter, m (ft)
Standard Fairing	2 (6.6) *est*	1.2 (3.9)

	1st Stage	2nd Stage
Stage designation	1st Stage	2nd Stage
Length, m (ft)	12.8 (42) *est*	1.6 (5.2) *est*
Diameter, m (ft)	1.2 (3.9)	1.2 (3.9)
Manufacturer	Rocket Lab	Rocket Lab
Propellant	LOX/kerosene	LOX/kerosene
Propellant mass, kg (lb)	6,900 (15,212) *est*	2,300 (5,071) *est*
Total thrust, kN (lbf)	183 (41,500)	22 (5,000)
Engine(s)	9 x Rutherford	1 x Rutherford Vacuum
Engine manufacturer	Rocket Lab	Rocket Lab
Engine thrust, kN (lbf)	22 (5,000)	22 (5,000)

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

Epsilon



The Epsilon is a vehicle under development by the Japan Aerospace Exploration Agency (JAXA), derived from the Nissan-built M-V discontinued in 2006. The vehicle will be used to send small payloads to low Earth orbits and polar orbits. The first launch of Epsilon took place during 2013, successfully placing a small payload into low Earth orbit (LEO).

The Epsilon comes in both a Standard Configuration and an Optional Configuration. The first stage of the Standard Configuration Epsilon is a solid motor similar to those on the H-IIA. An M-34c solid motor constitutes the second stage, and a KM-2Vb represents the third stage. A payload adapter and fairing complete the system. The Optional Configuration features an additional compact Post Boost Stage integrated with the third stage for Sun-synchronous orbits (SSO).

The vehicle is launched from Uchinoura Space Center, formerly called Kagoshima Space Center.

Launch service provider
JAXA

Organization Headquarters
Japan

Manufacturer
IHI

Mass, kg (lb)
90,800 (200,180)

Length, m (ft)
24.4 (80.1)

Diameter, m (ft)
2.5 (8.2)

Year of First Launch
2013

Number of Launches
1

Reliability
100%

Launch site
Uchinoura Space Center

GTO capacity, kg (lb)
N/A

LEO capacity, kg (lb)
700 -1,200 (1,543-2,646)

SSO capacity, kg (lb)
450 (992)

Estimated Price per Launch
$39M

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet
Epsilon

The Epsilon launch vehicle at the launch site just prior to its inaugural mission in 2013 (Source: JAXA)

Fairing	Length, m (ft)	Diameter, m (ft)
Standard Fairing	10 (32.8)	2.5 (8.2)

	1st Stage	2nd Stage	3rd Stage	4th Stage
Stage designation	SRB-A3	M-34c	KM-V2b	Post Boost Stage
Length, m (ft)	15 (49.2)	5 (16.4)	3 (9.8)	0.5 (1.6)
Diameter, m (ft)	2.5 (8.2)	2.5 (8.2)	2.5 (8.2)	2 (6.6)
Manufacturer	Nissan	Nissan	Nissan	Nissan
Propellant	Solid	Solid	Solid	Hydrazine
Propellant mass, kg (lb)	66,000 (145,505)	10,800 (23,800)	2,500 (5,512)	100 (220)
Total thrust, kN (lbf)	1,580 (355,198)	377.2 (84,798)	81.3 (18,277)	< 1 (225)
Engine(s)	--	--	--	3 units
Engine manufacturer	--	--	--	Nissan
Engine thrust, kN (lbf)	1,580 (355,198)	377.2 (84,798)	81.3 (18,277)	<0.33 (74)

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

Falcon 9

Space Exploration Technologies (SpaceX), founded in 2002, first launched its Falcon 9 in 2010 from Cape Canaveral Air Force Station (CCAFS). The vehicle is designed to launch government and commercial payloads to any orbit. It is also used to transport the Dragon cargo module to the International Space Station (ISS), and in 2017 will begin transporting crewed versions of the Dragon. SpaceX will also provide Falcon 9 launches under the Air Force's Orbital/Suborbital Program-3 (OSP-3).

The vehicle consists of a first stage powered by nine SpaceX Merlin-1D engines, a second stage powered by a single Merlin-1D Vacuum engine, a payload adapter, and a large payload fairing. Launches of the company's Dragon capsule do not require a fairing.

The first version of the Falcon 9 (v1.0) launched successfully five times since its introduction in 2010. The current upgraded version of the Falcon 9 (v1.1) was introduced in September 2013. Falcon 9 v1.1 features a longer first stage, new higher thrust engines (the Merlin-1D instead of the Merlin-1C), and an octagonal arrangement of engines on the first stage (instead of a "tic-tac-toe" pattern) to relieve loads on the vehicle during launch. The figures in this fact sheet reflect the upgraded Falcon 9. SpaceX introduced the Falcon 9 (Full Thrust) in 2015, featuring 20 percent greater capacity than the Falcon 9 v1.1. Falcon 9 FT will ultimately replace the earlier version.

The Falcon 9 v1.1 flew six times in 2015, with one failure in June. SpaceX resumed launch activity in December 2015, with introduction of the Falcon 9 FT. This vehicle performed well, successfully deploying 11 ORBCOMM satellites to low Earth orbit (LEO). In addition, the vehicle's first stage landed vertically 10 minutes following launch as planned, marking the first time in history such an event took place for a vehicle capable of orbital flight.

Launch service provider
SpaceX

Organization Headquarters
USA

Manufacturer
SpaceX

Mass, kg (lb)
541,300 (1,194,000)

Length, m (ft)
70 (239)

Diameter, m (ft)
3.7 (12)

Year of First Launch
2010 (Falcon 9 family)

Number of Launches
20 (Falcon 9 family)

Reliability
95%

Launch sites
CCAFS (SLC-40)
VAFB (SLC-3E)

GTO capacity, kg (lb)
4,850 (10,692)

LEO capacity, kg (lb)
13,150 (28,991)

Estimated Price per Launch
$61.2M

Unless otherwise noted, this fact sheet reflects data for the Falcon 9 FT, which debuted in December 2015.

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

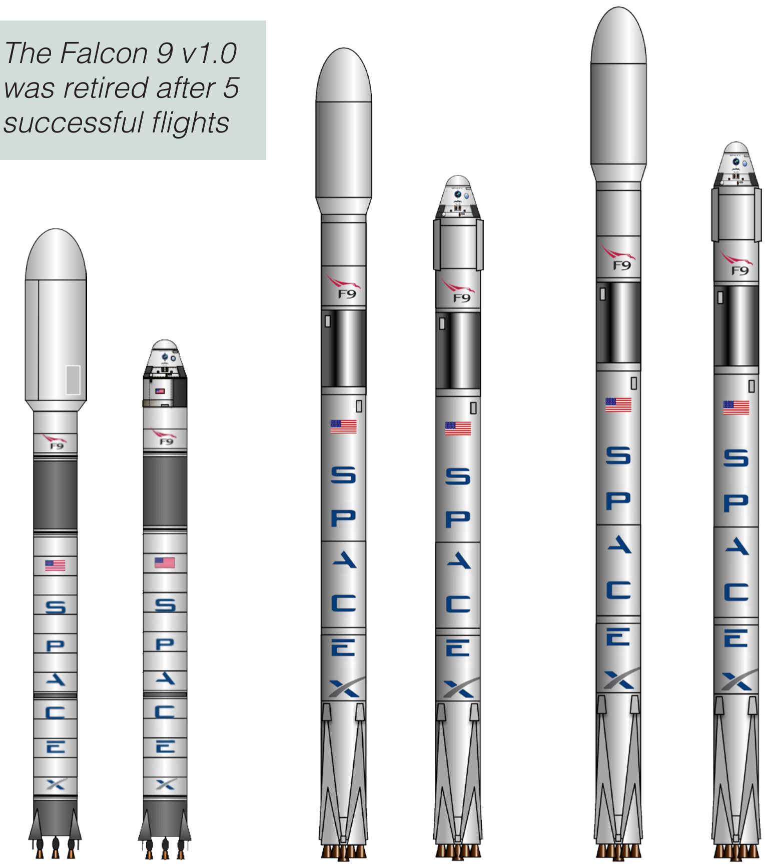
FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

Falcon 9

FAA AST

The Falcon 9 v1.0 was retired after 5 successful flights



Falcon 9 v1.0
Retired (2010-2013)

Falcon 9 v1.1
Active (2013-2016)

Falcon 9 FT
Active (2015-)

The Grasshopper, and later the Falcon 9R Dev 1, were used to test first stage reusability. SpaceX is building another test vehicle, the Falcon 9R Dev 2

Fairing	Length, m (ft)	Diameter, m (ft)
Standard Fairing	13.2 (43.3)	5.2 (17.1)

	1st Stage	2nd Stage
Stage designation	1st Stage	2nd Stage
Length, m (ft)	42.6 (139.8)	12.6 (41.3)
Diameter, m (ft)	3.7 (12)	3.7 (12)
Manufacturer	SpaceX	SpaceX
Propellant	LOX/Kerosene	LOX/Kerosene
Propellant mass, kg (lb)	411,000 (906,010)	73,400 (161,819)
Total thrust, kN (lbf)	5,885 (1,323,000)	801 (180,000)
Engine(s)	9 x Merlin-1D	1 x Merlin-1D
Engine manufacturer	SpaceX	SpaceX
Engine thrust, kN (lbf)	653.8 (147,000)	801 (180,000)

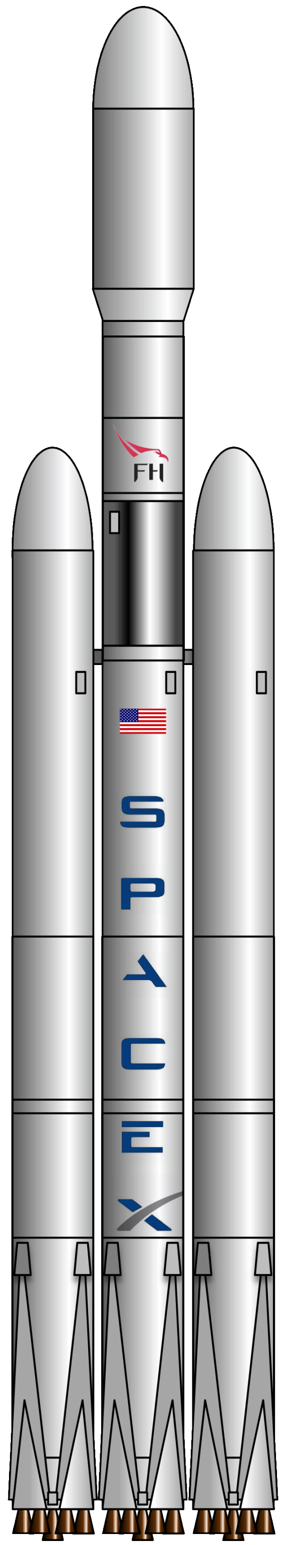
Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet
Falcon Heavy



Space Exploration Technologies (SpaceX), founded in 2002, is developing the Falcon Heavy. This vehicle leverages the same components used to manufacture the Falcon 9.

The first stage of the Falcon Heavy essentially consists of three Falcon 9 first stages linked together with propellant crossfeed lines that allow the center center core to tap propellant from the side boosters. The core and boosters are each powered by nine Merlin-1D engines. Each booster is designed to be reused, and requires three separate landing pads. The second stage is similar to the one used for the Falcon 9.

The lift capacity of the Falcon Heavy is 53,000 kg (116,845 lb) to low Earth orbit (LEO), making it the most powerful U.S.-built launch vehicle since the Saturn V.

The first launch of the Falcon Heavy is scheduled to take place in 2016 from Kennedy Space Center's (KSC) LC-39A. The mission will be a test demonstration. Customers who have signed contracts for a Falcon Heavy flight include the Department of Defense, Arabsat, Intelsat, Inmarsat, and ViaSat.

SpaceX lists $90M for a launch of a payload at or below 6,400 kg (14,110 lb) to geosynchronous transfer orbit (GTO). With a GTO capacity of 21,200 kg, this means the vehicle will be able to send up to three payloads to this orbit.

Launch service provider
SpaceX

Organization Headquarters
USA

Manufacturer
SpaceX

Mass, kg (lb)
1,394,000 (3,075,000)

Length, m (ft)
70 (229.6)

Width, m (ft)
12.2 (39.9)

Year of Planned First Launch
2016

Launch sites
KSC (LC-39A)
VAFB (SLC-4E)

GTO capacity, kg (lb)
21,200 (46,738)

LEO capacity, kg (lb)
53,000 (116,845)

Estimated Price per Launch
$270M

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet
Falcon Heavy

FAA AST

An artist's rendering of the Falcon Heavy at KSC's LC-39A. Source: SpaceX

Fairing	Length, m (ft)	Diameter, m (ft)
Standard Fairing	13.2 (43.3)	5.2 (17.1)

	Liquid Boosters*	1st Stage	2nd Stage
Stage designation	Boosters	1st Stage	2nd Stage
Length, m (ft)	42.6 (139.8)	42.6 (139.8)	12.6 (41.3)
Diameter, m (ft)	3.7 (12)	3.7 (12)	3.7 (12)
Manufacturer	SpaceX	SpaceX	SpaceX
Propellant	LOX/Kerosene	LOX/Kerosene	LOX/Kerosene
Propellant mass, kg (lb)	411,000 (906,010)	411,000 (906,010)	73,400 (161,819)
Total thrust, kN (lbf)	5,885 (1,323,000)	5,885 (1,323,000)	801 (180,000)
Engine(s)	9 x Merlin-1D	9 x Merlin-1D	1 x Merlin-1D
Engine manufacturer	SpaceX	SpaceX	SpaceX
Engine thrust, kN (lbf)	653.8 (147,000)	653.8 (147,000)	801 (180,000)

** Figures are for each booster. Total thrust is sum of all boosters.*

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

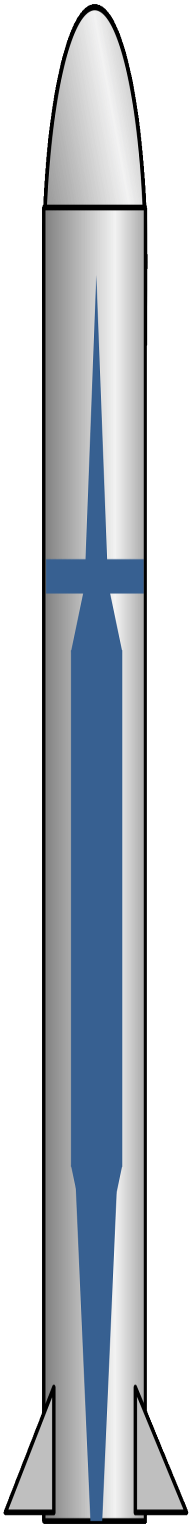
Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

GOLauncher-2



U.S.-based Generation Orbit Launch Services was founded in 2011 to provide dedicated orbital launch services to microsatellite operators. The company, which is a subsidiary of Atlanta-based SpaceWorks Engineering, forecasts significant grwoth in microsatellites per year. Generation Orbit aims to tap this rapidly growing market by offering low-cost, rapid launch cycles.

The GOLauncher system features an air-launched approach. The first stage consists of a Gulfstream III aircraft capable of launching the suborbital GOLauncher-1 or the orbital GOLauncher-2 from a fuselage mount.

The two-stage GOLauncher-2 is designed to send 45 kg (100 lb) to low Earth orbit (LEO). The vehicle can accommodate three payload configurations: A single microsatellite of up to 45 kg, a cluster of nanosatellites, or a dedicated CubeSat mission. Because the vehicle is air-launched, a wide range of orbital options exist, with inclinations of 0° to 90°.

In 2015, Generation Orbit was awarded a Phase II Small Business Innovative Research (SBIR) contract from the Air Force Research Laboratory (AFRL) for continued development of GOLauncher-1. Though this work focuses on the suborbital launch vehicle, it is expected lessons learned will be applied to the company's orbital capability.

As of the end of 2015, few details regarding the technical specifications of the GOLauncher-2 are publicly available.

Launch service provider
Generation orbit

Organization Headquarters
USA

Manufacturer
Generation orbit

Mass, kg (lb)
Undisclosed

Length, m (ft)
25.3 (83)

Wingspan, m (ft)
23.7 (77.8)

Year of Planned First Launch
2017

Launch site
Cecil Field Spaceport

GTO capacity, kg (lb)
N/A

LEO capacity, kg (lb)
45.4 (100)

Estimated Price per Launch
$2.5M

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

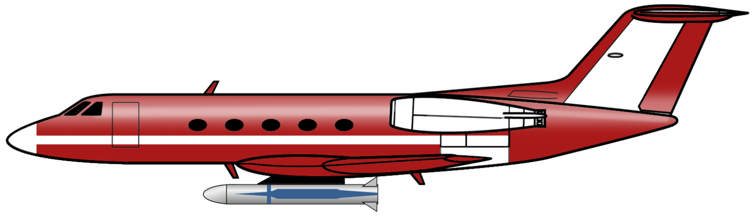
Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

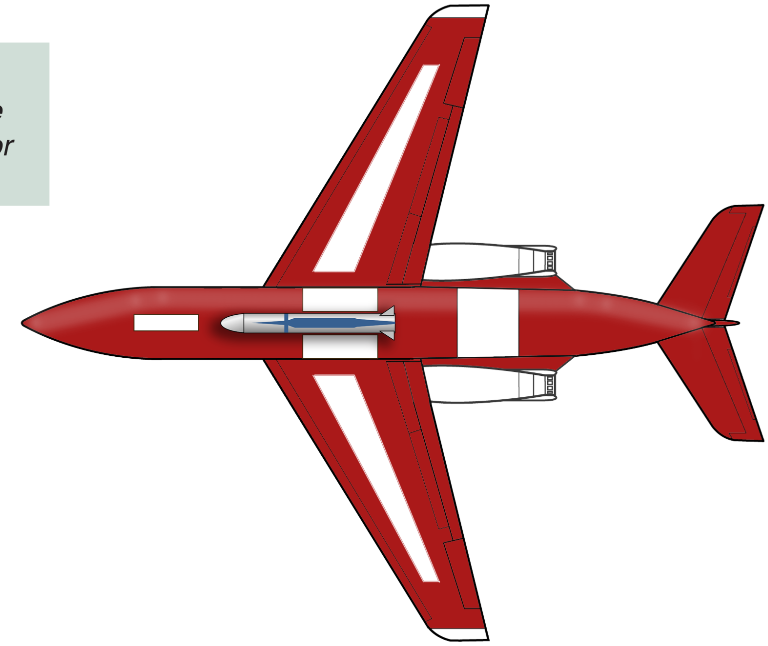
Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

FAA AST

Launch Vehicle Fact Sheet
GOLauncher-2





A Gulfstream III business jet is the baseline carrier for GOLauncher-2

Fairing	Length, m (ft)	Diameter, m (ft)
Standard Fairing	1.1 (3.7) *est*	0.8 (2.7) *est*

	1st Stage	2nd Stage	3rd Stage
Stage designation	Gulfstream III	1st Stage	2nd Stage
Length, m (ft)	25.3 (83)	5.9 (19.5) *est*	1 (3.3) *est*
Diameter/Wingspan, m (ft)	23.7 (77.8)	0.8 (2.7) *est*	0.8 (2.7) *est*
Manufacturer	Gulfstream Aerospace	Generation Orbit	Generation Orbit
Propellant	Kerosene (Jet-A1)	Solid	LOX/kerosene
Propellant mass, kg (lb)	14,379 (31,700)	Undisclosed	Undisclosed
Total thrust, kN (lbf)	101.4 (22,800)	Undisclosed	Undisclosed
Engine(s)	2 x Spey RB.163 Mk 511-8	Undisclosed	Undisclosed
Engine manufacturer	Rolls-Royce	Generation Orbit	Ventions
Engine thrust, kN (lbf)	50.7 (11,400)	Undisclosed	Undisclosed

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

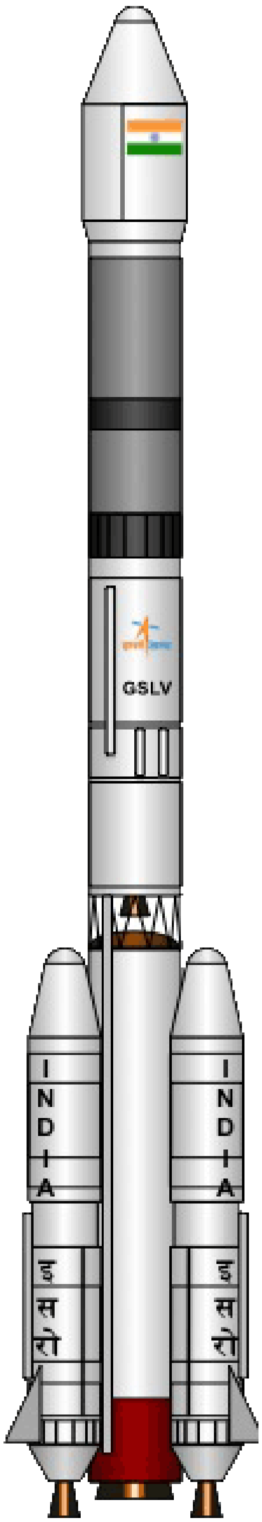
Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

GSLV



The Geosynchronous Satellite Launch Vehicle (GSLV) project began in 1990 with the objective of achieving an indigenous satellite launch capability to geosynchronous orbit (GEO). The vehicle was developed by the Indian Space Research organization (ISRO).

GSLV uses major components that are already proven in the PSLV vehicles in the form of the S125/S139 solid booster and the liquid-fueled Vikas engine. Engines are developed at ISRO's Liquid Propulsion Systems Centre (LPSC).

The current variant, GSLV Mk.II was introduced in 2010 and uses an indigenous cryogenic engine, the CE-7.5 in the third stage instead of the Russian cryogenic engine used by the vehicle's older version, GSLV Mk I. The 49.1 meter (161 ft) tall GSLV, with a lift-off mass of 414.8 metric tons, is a three-stage vehicle that employs solid, liquid and cryogenic propulsion technologies. The payload fairing is 7.8 meter (26 ft) long and 3.4 meters (11.2 ft) in diameter. The GSLV can place approximately 5,000 kg (11,023 lb) into low earth orbit (LEO). GSLV can place 2,500 kg (5,516 lb) into geosynchronous transfer orbit (GTO).

After experiencing four failures and one partially successful mission, the vehicle is not considered reliable. ISRO is working to replace the GSLV with the LVM3, which was successfully launched on a suborbital test mission in early 2015. India's objective is to develop a fully indigenous launch capability, no longer relying on Arianespace for missions to GTO.

Launch service provider
ISRO/Antrix

Organization Headquarters
India

Manufacturer
ISRO

Mass, kg (lb)
414,750 (914,637)

Length, m (ft)
49.13 (161.2)

Wingspan, m (ft)
2.8 (9.2)

Year of First Launch
2001

Number of Launches
9

Reliability
56%

Launch sites
Satish Dhawan (FLP, SLP)

GTO capacity, kg (lb)
2,500 (5,516)

LEO capacity, kg (lb)
5,000 (11,023)

Estimated Price per Launch
$27M

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

GSLV

GSLV
Mk I

GSLV
Mk II

The GSLV Mk I has flown six times, while the GSLV Mk II hjas flown three times. There were three variants of the GSLV Mk I, each distinguished by differences in propellant capacity and quality across stages and solid boosters. Only one variant, the GSLV Mk I(c) remains in service. The GSLV Mk II differs from the Mk I primarily because of the third stage, which is built by ISRO. Upper stages used for the Mk I were built in Russia.

Fairing	Length, m (ft)	Diameter, m (ft)
Standard Fairing	7.8 (26)	3.4 (11.2)

	Liquid Boosters*	1st Stage	2nd Stage	3rd Stage
Stage designation	Strap-on Motors	GS1	GS2	CUS
Length, m (ft)	19.7 (64.6)	20.3 (66.7)	11.6 (38)	8.7 (28.6)
Diameter, m (ft)	2.1 (6.8)	2.8 (9.1)	2.8 (9.1)	2.8 (9.1)
Manufacturer	ISRO	ISRO	ISRO	ISRO
Propellant	N_2O_4/UDMH	Solid	N_2O_4/UDMH	LOX/H_2
Propellant mass, kg (lb)	40,000 (88,200)	129,000 (284,400)	37,500 (82,600)	12,400 (27,300)
Total thrust, kN (lbf)	680 (152,870)	4,700 (1,056,602)	800 (179,847)	75 (16,861)
Engine(s)	L40H Vikas 2	S139	Vikas	CE-7.5
Engine manufacturer	ISRO/LPSC	ISRO/LPSC	ISRO/LPSC	ISRO/LPSC
Engine thrust, kN (lbf)	170 (38,218)	4,700 (1,056,602)	800 (179,847)	75 (16,861)

** Figures are for each booster. Total thrust is sum of all boosters.*

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

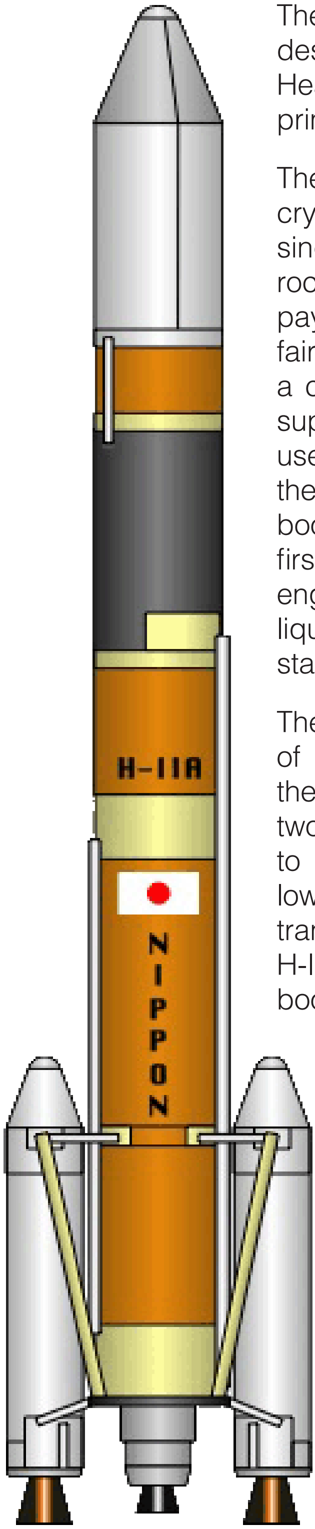
Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

H-IIA/B



The two-stage H-IIA and H-IIB, designed and built by Mitsubishi Heavy Industries (MHI), are Japan's primary launch vehicles.

The H-IIA vehicle features a cryogenic core stage powered by a single LE-7A engine, two large liquid rocket boosters, an upper stage, a payload adapter, and a payload fairing. The vehicle may also employ a combination of solid boosters to supplement thrust. The H-IIA 202 uses two solid rocket boosters, and the H-IIA 204 uses four solid rocket boosters. The H-IIB features a large first stage powered by two LE-7A engines and supplemented by four liquid rocket boosters and a second stage powered by an LE-5B engine.

There are currently two versions of the H-IIA and one version of the H-IIB available. The H-IIA (with two or four solid boosters) is used to launch a variety of satellites to low Earth orbit, geosynchronous transfer orbits, and beyond. The H-IIB (with four upgraded solid boosters) is currently used to launch the H-II Transfer Vehicle (HTV) to the International Space Station (ISS), and has recently been offered as an option for commercial satellite customers.

The H-II vehicle family can trace its lineage through the H-I, the N-1, and ultimately the U.S. Thor intermediate range ballistic missile.

In 2014, the Japan Aerospace Exploration Agency (JAXA) requested the MHI begin development of the H-III, a replacement for the H-IIA/B expected by 2020.

Launch service provider
MHI Launch Services

Organization Headquarters
Japan

Manufacturer
Mitsubishi Heavy Industries

Mass, kg (lb)
89,000-530,000
(637,136-1,168,450)

Length, m (ft)
53-57 (173.9-187)

Diameter, m (ft)
4 (13.1)

Year of First Launch
2001 (H-IIA), 2009 (H-IIB)

Number of Launches
29 (H-IIA), 5 (H-IIB)

Reliability
97% (H-IIA), 100% (H-IIB)

Launch sites
Tanegashima (LA-Y)

GTO capacity, kg (lb)
4,000-6,000 (8,818-13,228)

LEO capacity, kg (lb)
10,000-16,500 (22,046-36,376)

SSO capacity, kg (lb)
3,600-4,400 (7,937-9,700)

Estimated Price per Launch
$90M-$112.5M

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

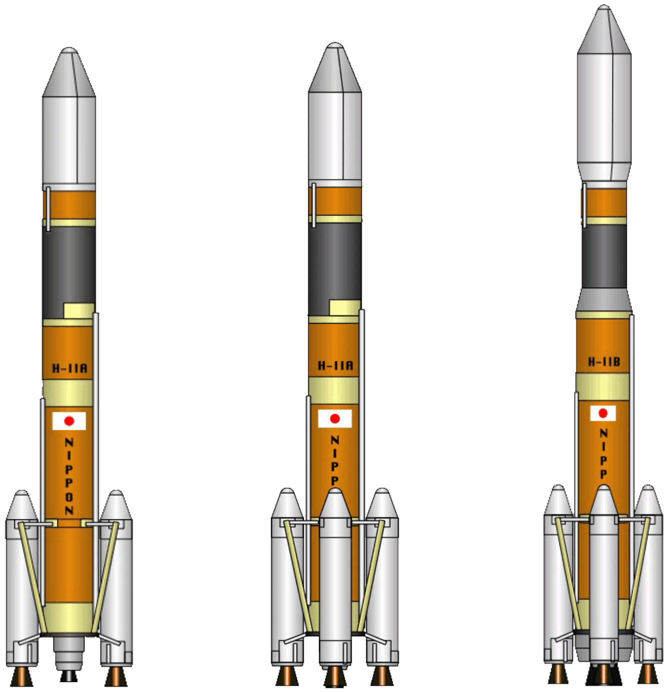
Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

H-IIA/B



H-IIA 202 | H-IIA 204 | H-IIB

The H-IIA is used for a variety of missions and represents the workhorse launch vehicle for Japan. The H-IIB has been used exlusively to send cargo to the ISS, but recently MHI Launch Services has made the vehicle avalabile for commercial use.

The first commercial mission using the H-IIA took place in 2015 with the launch of Telstar-12 Vantage.

Fairing	Length, m (ft)	Diameter, m (ft)
Standard Fairing	12 (39.4)	4.07 (13.4)

	Solid Boosters (H-IIA)*	Solid Boosters (H-IIB)*	1st Stage	2nd Stage
Stage designation	SRB-A	SRB-A3	1st Stage	2nd Stage
Length, m (ft)	15 (49.2)	15.1 (49.5)	37 (121.4)	11 (36.1)
Diameter, m (ft)	2.5 (8.2)	2.5 (8.2)	4 (13.1)	4 (13.1)
Manufacturer	Nissan	Nissan	Mitsubishi	Mitsubishi
Propellant	Solid	Solid	LOX/LH_2	LOX/LH_2
Propellant mass, kg (lb)	60,500 (133,380)	66,000 (145,505)	101,000 (222,667)	17,000 (37,479)
Total thrust, kN (lbf)	2,260 (508,068)	1,580 (355,198)	1,098 (246,840)	137 (30,799)
Engine(s)	--	--	LE-7A	LE-5B
Engine manufacturer	--	--	Mitsubishi	Mitsubishi
Engine thrust, kN (lbf)	2,260 (508,068)	1,580 (355,198)	1,098 (246,840)	137 (30,799)

** Figures are for each booster. Total thrust is sum of all boosters.*

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

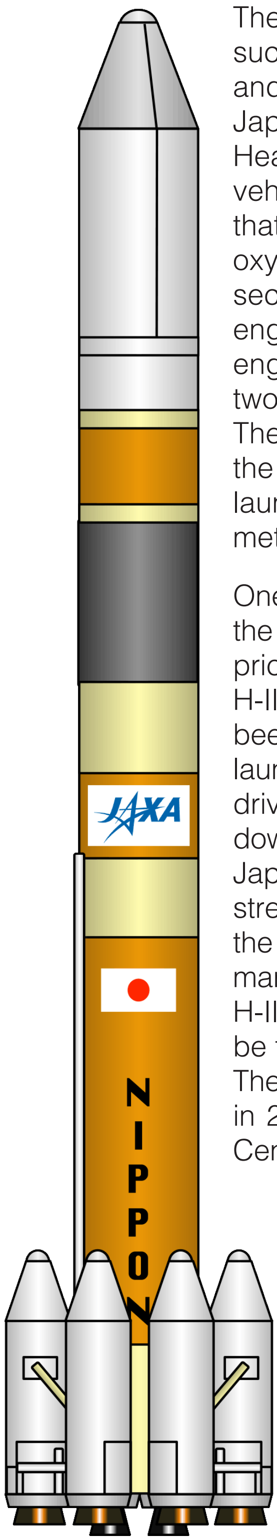
Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

H-III



The H-III launch vehicle is the successor to the H-IIA launch vehicle, and is currently in development by the Japanese government and Mitsubishi Heavy Industries. This 60-meter-tall vehicle will be powered by a core stage that includes a liquid hydrogen/liquid oxygen engine, named the LE-9. The second stage will use a single LE-5B engine. In addition to the core stage engine, the H-III will be powered by two, four, or six solid rocket boosters. There are three proposed variants to the H-III. Total capacity for the new launch vehicle is projected to be 6.5 metric tons of payload to GTO.

One of the key differentiators between the H-III and its predecessor is a lower price point. The typical cost of an H-IIA is $100 million, which has not been competitive in the commercial launch industry. Japan intends to drive launch costs for the new vehicle down to $50-70 million. Whereas the Japanese government would like to strengthen its competitive posture in the international commercial launch market through development of the H-III, the primary use of the vehicle will be to lift government payloads to orbit. The first launch is estimated to occur in 2020 from the Tanegashima Space Center in Japan.

Launch service provider
MHI Launch Services

Organization Headquarters
Japan

Manufacturer
Mitsubishi Heavy Industries

Mass, kg (lb)
Undisclosed

Length, m (ft)
63 (206.7)

Diameter, m (ft)
5.2 (17.1)

Year of Planned First Launch
2020

Launch site
Tanegashima (LA-Y)

GTO capacity, kg (lb)
6,500 (14,330)

LEO capacity, kg (lb)
10,000 (22,046)

SSO capacity, kg (lb)
4,00 (8,818)

Estimated Price per Launch
$65M

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

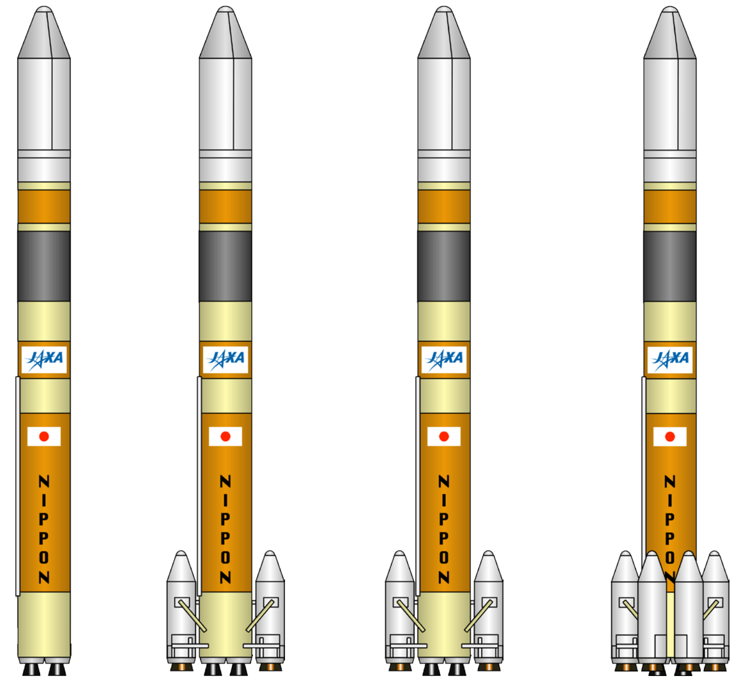
Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

H-III



H-III H-III2 H-III4 H-III6

Fairing	Length, m (ft)	Diameter, m (ft)
Standard Fairing	12 (39.4) *est*	4.07 (13.4) *est*

	Solid Boosters*	1st Stage	2nd Stage
Stage designation	SRB-A3 derivative	1st Stage	2nd Stage
Length, m (ft)	Undisclosed	Undisclosed	11 (36.1)
Diameter, m (ft)	Undisclosed	Undisclosed	4 (13.1)
Manufacturer	Nissan	Mistubishi	Mitsubishi
Propellant	Solid	LOX/LH_2	LOX/LH_2
Propellant mass, kg (lb)	Undisclosed	Undisclosed	17,000 (37,479)
Total thrust, kN (lbf)	Undisclosed	2,896 (652,000)	137 (30,799)
Engine(s)	--	2 x LE-9	LE-5B
Engine manufacturer	--	Mitsubishi	Mitsubishi
Engine thrust, kN (lbf)	Undisclosed	1,448 (326,000)	137 (30,799)

** Figures are for each booster. Total thrust is sum of all boosters.*

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

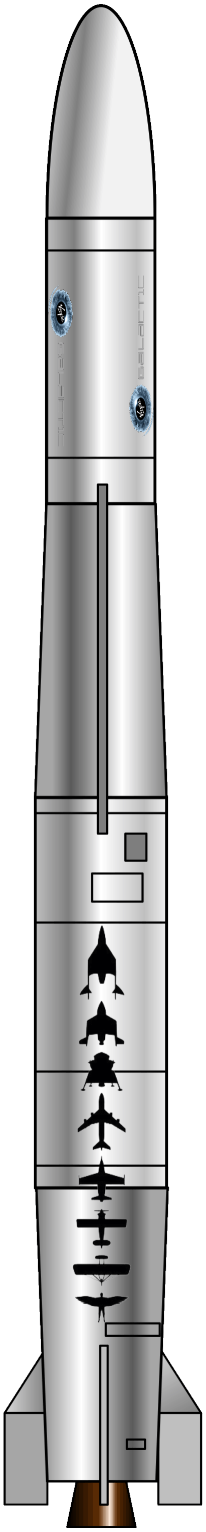
Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

LauncherOne



Virgin Galactic and The Spaceship Company are co-developing the air-launched, two-stage LauncherOne vehicle. The Spaceship Company is a joint venture between Virgin Galactic and Northrop Grumman-owned Scaled Composites.

LauncherOne is designed to address the growing demand for microsatellites by providing dedicated microsatellite services, including rapid scheduling and fast constellation replenishment. The Virgin Galactic is more widely known as the company poised to provide space tourism flights with its SpaceShipTwo vehicles, it will also be the launch service provider for LauncherOne.

Originally conceived as a vehicle capable of sending 225 kg to low Earth orbit (LEO), the company has since increased that capacity to 400 kg to address the diverse needs of the microsatellite market. This meant that the original carrier aircraft, the WhiteKnightTwo, was no longer able to lift LauncherOne. As a result, Virgin Galactic has secured a Boeing 747-400 aircraft, repurposed from its former role as a Virgin Atlantic airliner.

Virgin Galactic has been selected by Skybox Imaging, Spaceflight Industries, GeoOptics, Planetary Resources, and OneWeb as a launch provider. The 2015 OneWeb contract covers 39 LauncherOne missions with an option for 100 more.

As of the end of 2015, few details regarding the technical specifications of the LauncherOne system are publicly available.

Launch service provider
Virgin Galactic

Organization Headquarters
USA

Manufacturer
Virgin Galactic
The Spaceship Company

Mass, kg (lb)
Undisclosed

Length, m (ft)
Undisclosed

Diameter, m (ft)
Undisclosed

Year of Planned First Launch
2017

Launch sites
Spaceport America

GTO capacity, kg (lb)
N/A

LEO capacity, kg (lb)
400 (882)

SSO capacity, kg (lb)
225 (496)

Estimated Price per Launch
$10M

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

FAA AST

Launch Vehicle Fact Sheet

LauncherOne

An artist's impression of the LauncherOne vehicle integrated with a Boeing 747-400 carrier aircraft. Source: Virgin Galactic

Fairing	Length, m (ft)	Diameter, m (ft)
Standard Fairing	Undisclosed	Undisclosed

	1st Stage	2nd Stage	3rd Stage
Stage designation	747-400 *Cosmic Girl*	1st Stage	2nd Stage
Length, m (ft)	70.6 (232)	Undisclosed	Undisclosed
Diameter/Wingspan, m (ft)	64.4 (211)	Undisclosed	Undisclosed
Manufacturer	Boeing	The Spaceship Company	The Spaceship Company
Propellant	Kerosene (Jet-A1)	LOX/kerosene	LOX/kerosene
Propellant mass, kg (lb)	175,652 (387,247)	Undisclosed	Undisclosed
Total thrust, kN (lbf)	1,097 (246,615)	335 (75,000)	22.2 (5,000)
Engine(s)	4 x GE CF6-80C2B5F	1 x NewtonThree	1 x NewtonFour
Engine manufacturer	General Electric	The Spaceship Company	The Spaceship Company
Engine thrust, kN (lbf)	274.2 (61,500)	335 (75,000)	22.2 (5,000)

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

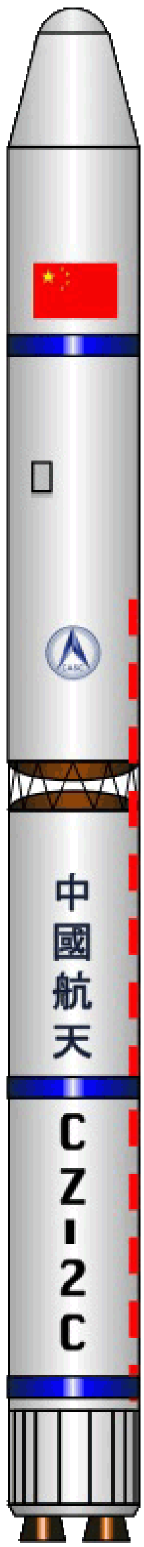
Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

Long March 2C



First launched from Jiuquan Space Launch Center in 1975, the Long March 2C launch vehicle has been a workhorse. The rocket is part of the Long March 2 family and is the successor to the Long March 2A launch vehicle. As of December 31, 2015, China has successfully launched 43 Long March 2C vehicles. There has only been one reported launch failure during its operational life.

There exist six variants of the Long March C launch vehicle, and these variants range from 2-stage to 3-stage designs, and are considered medium-capacity vehicles, capable of lifting payloads to low Earth orbit (LEO), geostationary transfer orbit (GTO), or direct to geosynchronous orbit (GEO), depending on the variant. Launches to LEO polar orbit are conducted from Taiyuan Satellite Launch Center, whereas launches to GTO and GEO are conducted from Xichang Satellite Launch Center.

The Long March 2C is expected to be retired before 2020 as China introduces several new Long March vehicles. A proposed variant of the Long March 5 may be pursued to fulfill the capability offered by the Long March 2C, since the new Long March 6 and Long March 11 are much smaller.

Launch service provider
PLA/CGWIC

Organization Headquarters
China

Manufacturer
SAST

Mass, kg (lb)
233,000 (513,677)

Length, m (ft)
42 (138)

Diameter, m (ft)
3.4 (11)

Year of First Launch
1982

Number of Launches
41

Reliability
98%

Launch sites
Jiuquan (LA-2, LA-4)
Taiyuan (LA-7, LA-9)
Xichang (LA-3)

GTO capacity, kg (lb)
1,250 (2,758)

LEO capacity, kg (lb)
3,850 (8,488)

SSO capacity, kg (lb)
1,900 (4,189)

Estimated Price per Launch
$30M

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

Long March 2C

A Long March 2C carrying Shijian-11 07 is launched from Jiuquan Satellite Launch Center in 2014. Source: www.news.cn

Fairing	Length, m (ft)	Diameter, m (ft)
Standard Fairing	7 (22.9)	3.4 (11.2)

	1st Stage	2nd Stage	3rd Stage
Stage designation	1st Stage	2nd Stage	2804
Length, m (ft)	25.7 (84.3)	7.8 (25.6)	1.5 (4.9)
Diameter, m (ft)	3.4 (11.2)	3.4 (11.2)	2.7 (8.9)
Manufacturer	SAST	SAST	SAST
Propellant	N_2O_4/UDMH	N_2O_4/UDMH	Solid
Propellant mass, kg (lb)	162,706 (358,705)	54,667 (120,520)	125 (275.6)
Total thrust, kN (lbf)	2,961.6 (665,794)	741.3 (166,651)	10.8 (2,428)
Engine(s)	4 x YF-21C	1 x YF-24E	--
Engine manufacturer	SAST	SAST	--
Engine thrust, kN (lbf)	740.4 (166,449)	741.3 (166,651)	10.8 (2,428)

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

Long March 2D

Primarily used to lift payloads to LEO and SSO, the 41-meter-tall, two-stage Long March 2D launch vehicle is part of the Long March 2 family of rockets. First launched from Jiuquan Satellite Launch Center in 1992, this Chinese launch vehicle has completed 25 successful launches. Two variants of the Long March 2D are known, and both are two-stage rockets that employe engines fueled by N_2O_4/UDMH.

In addition, this launch vehicle can use two different types of payload fairings (Type A: 2.9-m diameter, Type B: 3.35-m diameter). The launch vehicle is capable of lifting a 1,300 kg payload to a 645 km sun synchronous orbit (SSO) orbit and 3,500 kg payload to a 200 km low Earth orbit (LEO) orbit. The vehicle is not used for missions to geosynchronous orbit (GEO).

The Long March 2D is expected to be retired before 2020 as China introduces several new Long March vehicles. A proposed variant of the Long March 5 may be pursued to fulfill the capability offered by the Long March 2D, since the new Long March 6 and Long March 11 are much smaller.

Launch service provider
PLA/CGWIC

Organization Headquarters
China

Manufacturer
SAST

Mass, kg (lb)
232,250 (512,024)

Length, m (ft)
41 (134.5)

Diameter, m (ft)
3.4 (11)

Year of First Launch
1992

Number of Launches
25

Reliability
100%

Launch sites
Jiuquan (LA-2, LA-4)

GTO capacity, kg (lb)
N/A

LEO capacity, kg (lb)
3,500 (7,716)

SSO capacity, kg (lb)
1,300 (2,866)

Estimated Price per Launch
$30M

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

Long March 2D

A Long March 2D carrying Tianhui-1C is launched from Jiuquan Satellite Launch Center in 2015. Source: Xinghua

Fairing	Length, m (ft)	Diameter, m (ft)
Standard Fairing	7 (22.9)	3.4 (11.2)

	1st Stage	2nd Stage
Stage designation	1st Stage	2nd Stage
Length, m (ft)	27.9 (91.5)	10.9 (35.8)
Diameter, m (ft)	3.4 (11.2)	3.4 (11.2)
Manufacturer	SAST	SAST
Propellant	N_2O_4/UDMH	N_2O_4/UDMH
Propellant mass, kg (lb)	182,000 (401,241)	52,700 (116,184)
Total thrust, kN (lbf)	2,961.6 (665,794)	742 (166,808)
Engine(s)	4 x YF-21C	1 x YF-24C
Engine manufacturer	SAST	SAST
Engine thrust, kN (lbf)	740.4 (166,449)	742 (166,808)

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

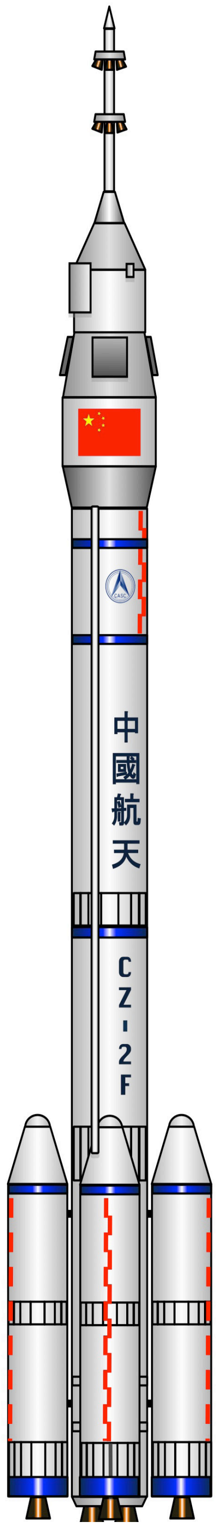
Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

Long March 2F



The Long March 2F, introduced in 1999, is China's only vehicle designed to transport astronauts. The two-stage vehicle is ultimately derived from the Long March 2C via the Long March 2E, a retired vehicle that was used to send payloads to geosynchronous orbit (GEO).

The Long March 2F carried the Shenzhou spacecraft, which consists of an orbital module, a descent module, and a service module. Shenzhou is partly derived from Soviet/Russian Soyuz hardware, which was purchased by the Chinese government in 1995. However, the Shenzhou is significantly different than the Soyuz in terms of dimensions, internal arrangement, and subsystems.

There have been eleven launches of the Long March 2F. Ten of these supported Shenzhou missions, six of which carried crews. The eleventh launch was of Tiangong-1 in 2011, China's first space station with a design not unlike the early Salyut/Almaz systems launched by the Soviet Union in the 1970s.

China's Tiangong-2 is scheduled for launch in 2016, followed by the crewed Shenzhou-11, which will dock with the station. Both of these missions will be launched by separate Long March 2F vehicles. Crewed missions are expected to be launched by the Long March 5 vehicle, which may be introduced in 2016.

Launch service provider
PLA/CNSA

Organization Headquarters
China

Manufacturer
CALT

Mass, kg (lb)
464,000 (1,022,945)

Length, m (ft)
62 (203.4)

Diameter, m (ft)
3.4 (11)

Year of First Launch
1999

Number of Launches
11

Reliability
100%

Launch sites
Jiuquan (LC-43/921)

GTO capacity, kg (lb)
N/A

LEO capacity, kg (lb)
8,400 (18,519)

SSO capacity, kg (lb)
N/A

Estimated Price per Launch
N/A

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

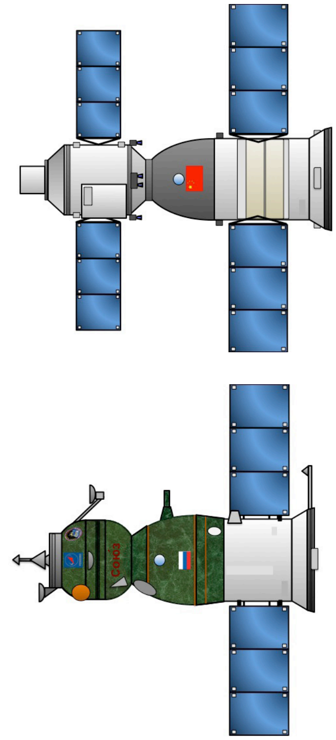
FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

Long March 2F

FAA AST

The Long March 2F carrying Shenzhou 9 is rolled to the launch pad in jiuquan in 2012. Source: SinoDefence



The Shenzhou spacecraft (above) is similar to the Russian Soyuz (below). China had purchased Soyuz hardware from Russia in 1995 to support China's 921-1 human spaceflight program begun in 1992.

	Liquid Boosters*	1st Stage	2nd Stage
Stage designation	Liquid Boosters (4)	1st Stage	2nd Stage
Length, m (ft)	15.3 (50.2)	23.7 (77.8)	13.5 (44.3)
Diameter, m (ft)	2.3 (7.5)	3.4 (11)	3.4 (11)
Manufacturer	CALT	CALT	CALT
Propellant	N_2O_4/UDMH	N_2O_4/UDMH	N_2O_4/UDMH
Propellant mass, kg (lb)	37,800 (83,335)	187,000 (412,264)	86,000 (189,598)
Total thrust, kN (lbf)	3,256 (731,978)	13,024 (2,927,912)	831 (186,816)
Engine(s)	1 x YF-20B	4 x YF-20B	1 x YF-24B
Engine manufacturer	CALT	CALT	CALT
Engine thrust, kN (lbf)	3,256 (731,978)	3,256 (731,978)	831 (186,816)

** Figures are for each booster. Total thrust is sum of all boosters.*

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

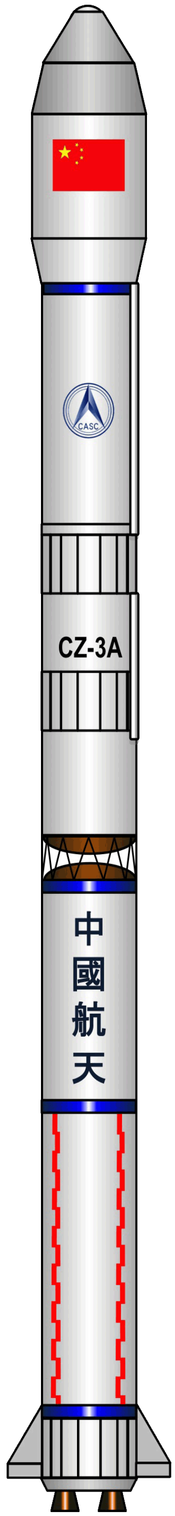
Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

Long March 3A



This operational launch vehicle has been launched successful 24 times since its first launch in 1994. Developed by the China Academy of Launch Vehicle Technology (CALT), Long March 3A is part of the Long March 3 rocket family and is considered an intermediate-capacity launch vehicle. Long March 3A is capable of lifting a 2,600 kg payload to geostationary transfer orbit (GTO) and a 6,000 kg payload to a 200 km low Earth orbit (LEO). The Chinese launch the three-stage Long March 3A from Xichang Satellite Launch Center, primarily to place communications and navigation satellites into GTO.

The Long March 3A divides into three stages. The first and second stages use a N_2O_4/UDMH fuel whereas the third stage uses a liquid oxygen (LOX) oxidizer and liquid hydrogen (LH_2) fuel. This launch vehicle is the predecessor to a higher-capacity launch vehicle in the Long March 3 family, the Long March 3B.

The Long March 3A is expected to be retired before 2020 as China introduces several new Long March vehicles, particularly the Long March 5 series.

Launch service provider
PLA/CGWIC

Organization Headquarters
China

Manufacturer
CALT/SAST

Mass, kg (lb)
241,000 (531,314)

Length, m (ft)
52.5 (172.2)

Diameter, m (ft)
3.4 (11)

Year of First Launch
1994

Number of Launches
23

Reliability
100%

Launch sites
Xichang (LA-2, LA-3)

GTO capacity, kg (lb)
2,600 (5,732)

LEO capacity, kg (lb)
8,500 (18,739)

SSO capacity, kg (lb)
N/A

Estimated Price per Launch
$70M

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

Long March 3A

A Long March 3A carrying Fengyun 2G is launched from Xichang in 2014.
Source: ChinaNews

Fairing	Length, m (ft)	Diameter, m (ft)
Standard Fairing	8.9 (29.2)	3.4 (11)

	1st Stage	2nd Stage	3rd Stage
Stage designation	1st Stage	2nd Stage	3rd Stage
Length, m (ft)	23.3 (76.4)	11.3 (37.1)	12.4 (40.7)
Diameter, m (ft)	3.4 (11)	3.4 (11)	3 (9.8)
Manufacturer	SAST	SAST	CALT
Propellant	N_2O_4/UDMH	N_2O_4/UDMH	LOX/LH_2
Propellant mass, kg (lb)	171,800 (378,754)	32,600 (71,871)	18,200 (40,124)
Total thrust, kN (lbf)	3,265 (734,001)	742 (166,808)	167 (37,543)
Engine(s)	4 x YF-21C	1 x YF-24E	1 x YF-75
Engine manufacturer	SAST	SAST	CALT
Engine thrust, kN (lbf)	816.3 (183,512)	742 (166,808)	167 (37,543)

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

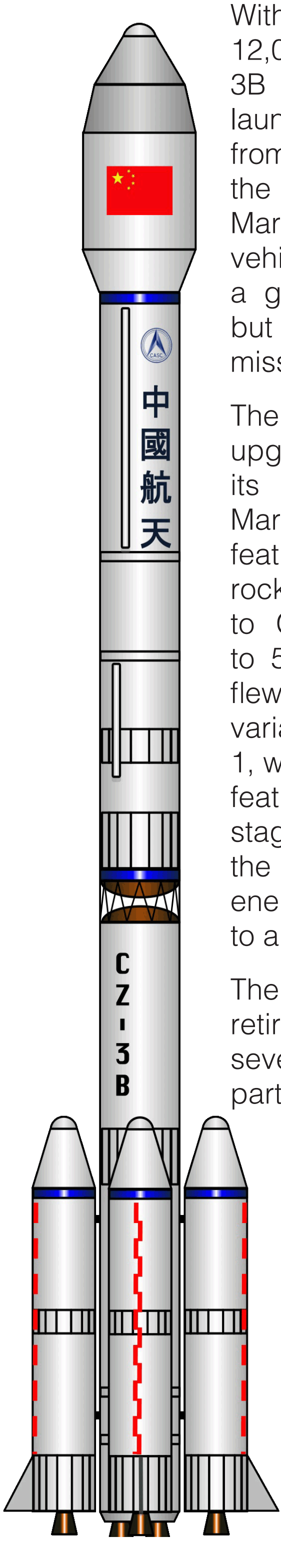
Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

Long March 3B/E



With a low Earth orbit (LEO) capacity of 12,000 kg (26,456 lb), the Long March 3B is currently China's most powerful launch vehicle. The vehicle is derived from the Long March 3A vehicle, with the key difference being that the Long March 3B uses four liquid boosters. The vehicle is primarily used for missions to a geostationary transfer orbit (GTO), but can be used for uncrewed science missions to the Moon (Chang'e-3).

The Long March 3B has been upgraded on a few occassions since its introduction in 1996. The Long March 3B/E ("E" for "enhanced") featured a larger first stage and liquid rocket boosters, increasing its capacity to GTO from 5,100 kg (11,244 lb) to 5,500 kg (12,125 lb). This variant flew for the first time in 2007. Another variant, called the Long March 3B/YZ-1, was introduced in 2015. This vehicle features a new, restartable upper stage called Yuanzheng-1, enabling the vehicle to send payloads to high energy orbits, such as a direct insertion to a geostationary orbit (GSO).

The Long March 3B is expected to be retired before 2020 as China introduces several new Long March vehicles, particularly the Long March 5 series.

Launch service provider
PLA/CGWIC

Organization Headquarters
China

Manufacturer
CALT/SAST

Mass, kg (lb)
458,970 (1,011,856)

Length, m (ft)
56.3 (184.7)

Diameter, m (ft)
3.4 (11)

Year of First Launch
2007

Number of Launches
22

Reliability
100%

Launch sites
Xichang (LA-2, LA-3)

GTO capacity, kg (lb)
5,500 (12,125)

LEO capacity, kg (lb)
12,000 (26,456)

SSO capacity, kg (lb)
5,700 (12,566)

Estimated Price per Launch
$70M

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

Long March 3B/E

A Long March 3B/YZ-1 carrying BDS I2-S is launched from Xichang Satellite Launch Center in 2015. Source: CNS/XNA

Fairing	Length, m (ft)	Diameter, m (ft)
Standard Fairing	8.9 (29.2)	4 (13.1)

	Liquid Boosters*	1st Stage	2nd Stage	3rd Stage	4rd Stage Option
Stage designation	Liquid Boosters (4)	1st Stage	2nd Stage	3rd Stage	Yuanzheng-1
Length, m (ft)	16.1 (52.8)	24.8 (81.4)	12.9 (42.3)	12.4 (40.7)	Undisclosed
Diameter, m (ft)	2.3 (7.5)	3.4 (11)	3.4 (11)	3 (9.8)	Undisclosed
Manufacturer	CALT	SAST	SAST	CALT	CALT
Propellant	N_2O_4/UDMH	N_2O_4/UDMH	N_2O_4/UDMH	N_2O_4/UDMH	N_2O_4/UDMH
Propellant mass, kg (lb)	41,100 (90,610)	186,200 (410,501)	49,400 (108,908)	18,200 (40,124)	Undisclosed
Total thrust, kN (lbf)	740.4 (166,449)	3,265 (734,001)	742 (166,808)	167 (37,543)	6.5 (1,500)
Engine(s)	1 x YF-25	4 x YF-21C	1 x YF-24E	1 x YF-75	1 x YF-50D
Engine manufacturer	CALT	SAST	SAST	CALT	CALT
Engine thrust, kN (lbf)	740.4 (166,449)	816.3 (183,512)	742 (166,808)	167 (37,543)	6.5 (1,500)

** Figures are for each booster. Total thrust is sum of all boosters.*

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

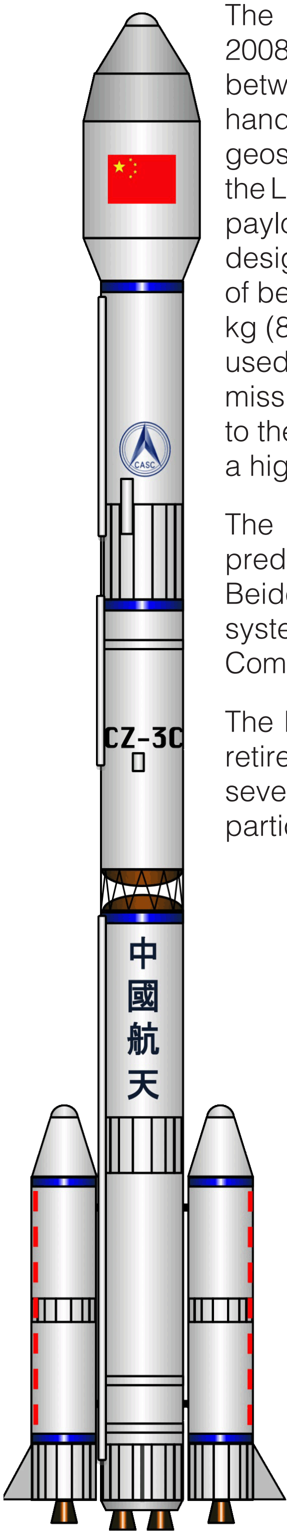
Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

Long March 3C



The Long March 3C, introduced in 2008, is designed to fill a capacity gap between the Long March 3A, which handles relatively small payloads to geostationary transfer orbit (GTO) and the Long March 3B, which handles large payloads to GTO. The Long March 3C is designed to send payloads with a mass of between 3,000 kg (6,614 lb) to 3,800 kg (8,378 lb). The vehicle is sometimes used for uncrewed Chang'e science missions, having launched Chang'e-2 to the Moon in 2010 and Chang'e-T1 to a high lunar orbit in 2014.

The Long March 3C has been predominantly used to support the Beidou global navigation satellite system, having sent seven Beidou Compass satellites to GTO.

The Long March 3C is expected to be retired before 2020 as China introduces several new Long March vehicles, particularly the Long March 5 series.

Launch service provider
PLA/CNSA

Organization Headquarters
China

Manufacturer
CALT/SAST

Mass, kg (lb)
345,000 (760,595)

Length, m (ft)
54.8 (179.8)

Diameter, m (ft)
3.4 (11)

Year of First Launch
2008

Number of Launches
12

Reliability
100%

Launch sites
Xichang (LA-2, LA-3)

GTO capacity, kg (lb)
3,800 (8,378)

LEO capacity, kg (lb)
N/A

SSO capacity, kg (lb)
N/A

Estimated Price per Launch
$70M

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

Long March 3C

A Long March 3C stands poised for launch from Xichang Satellite Launch Center in 2011. Source: ChinaDailyMail.com

Fairing	Length, m (ft)	Diameter, m (ft)
Standard Fairing	8.9 (29.2)	4 (13.1)

	Liquid Boosters*	1st Stage	2nd Stage	3rd Stage
Stage designation	Liquid Boosters (2)	1st Stage	2nd Stage	3rd Stage
Length, m (ft)	16.1 (52.8)	24.8 (81.4)	12.9 (42.3)	12.4 (40.7)
Diameter, m (ft)	2.3 (7.5)	3.4 (11)	3.4 (11)	3 (9.8)
Manufacturer	CALT	SAST	SAST	CALT
Propellant	N_2O_4/UDMH	N_2O_4/UDMH	N_2O_4/UDMH	N_2O_4/UDMH
Propellant mass, kg (lb)	41,100 (90,610)	186,200 (410,501)	49,400 (108,908)	18,200 (40,124)
Total thrust, kN (lbf)	740.4 (166,449)	3,265 (734,001)	742 (166,808)	167 (37,543)
Engine(s)	1 x YF-25	4 x YF-21C	1 x YF-24E	1 x YF-75
Engine manufacturer	CALT	SAST	SAST	CALT
Engine thrust, kN (lbf)	740.4 (166,449)	816.3 (183,512)	742 (166,808)	167 (37,543)

** Figures are for each booster. Total thrust is sum of all boosters.*

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

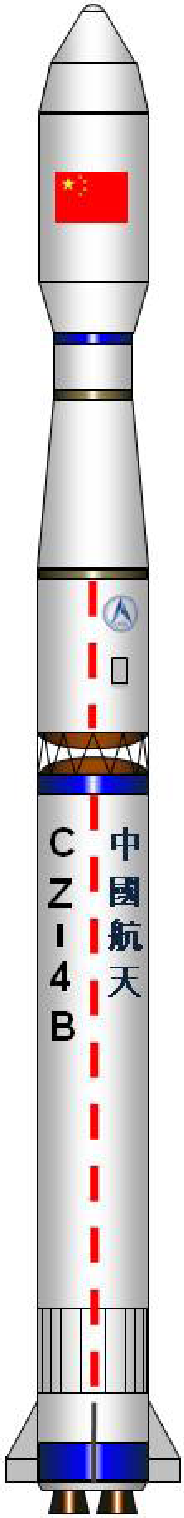
Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

Long March 4B



The Long March 4B, like the similar Long March 4C, is a workhorse launch vehicle used by the Chinese since 1999 to send payloads into polar orbits from the Taiyuan Satellite Launch Center near Beijing. On only one occassion, the vehicle was launched from Jiuquan. The Long March 4 series was originally conceived as a backup for the Long March 3 series in support of missions to geostationary transfer orbit (GTO). However, the vehicle proved more capable for polar orbiting missions. The vehicle is manufactured by the Shanghai Academy of Spaceflight Technology (SAST).

The vehicle is based on the Long March 4 vehicle, conceived in the late 1980s but never built. The Long March 4B was an imporvment to that original design, featuring a larger payload fairing; improved telemetry, tracking, control, and self-destruction systems; and new propulsion elements designed to increase the vehicle's capacity to orbit.

The Long March 4B is expected to be retired before 2020 as China introduces several new Long March vehicles, particularly the Long March 5 series.

Launch service provider
PLA/CGWIC

Organization Headquarters
China

Manufacturer
SAST

Mass, kg (lb)
249,200 (549,392)

Length, m (ft)
45.8 (150.3)

Diameter, m (ft)
3.4 (11)

Year of First Launch
1999

Number of Launches
26

Reliability
96%

Launch sites
Jiuquan (LA-4)
Taiyuan (LA-7)

GTO capacity, kg (lb)
1,500 (3,307)

LEO capacity, kg (lb)
4,200 (9,259)

SSO capacity, kg (lb)
2,800 (6,173)

Estimated Price per Launch
$30M

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

FAA AST

Launch Vehicle Fact Sheet

Long March 4B

A Long March 4B carrying Ziyuan 3 and VesselSat-2 is launched from Taiyuan in 2012. Source: Xinghua

Fairing	Length, m (ft)	Diameter, m (ft)
Standard Fairing	8.5 (27.9)	3.4 (11.2)

	1st Stage	2nd Stage	3rd Stage
Stage designation	1st Stage	2nd Stage	3rd Stage
Length, m (ft)	27.9 (91.5)	10.9 (35.8)	14.8 (48.6)
Diameter, m (ft)	3.4 (11.2)	3.4 (11)	2.9 (9.5)
Manufacturer	SAST	SAST	SAST
Propellant	N_2O_4/UDMH	N_2O_4/UDMH	N_2O_4/UDMH
Propellant mass, kg (lb)	182,000 (401,241)	52,700 (116,184)	14,000 (30,865)
Total thrust, kN (lbf)	3,265 (734,001)	741.3 (166,651)	206 (46,311)
Engine(s)	4 x YF-21C	1 x YF-24C	2 x YF-40
Engine manufacturer	SAST	SAST	SAST
Engine thrust, kN (lbf)	816.3 (183,512)	741.3 (166,651)	103 (23,155)

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

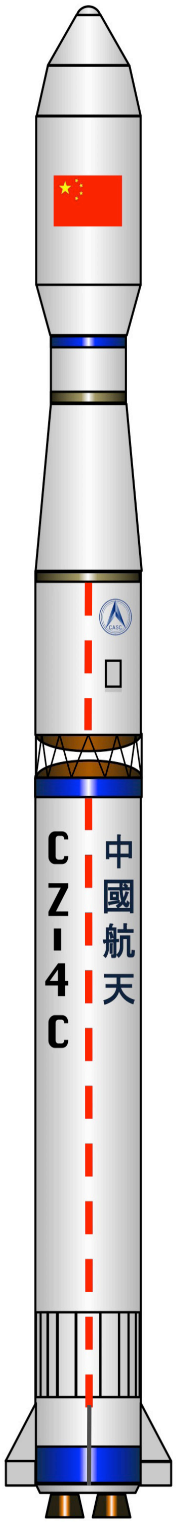
Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

Long March 4C



The Long March 4C is derived from the Long March 4B, but both vehicles are used to support missions to low Earth orbit (LEO) and sun synchronous orbits (SSO). Unlike the Long March 4B, which is primarilly launched from the Taiyuan Satellite Launch Center, the Long March 4C is also frequently launched from the Jiuquan Satellite Launch Center. Launches from Taiyuan typically support meteorology missions, whereas those from Jiuquan support image intelligence missions. The vehicle is manufactured by the Shanghai Academy of Spaceflight Technology (SAST).

The Long March 4C differs from the Long March 4B in that it features a larger volume payload fairing and a restartable third stage.

The Long March 4C is expected to be retired before 2020 as China introduces several new Long March vehicles, particularly the Long March 5 series.

Launch service provider
PLA/CGWIC

Organization Headquarters
China

Manufacturer
SAST

Mass, kg (lb)
Undisclosed

Length, m (ft)
Undisclosed

Diameter, m (ft)
Undisclosed

Year of First Launch
2006

Number of Launches
17

Reliability
100%

Launch sites
Jiuquan (LA-4)
Taiyuan (LA-7, LA-9)

GTO capacity, kg (lb)
1,500 (3,307)

LEO capacity, kg (lb)
4,200 (9,259)

SSO capacity, kg (lb)
2,800 (6,73)

Estimated Price per Launch
$30M

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

Long March 4C

A Long March 4C carrying Yaogan 15 is launched from Taiyuan in 2012. Source: ChinaNews

Fairing	Length, m (ft)	Diameter, m (ft)
Standard Fairing	8.5 (27.9)	3.4 (11.2)
Larger Fairing	Undisclosed	Undisclosed

	1st Stage	2nd Stage	3rd Stage
Stage designation	1st Stage	2nd Stage	3rd Stage
Length, m (ft)	27.9 (91.5)	10.9 (35.8)	14.8 (48.6)
Diameter, m (ft)	3.4 (11.2)	3.4 (11)	2.9 (9.5)
Manufacturer	SAST	SAST	SAST
Propellant	N_2O_4/UDMH	N_2O_4/UDMH	N_2O_4/UDMH
Propellant mass, kg (lb)	182,000 (401,241)	52,700 (116,184)	14,000 (30,865)
Total thrust, kN (lbf)	3,265 (734,001)	741.3 (166,651)	201.8 (45,366)
Engine(s)	4 x YF-21C	1 x YF-24C	2 x YF-40A
Engine manufacturer	SAST	SAST	SAST
Engine thrust, kN (lbf)	816.3 (183,512)	741.3 (166,651)	100.9 (22,683)

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

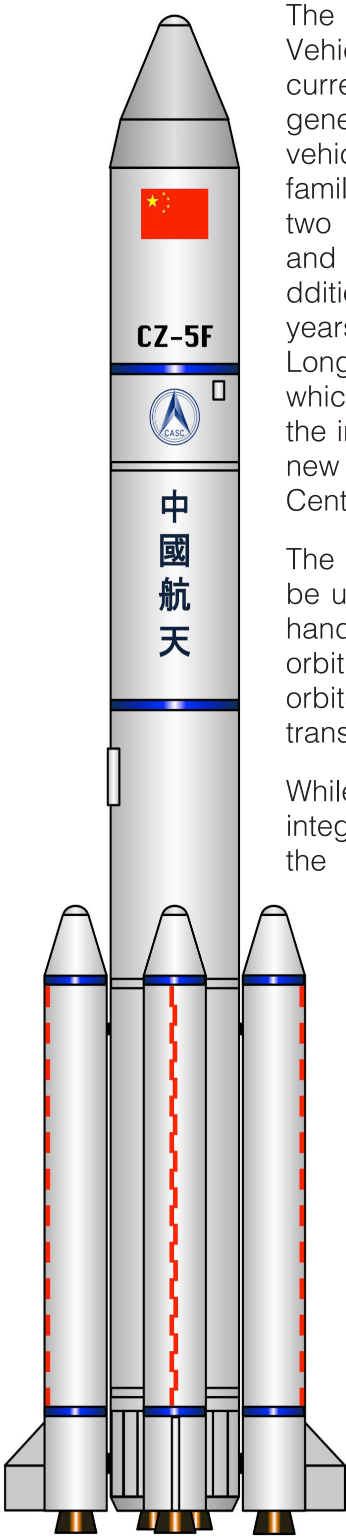
Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

Long March 5



The China Academy of Launch Vehicle Technology (CALT) is currently developing the next generation of Chinese launch vehicles, the Long March 5 family. The effort is focused on two versions, the Long March 5 and Long March 5B, with several dditional variants expected in the years to follow. The first launch of a Long March 5 is expected in 2016, which will apparently represent the inaugural launch from China's new Wencheng Satellite Launch Center located on Hainan Island.

The Long March 5 series may be used for the bulk of launches, handling missions to low Earth orbit (LEO), sun synchronous orbits (SSO), and geostationary transfer orbit (GTO).

While CALT is the systems integrator for Long March 5, the Academy of Aerospace Propulsion Technology (AAPT) is developing the new engines.

Since the Long March 5 will replace the Long March 3B/E for GTO launches, it is likely the vehicle will be marketed as an option for satellite operators worldwide.

Launch service provider
PLA/CNSA/CGWIC

Organization Headquarters
China

Manufacturer
CALT

Mass, kg (lb)
869,000 (1,915,817)

Length, m (ft)
62 (203.4)

Diameter, m (ft)
5 (16.4)

Year of Planned First Launch
2016

Launch sites
Wenchang

GTO capacity, kg (lb)
14,000 (30,865)

LEO capacity, kg (lb)
25,000 (55,116)

SSO capacity, kg (lb)
N/A

Estimated Price per Launch
Undisclosed

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

FAA AST

Launch Vehicle Fact Sheet
Long March 5

The Long March 5 takes shape at CALT. Source: Xinghua

Fairing	Length, m (ft)	Diameter, m (ft)
Standard Fairing	12.5 (41)	5.2 (17.1)

	Liquid Boosters*	1st Stage	2nd Stage Option	2nd Stage Option	3rd Stage
Stage designation	Liquid Boosters (4)	1st Stage	2nd Stage	2nd Stage	3rd Stage
Length, m (ft)	Undisclosed	Undisclosed	Undisclosed	Undisclosed	Undisclosed
Diameter, m (ft)	3.4 (11)	5 (16.4)	5 (16.4)	5 (16.4)	
Manufacturer	CALT	CALT	CALT	CALT	CALT
Propellant	LOX/Kerosene	LOX/H_2	LOX/H_2	LOX/H_2	LOX/H_2
Propellant mass, kg (lb)	Undisclosed	Undisclosed	Undisclosed	Undisclosed	Undisclosed
Total thrust, kN (lbf)	2,358 (530,100)	1,018 (228,856)	44.2 (9,937)	176.6 (39,701)	78.5 (17,648)
Engine(s)	2 x YF-100	2 x YF-77	1 x YF-73	2 x YF-75D	1 x YF-75
Engine manufacturer	AAPT	AAPT	AAPT	AAPT	AAPT
Engine thrust, kN (lbf)	1,179 (265,050)	509 (114,428)	44.2 (9,937)	88.3 (19,851)	78.5 (17,648)

* *Figures are for each booster. Total thrust is sum of all boosters.*

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

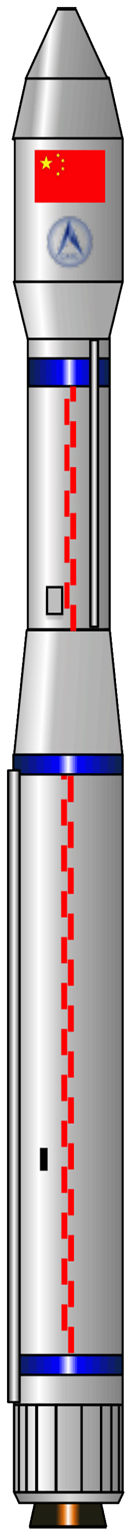
Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

Long March 6



The Long March 6 is a cooperative effort between China Aerospace Science and Technology Corporation (SAST) and the China Academy of Launch Vehicle Technology (CALT). It is a small, liquid-fueled vehicle that has a low Earth orbit (LEO) payload capacity less than that provided by the currently available small-class Long March 2C, meaning the vehicle serves a niche previously not directly addressed.

Pursuit of a small-class launch vehicle started in the late 1990s and resulted in the Kaitouzhe (launched in 2002 and 2003). The vehicle used solid propellant and was easily transported using a trailer. Following a failure in 2003, the Kaitouzhe program ended. The Long March 6, Long March 11, and Kuaizhou vehicles have been under development since, each vehicle offering small capacity options for the government and, potentially, commercial satellite oeprators. Of these vehicles, the Long March 6 has the highest capacity to LEO at 1,500 kg (3,307 kg).

The vehicle is easily transported via a mobile trailer from the manufacturing and systems integration site to the launch site. This, combined with public statements from the Chinese government, indicate that the vehicle will be used to support rapid deployment missions for the People's Liberation Army (PLA).

Its inaugural launch from the Taiyuan Satellite Launch Center in 2015 was notable because it carried 20 microsatellites, some of which were built in China using the CubeSat standard (10 cm cubic form factor). For this reason, it is possible the vehicle will be offered as a commercial option.

Launch service provider
PLA/CGWIC

Organization Headquarters
China

Manufacturer
SAST/CALT

Mass, kg (lb)
103,217 (227,555)

Length, m (ft)
29 (95.1)

Diameter, m (ft)
3.4 (11)

Year of First Launch
2015

Number of Launches
1

Reliability
100%

Launch sites
Taiyuan (LA-16)
Wenchang

GTO capacity, kg (lb)
N/A

LEO capacity, kg (lb)
1,500 (3,307)

SSO capacity, kg (lb)
1,080 (2,381)

Estimated Price per Launch
Undisclosed

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

Long March 6

FAA AST

The Long March 6 being transported to the launch site. Source:

Fairing	Length, m (ft)	Diameter, m (ft)
Standard Fairing	5.7 (18.7)	2.3 (7.5)
Large Fairing	5.7 (18.7)	2.6 (8.5)

	1st Stage	2nd Stage	3rd Stage
Stage designation	1st Stage	2nd Stage	3rd Stage
Length, m (ft)	15 (49.2)	7.3 (24)	1.8 (5.9)
Diameter, m (ft)	3.4 (11)	2.3 (7.5)	2.3 (7.5)
Manufacturer	CALT	SAST	SAST
Propellant	LOX/Kerosene	LOX/Kerosene	H_2O_2/Kerosene
Propellant mass, kg (lb)	76,000 (167,551)	15,000 (33,069)	Undisclosed
Total thrust, kN (lbf)	1,179 (265,050)	175 (39,342)	16 (3,597)
Engine(s)	1 x YF-100	1 x YF-115	4 x YF-85
Engine manufacturer	AAPT	AAPT	AAPT
Engine thrust, kN (lbf)	1,179 (265,050)	175 (39,342)	4 (899)

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

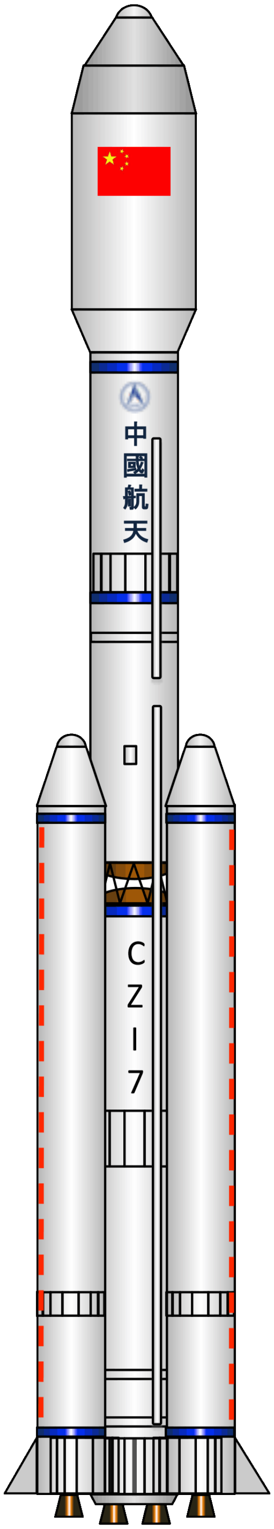
Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

Long March 7



The China Academy of Launch Vehicle Technology (CALT) is currently developing the next generation of Chinese launch vehicles, the Long March 7 family. The first launch of a Long March 7 is expected in 2016 from China's new Wencheng Satellite Launch Center located on Hainan Island.

The Long March 7 series is being designed to handle missions to low Earth orbit (LEO) and sun synchronous orbits (SSO). It will apparently not be used for missions destined for geostationary transfer orbit (GTO). The vehicle will replace the Long March 2F as a means to send astronauts into space.

While CALT is the systems integrator for Long March 7, the Academy of Aerospace Propulsion Technology (AAPT) is developing the new engines.

Launch service provider
PLA/CGWIC

Organization Headquarters
China

Manufacturer
CALT

Mass, kg (lb)
594,000 (1,309,546)

Length, m (ft)
53.1 (174.2)

Diameter, m (ft)
3.4 (11)

Year of Planned First Launch
2016

Launch sites
Wenchang

GTO capacity, kg (lb)
N/A

LEO capacity, kg (lb)
13,500 (29,762)

SSO capacity, kg (lb)
5,500 (12,125)

Estimated Price per Launch
Undisclosed

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

Long March 7

The Long March 7 being manufactured at a CALT facility. Delays in development have apparently been caused by problems with propellant supply system designs with the Long March 5 and Long March 7. Source: Aviation Week and Space Technology

A Long March 7 stands upon its mobile launch platform at the Wencheng Satellite Launch Center in 2015. Source: Popular Science

Fairing	Length, m (ft)	Diameter, m (ft)
Standard Fairing	Undisclosed	Undisclosed

	Liquid Boosters*	2nd Stage	3rd Stage
Stage designation	K2 Liquid Boosters (4)	K3 1st Stage	2nd Stage
Length, m (ft)	Undisclosed	15 (49.2)	7.3 (24)
Diameter, m (ft)	2.3 (7.5)	3.4 (11)	2.3 (7.5)
Manufacturer	CALT	CALT	SAST
Propellant	LOX/Kerosene	LOX/Kerosene	LOX/Kerosene
Propellant mass, kg (lb)	Undisclosed	76,000 (167,551)	15,000 (33,069)
Total thrust, kN (lbf)	4,716 (1,060,199)	2,358 (530,100)	700 (157,366)
Engine(s)	1 x YF-100	2 x YF-100	4 x YF-115
Engine manufacturer	AAPT	AAPT	AAPT
Engine thrust, kN (lbf)	1,179 (265,050)	1,179 (265,050)	175 (39,342)

** Figures are for each booster. Total thrust is sum of all boosters.*

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

Long March 11

The solid-fueled Long March 11 first flew in 2015, just days after China had successfully introduced the liquid-fueled Long March 6. Whereas the Long March 6 can send payloads with a mass of 1,500 kg (3,307 lb) to low Earth orbit (LEO), the Long March 11 can only send payloads of up to 700 kg (1,543 lb) to LEO. Like the Long March 6, the Long March 11 can be transported relatively easily between a storage facility and the launch site, enabling rapid deployment of satellites. The fact that the Long March 11 is storable is notable.

Little else is publicly known about the vehicle, but it may have benefited from development of the Kaitouzhe launch vehicle that flew twice; once successfully in 2002 and once unsuccessfully in 2003. It appears the vehicle is transported within a protective shroud. While a photograph indicates it is erected upon the launch pad within the shroud, it is unclear if the shroud is removed prior to launch or falls away during launch.

It is unlikely this vehicle will be offered commercially, since it appears to be optimized for military use.

Launch service provider
PLA

Organization Headquarters
China

Manufacturer
CALT

Mass, kg (lb)
58,000 (127,868) *est*

Length, m (ft)
20.8 (68.2) est

Diameter, m (ft)
2 (6.6) *est*

Year of First Launch
2015

Number of Launches
1

Reliability
100%

Launch sites
Jiuquan

GTO capacity, kg (lb)
N/A

LEO capacity, kg (lb)
700 (1,543)

SSO capacity, kg (lb)
350 (772)

Estimated Price per Launch
Undisclosed

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

Long March 11

The Long March 11 is apparently transported and erected within a protective shroud. Source: CCTV

Few clear images of the Long March 11 exist. This photo shows the vehicle being prepared for launch. Source: Weibo.com

Fairing	Length, m (ft)	Diameter, m (ft)
Standard Fairing	2 (6.6) *est*	1.6 (5.2) *est*

	1st Stage	2nd Stage	3rd Stage	4th Stage
Stage designation	1st Stage	2nd Stage	3rd Stage	4th Stage
Length, m (ft)	9 (29.5) *est*	3 (9.8) *est*	1 (3.3) *est*	Undisclosed
Diameter, m (ft)	2 (6.6) *est*	2 (6.6) *est*	1.4 (4.6) *est*	Undisclosed
Manufacturer	CALT	CALT	CALT	CALT
Propellant	Solid	Solid	Solid	Undisclosed
Propellant mass, kg (lb)	Undisclosed	Undisclosed	Undisclosed	Undisclosed
Total thrust, kN (lbf)	Undisclosed	Undisclosed	Undisclosed	Undisclosed
Engine(s)	--	--	--	1 x YF-50
Engine manufacturer	--	--	--	CALT
Engine thrust, kN (lbf)	--	--	--	Undisclosed

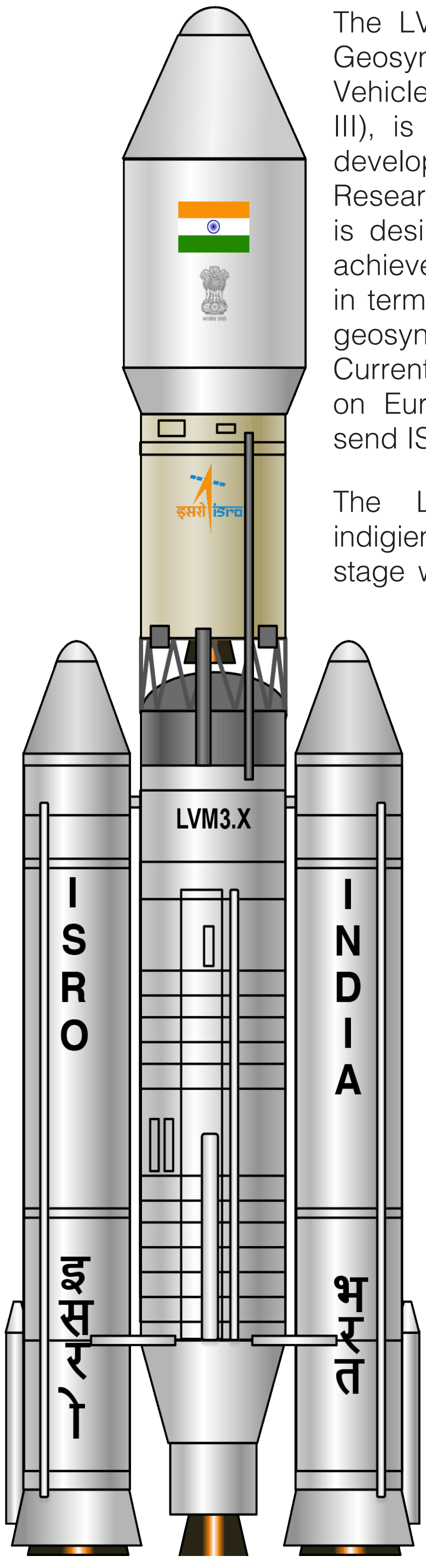
Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet
LVM3



The LVM3, formally called the Geosynchronous Space Launch Vehicle Mark III (GSLV Mk III), is a launch vehicle being developed by the Indian Space Researc organization (ISRO). It is designed to enable India to achieve complete self reliance in terms of sending satellites to geosynchronous orbits (GEO). Currently, India largely depends on Europe's Ariane 5 ECA to send ISRO payloads to GEO.

The LVM3 will feature an indigienously built cryogenic stage with higher capacity than GSLV. The GSLV Mk I used a Russian-build engine for the cryogenic upper stage. The engines are developed by ISRO's Liquid Propulsion Systems Centre (LPSC).

The first experimental flight of LVM3 was a suborbital launch of the Crew Module Atmospheric Re-entry Experiment (CARE) reentry test capsule. The successful launch took place from the Satish Dhawan Space Center on December 18, 2014. The capsule reentered, deployed its parachutes as planned, and splashed down in the Bay of Bengal.

Launch service provider
ISRO/Antrix

Organization Headquarters
India

Manufacturer
ISRO

Mass, kg (lb)
640,000 (1,410,000)

Length, m (ft)
43.4 (142.5)

Diameter, m (ft)
4 (13.1)

Year of Planned First Launch
2016

Launch sites
Satish Dhawan (SLP)

GTO capacity, kg (lb)
4,000 (8,818)

LEO capacity, kg (lb)
8,000 (17,637)

SSO capacity, kg (lb)
N/A

Estimated Price per Launch
$60M

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

LVM3

The LVM3 on the pad at Satish Dhawan Space Center prior to its inaugural launch in December 2014. Source: ISRO

Fairing	Length, m (ft)	Diameter, m (ft)
Standard Fairing	6 (19.7)	5 (16.4)

	Liquid Boosters*	1st Stage	2nd Stage
Stage designation	S200 (2)	L110	C25
Length, m (ft)	25 (82)	17 (55.8)	13.5 (44.3)
Diameter, m (ft)	3.2 (10.5)	4 (13.1)	4 (13.1)
Manufacturer	ISRO	ISRO	ISRO
Propellant	Solid	N_2O_4/UDMH	LOX/H_2
Propellant mass, kg (lb)	207,000 (456,357)	110,000 (242,508)	27,000 (59,525)
Total thrust, kN (lbf)	5,150 (1,157,766)	1,598 (359,245)	186 (41,815)
Engine(s)	--	2 x Vikas	1 x CE-20
Engine manufacturer	--	ISRO/LPSC	ISRO/LPSC
Engine thrust, kN (lbf)	--	799 (179,622)	186 (41,815)

** Figures are for each booster. Total thrust is sum of all boosters.*

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

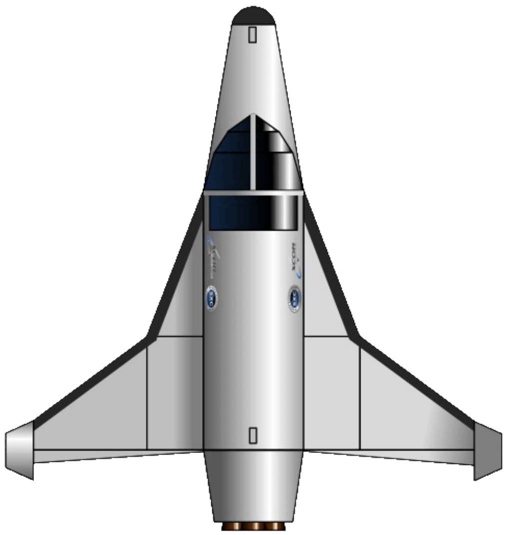
Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

FAA AST

Launch Vehicle Fact Sheet

Lynx Mark III



XCOR Aerospace is developing the Lynx suborbital reusable vehicle, which builds on XCOR's previously demonstrated rocket-powered aircraft, the EZ-Rocket and X-Racer.

The Lynx family of vehicles are piloted horizontal take-off/horizontal landing (HTHL) vehicles designed to carry one pilot and one participant. The initial Mark I test vehicle will not cross the boundary of space, but the Mark II and Mark III are designed to reach over 100 kilometers (62 miles) altitude.

XCOR is developing the Lynx vehicle through a phased approach. The Lynx Mark I test vehicle currently under construction is expected to start flying in 2016 or 2017. The Lynx Mark II operational vehicle will likely not enter service until at least 2017. The more capable Lynx Mark III vehicle, with introduction anticipated no earlier than 2018, will include a dorsal pod for larger suborbital payloads, space telescopes, or for launching small satellites.

The Lynx vehicles will initially fly from the Mojave Air and Space Port; however, they can operate from any licensed spaceport with a 2,400-meter (8,000-foot) runway.

In 2014, XCOR started development of its new headquarters at Midland International Air and Space Port, Texas. Manufacturing of Lynx II and Lynx III vehicles will take place at a hangar adjacent to the Shuttle Landing Facility (SLF) at Kennedy Space Center, Florida.

Launch service provider
XCOR Aerospace

Organization Headquarters
USA

Manufacturer
XCOR Aerospace

Mass, kg (lb)
4,850 (10,692)

Length, m (ft)
8.5 (27.9)

Wingspan, m (ft)
7.3 (24)

Year of Planned First Launch
2018

Launch sites
KSC (Runway)
Midland International Airport

GTO capacity, kg (lb)
N/A

LEO capacity, kg (lb)
10 (22)

Estimated Price per Launch
$545,000

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

FAA AST

Launch Vehicle Fact Sheet

Lynx Mark III

The Lynx Mark I continues to take shape in this 2015 photo. Source: XCOR Aerospace

Fairing	Length, m (ft)	Diameter, m (ft)
Standard Fairing	N/A	N/A

	1st Stage	2nd Stage
Stage designation	Lynx Mark III	2nd Stage
Length, m (ft)	10 (33)	3.4 (11.2) *est*
Diameter/Wingspan, m (ft)	7.3 (24)	0.7 (2.3) *est*
Manufacturer	XCOR Aerospace	XCOR Aerospace
Propellant	LOX/Kerosene	Undisclosed
Propellant mass, kg (lb)	Undisclosed	Undisclosed
Total thrust, kN (lbf)	12.9 (2,900)	Undisclosed
Engine(s)	4 x XR-5K18	Undisclosed
Engine manufacturer	XCOR Aerospace	XCOR Aerospace
Engine thrust, kN (lbf)	51.6 (11,600)	Undisclosed

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

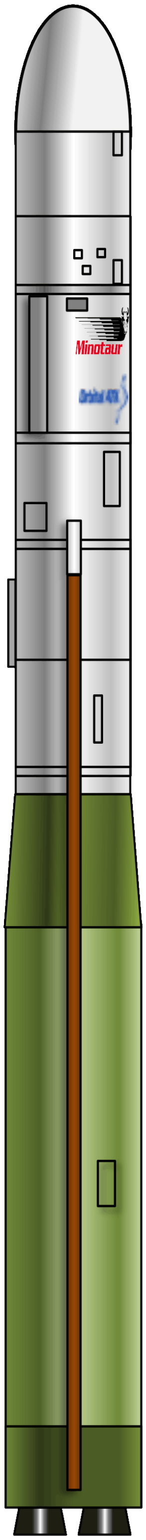
Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

Minotaur I



Orbital ATK provides the Minotaur I as a responsive and cost-effective launch solution for U.S. Government spacecraft. The launch vehicle is composed of residual 1960s era Minuteman II first and second stage solid rocket motors integrated with Orion upper stages.

Because it leverages retired ballistic missile components that were designed to be stored for long periods of time, the Minotaur I requires little in the way of launch infrastructure and processing. This makes it an attractive choice for small military payloads in particular.

The M55 first stage is powered by four individual nozzles that can be gimballed for attitude control. When launched from Virginia's Mid-Atlantic Regional Spaceport (MARS), the first stage is protected from cold weather by an insulative blanket that peels away as the vehicle clears the tower. An optional Hydrazine Auxiliary Propulsion Stage (HAPS) is also available as a fifth stage, though this has not been used on previous missions. Eleven successful launches of the Minotaur I placed 62 satellites into orbit.

Minotaur I missions are provided under the Orbital/Suborbital Program (OSP) managed by the U.S. Air Force Space and Missile Systems Center (SMC), Advanced Systems and Development Directorate, Rocket Systems Launch Program.

Launch service provider
Orbital ATK

Organization Headquarters
USA

Manufacturer
Orbital ATK

Mass, kg (lb)
36,200 (79,807)

Length, m (ft)
19.2 (63)

Diameter, m (ft)
1.7 (5.6)

Year of First Launch
2000

Number of Launches
11

Reliability
100%

Launch sites
VAFB (SLC-8)
MARS (LP-0B)

GTO capacity, kg (lb)
N/A

LEO capacity, kg (lb)
580 (1,279)

SSO capacity, kg (lb)
331 (730)

Estimated Price per Launch
$40M

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

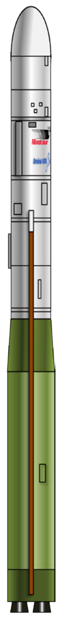
Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

Minotaur I

FAA AST



Minotaur I
Standard Fairing

Minotaur I
Extended Fairing

A Minotaur I lifts off from MARS on November 20, 2013 carrying 29 payloads. At the time, this was a U.S. record for number of payloads launched at once. Note the insulative blanket, which peels away seconds after lift off. Source: Orbital ATK

Fairing	Length, m (ft)	Diameter, m (ft)
Standard Fairing	3.8 (12.5)	1.3 (4.3)
Stretched Fairing	6.1 (20)	1.6 (5.2)

	1st Stage	2nd Stage	3rd Stage	4th Stage
Stage designation	M55 A1	SR19	Orion-50XL	Orion-38
Length, m (ft)	7 (22.9)	2.6 (8.4)	2.3 (7.2)	1.8 (5.8)
Diameter, m (ft)	1.7 (5.5)	1.3 (4.3)	1.2 (4.1)	1.2 (4.1)
Manufacturer	Orbital ATK	Orbital ATK	Orbital ATK	Orbital ATK
Propellant	Solid	Solid	Solid	Solid
Propellant mass, kg (lb)	20,785 (45,823)	6,237 (13,750)	3,930 (8,664)	770 (1,698)
Total thrust, kN (lbf)	935 (210,000)	268 (60,000)	118.2 (26,600)	34.8 (7,800)

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

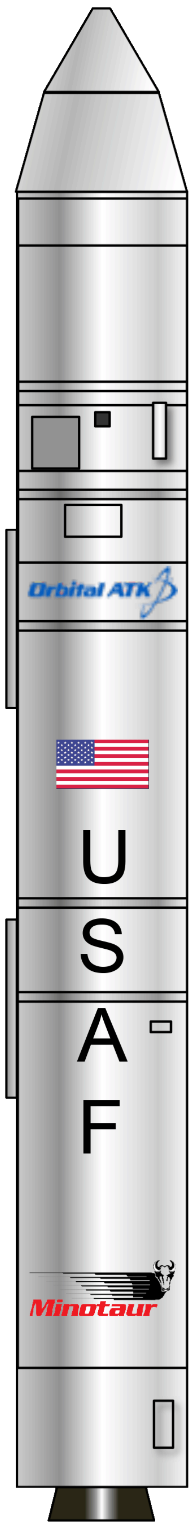
Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

Minotaur IV



The Minotaur IV is an orbital launch vehicle offered by Orbital ATK. The vehicle is derived from the Peacekeeper intercontinental ballistic missile (ICBM).

The four-stage vehicle is exclusively provided for U.S. Government customers. Though designed primarily for orbital launches, the Minotaur IV is also periodically used for suborbital missions. Most notably, the vehicle was used to deploy Hypersonic Technology Vehicles (HTV) for the Defense Advanced Research Projects Agency (DARPA).

There are three versions of the Minotaur IV. The Minotaur IV Lite is a three-stage version used for suborbital missions. The Minotaur IV+ uses a more powerful Star-48V upper stage instead of the Orion-38 used by the standard Minotaur IV.

Minotaur IV missions are provided under the Orbital/Suborbital Program (OSP) managed by the U.S. Air Force Space and Missile Systems Center (SMC), Advanced Systems and Development Directorate, Rocket Systems Launch Program.

Launch service provider
Orbital ATK

Organization Headquarters
USA

Manufacturer
Orbital ATK

Mass, kg (lb)
86,300 (190,259)

Length, m (ft)
23.9 (78.4)

Diameter, m (ft)
2.3 (7.5)

Year of First Launch
2010

Number of Launches
3

Reliability
100%

Launch sites
CCAFS (SLC-46)
VAFB (SLC-8)
MARS (LP-0B)
PSCA (LP-1)

GTO capacity, kg (lb)
N/A

LEO capacity, kg (lb)
1,600 (3,527)

SSO capacity, kg (lb)
1,190 (2,624)

Estimated Price per Launch
$46M

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

Minotaur IV

Minotaur IV Lite
Suborbital

Minotaur IV
Orion-38
as 4th Stage

Minotaur IV+
STAR-48V
as 4th Stage

Fairing	Length, m (ft)	Diameter, m (ft)
Standard Fairing	4.11 (13.5)	2.1 (6.7)

	1st Stage	2nd Stage	3rd Stage	4th Stage	5th Stage
Stage designation	SR-118	SR-119	SR-120	Orion-38	STAR-48V
Length, m (ft)	8.5 (27.9)	7.9 (25.9)	2.4 (7.9)	1.8 (5.8)	2 (6.6)
Diameter, m (ft)	2.3 (7.5)	2.3 (7.5)	2.3 (7.5)	1.2 (4.1)	1.2 (3.9)
Manufacturer	Orbital ATK	Orbital ATK	Orbital ATK	Orbital ATK	Orbital ATK
Propellant	Solid	Solid	Solid	Solid	Solid
Propellant mass, kg (lb)	45,400 (100,090)	24,500 (54,013)	7,080 (15,609)	770 (1,698)	2,010 (4,431)
Total thrust, kN (lbf)	1,607 (361,000)	1,365 (307,000)	329 (74,000)	34.8 (7,800)	64 (14,000)

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

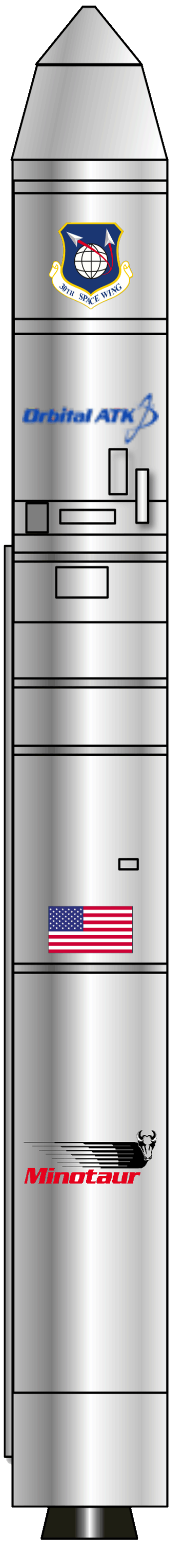
Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

Minotaur V



Orbital ATK is the manufacturer and launch service provider of the Minotaur V. The vehicle is used primarily for payloads destined for geosynchronous transfer orbit (GTO) or orbital trajectories to the Moon and beyond. The U.S. Government is the primary customer for this vehicle.

The first, second, and third stages of the Minotaur V are legacy systems - they are former Peacekeeper solid rocket motors re-purposed for orbital launch. Though the Minotaur V has flown only once, each Peacekeeper stage has a record fo 50 flights.

As of December 2015, the Minotaur V has only been used once. It successfully launched NASA's Lunar Atmosphere and Dust Environment Explorer (LADEE) on September 7, 2013 from Virginia's Mid-Atlantic Regional Spaceport (MARS).

Minotaur V missions are provided under the Orbital/Suborbital Program (OSP) managed by the U.S. Air Force Space and Missile Systems Center (SMC), Advanced Systems and Development Directorate, Rocket Systems Launch Program.

Launch service provider
Orbital ATK

Organization Headquarters
USA

Manufacturer
Orbital ATK

Mass, kg (lb)
89,373 (197,034)

Length, m (ft)
24.5 (80.6)

Diameter, m (ft)
2.3 (7.5)

Year of First Launch
2013

Number of Launches
1

Reliability
100%

Launch sites
VAFB (SLC-8)
MARS (LP-0B)
PSCA (LP-1)

GTO capacity, kg (lb)
532 (1,173)

LEO capacity, kg (lb)
N/A

Estimated Price per Launch
$55M

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

Minotaur V

FAA AST

The Minotaur V with NASA's LADEE probe poised for launch in 2015. Source: NASA

Fairing	Length, m (ft)	Diameter, m (ft)
Standard Fairing	4.11 (13.5)	2.1 (6.7)

	1st Stage	2nd Stage	3rd Stage	4th Stage	5th Stage
Stage designation	SR-118	SR-119	SR-120	STAR-48V	STAR-37FM/V
Length, m (ft)	8.5 (27.9)	7.9 (25.9)	2.4 (7.9)	2 (6.6)	1.7 (5.5)
Diameter, m (ft)	2.3 (7.5)	2.3 (7.5)	2.3 (7.5)	1.2 (3.9)	0.9 (3.1)
Manufacturer	Orbital ATK	Orbital ATK	Orbital ATK	Orbital ATK	Orbital ATK
Propellant	Solid	Solid	Solid	Solid	Solid
Propellant mass, kg (lb)	45,400 (100,090)	24,500 (54,013)	7,080 (15,609)	2,010 (4,431)	1,066 (2,350)
Total thrust, kN (lbf)	1,607 (361,000)	1,365 (307,000)	329 (74,000)	64 (14,000)	47.3 (10,633)

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

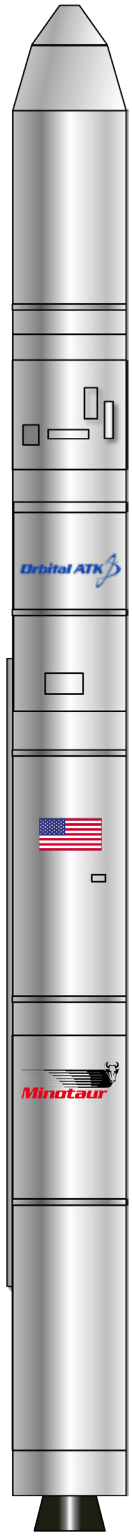
Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

Minotaur VI



The Minotaur VI, offered by Orbital ATK, is derived from the Minotaur IV. The five-stage vehicle is essentially identical to the Minotaur IV, except that it features an additional SR-118 solid motor stage. The only new piece of hardware is the interstage assembly that separates the two SR-118 stages.

The vehicle is designed to leverage flight-proven hardware in the Minotaur IV and V vehicles, but adding additional low Earth orbit (LEO) capacity and increasing capability for geosynchronous transfer orbit (GTO) and Earth escape trajectories.

As of publication, no Minotaur VI vehicles have flown, and a contract for a Minotaur VI mission has not yet been signed.

Minotaur VI missions are provided under the Orbital/Suborbital Program (OSP) managed by the U.S. Air Force Space and Missile Systems Center (SMC), Advanced Systems and Development Directorate, Rocket Systems Launch Program.

Launch service provider
Orbital ATK

Organization Headquarters
USA

Manufacturer
Orbital ATK

Mass, kg (lb)
89,373 (197,034)

Length, m (ft)
32.6 (107)

Diameter, m (ft)
2.3 (7.5)

Year of Planned First Launch
TBD

Launch sites
VAFB (SLC-8)
MARS (LP-0B)
PSCA (LP-1)

GTO capacity, kg (lb)
860 (1,896)

LEO capacity, kg (lb)
2,600 (5,732)

SSO capacity, kg (lb)
2,250 (4,960)

Estimated Price per Launch
$60M

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

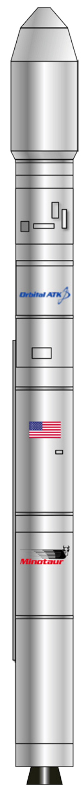
FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

Minotaur VI

FAA AST

Minotaur VI
Standard Fairing



Minotaur VI
Large Fairing

Though the Minotaur VI has been available to customers for a few years, none have flown.

Fairing	Length, m (ft)	Diameter, m (ft)
Standard Fairing	5.3 (17.4)	2 (0.6)
Large Fairing	5.3 (17.4)	2.5 (8.2)

	1st Stage	2nd Stage	3rd Stage	4th Stage	5th Stage
Stage designation	SR-118	SR-118	SR-119	SR-120	STAR-48V
Length, m (ft)	8.5 (27.9)	8.5 (27.9)	7.9 (25.9)	2.4 (7.9)	2 (6.6)
Diameter, m (ft)	2.3 (7.5)	2.3 (7.5)	2.3 (7.5)	2.3 (7.5)	1.2 (3.9)
Manufacturer	Orbital ATK	Orbital ATK	Orbital ATK	Orbital ATK	Orbital ATK
Propellant	Solid	Solid	Solid	Solid	Solid
Propellant mass, kg (lb)	45,400 (100,090)	45,400 (100,090)	24,500 (54,013)	7,080 (15,609)	2,010 (4,431)
Total thrust, kN (lbf)	1,607 (361,000)	1,607 (361,000)	1,365 (307,000)	329 (74,000)	64 (14,000)

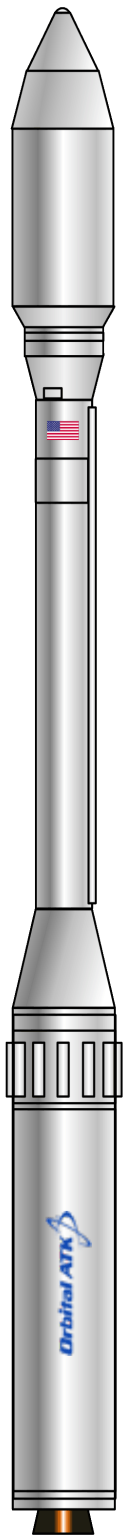
Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet
Minotaur-C



Orbital ATK offers the four-stage small-class vehicle, Minotaur-C, as an option for satellite customers. The Minotaur-C is an upgraded version of the Taurus first introduced in 1994 and developed under sponsorship of the Defense Advance Research Projects Agency (DARPA). Several variants of the Minotaur-C are available, allowing Orbital ATK to mix and match different stages and fairings to address customer needs.

The Minotaur-C launches from SLC-376E at Vandenberg Air Force Base (VAFB), though it may also be launched from SLC-46 at Cape Canaveral Air Force Station (CCAFS) and Pad 0-B at Virginia's Mid-Atlantic Regional Spaceport (MARS).

Skybox Imaging signed a contract with Orbital ATK in 2014 for the launch of six SkySat satellites on a single Minotaur-C. The launch is planned for 2016.

Launch service provider
Orbital ATK

Organization Headquarters
USA

Manufacturer
Orbital ATK

Mass, kg (lb)
77,000 (170,000)

Length, m (ft)
32 (104)

Diameter, m (ft)
1.6 (5.2)

Year of Planned First Launch
2016

Launch sites
CCAFS (SLC-46)
VAFB (LC-576E)
MARS (LP-0B)
PSCA (LP-1)

GTO capacity, kg (lb)
N/A

LEO capacity, kg (lb)
1,278-1,458 (2,814-3,214)

SSO capacity, kg (lb)
912-1,054 (2,008-2,324)

Estimated Price per Launch
$40M-$50M

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

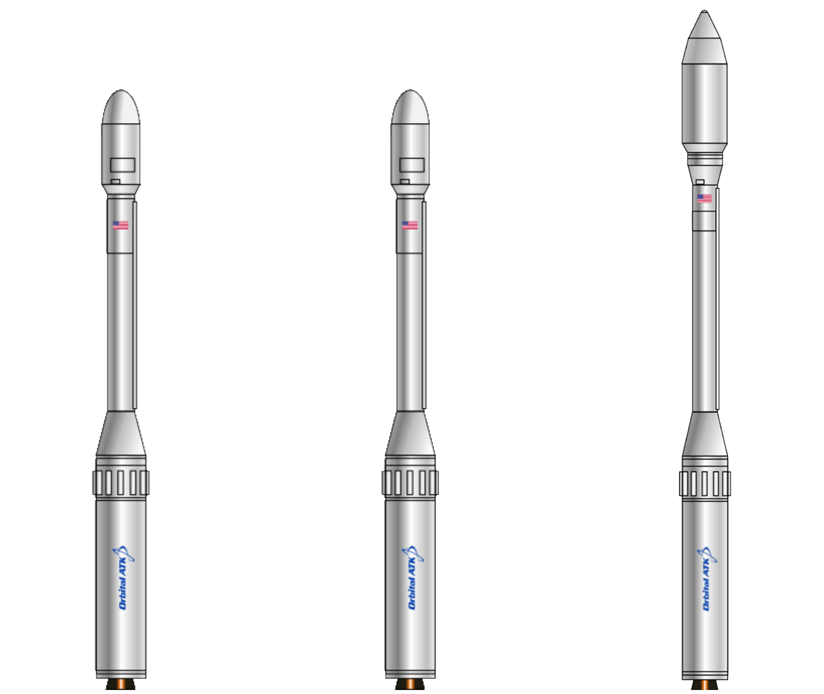
Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

Minotaur-C



3110 Minotaur-C 3113 Minotaur-C 3210 Minotaur-C

The Minotaur-C is essentially and upgraded version of the flight proven Taurus vehicle once offered by Orbital Sciences Corporation (now Orbital ATK).

Fairing	Length, m (ft)	Diameter, m (ft)
2.3-Meter Fairing	1.6 (5.2)	2.3 (7.5)
1.6-Meter Fairing	2.2 (7.2)	1.6 (5.2)

	1st Stage	2nd Stage	3rd Stage Option	3rd Stage Option	4th Stage Option
Stage designation	Castor-120	Orion-50SXLG	Orion-38	STAR-37	STAR-37
Length, m (ft)	9.1 (29.9)	8.9 (29.2)	1.3 (4.3)	2.3 (7.5)	2.3 (7.5)
Diameter, m (ft)	2.4 (7.9)	1.3 (4.3)	1 (3.3)	0.7 (2.3)	0.7 (2.3)
Manufacturer	Orbital ATK	Orbital ATK	Orbital ATK	Orbital ATK	Orbital ATK
Propellant	Solid	Solid	Solid	Solid	Solid
Propellant mass, kg (lb)	48,960 (107,939)	15,023 (33,120)	770 (1,697)	1,066 (2,350)	1,066 (2,350)
Total thrust, kN (lbf)	1,904 (428,120)	704 (157,729)	36 (8,062)	47.3 (10,625)	47.3 (10,625)

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

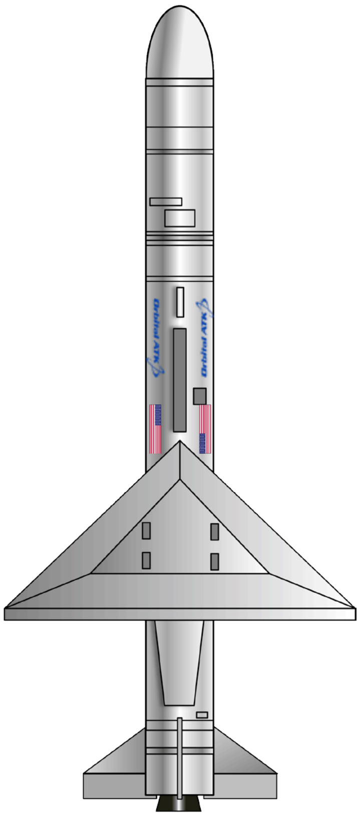
Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

Pegasus XL



Orbital ATK's Pegasus XL is a small-class, air-launched vehicle. Orbital ATK offers the Pegasus XL as a means to launch small satellites to low Earth orbits (LEO).

The vehicle is derived from the first generation Standard Pegasus first launched in 1990. It is normally composed of three solid propellant stages manufactured by ATK, but it may also include an Orbital-built Hydrazine Auxiliary Propulsion System (HAPS) as a fourth stage. The vehicle uses a 1.2-meter (3.9-foot) payload fairing. The first, second, and third stages are manufactured by ATK and include Orion-50SXL, Orion-50XL, and Orion-38 motors, respectively. The Orion-50SXL is also integrated with a wing, enabling aerodynamic flight during the launch phase. The vehicle is air-launched from a Lockheed-built L-1011 aircraft.

The Pegasus XL has flown 26 consecutive successful missions since 1997, but did not fly in 2014 or 2015.

LEO capacity figures are for the Pegasus XL without a HAPS fourth stage from Cape Canaveral Air Force Station (CCAFS). Sun-synchronous orbit (SSO) figures are for the same vehicle configuration launched from Vandenberg Air Force Base (VAFB).

Launch service provider
Orbital ATK

Organization Headquarters
USA

Manufacturer
Orbital ATK

Mass, kg (lb)
23,130 (50,993)

Length, m (ft)
16.9 (55.4)

Diameter, m (ft)
1.3 (4.2)

Year of First Launch
1994

Number of Launches
32

Reliability
91%

Launch sites
CCAFS, Kwajalein, VAFB, WFF

GTO capacity, kg (lb)
N/A

LEO capacity, kg (lb)
450 (992)

SSO capacity, kg (lb)
325 (717)

Estimated Price per Launch
$40M

FAA AST

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

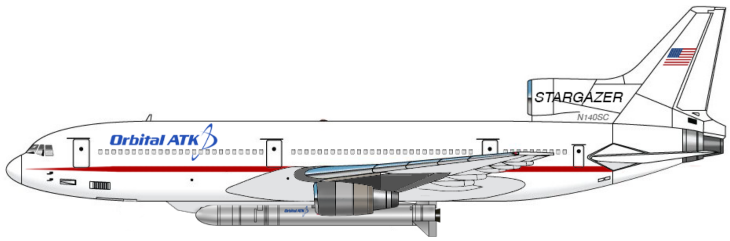
Publication produced for FAA AST by The Tauri Group under contract.

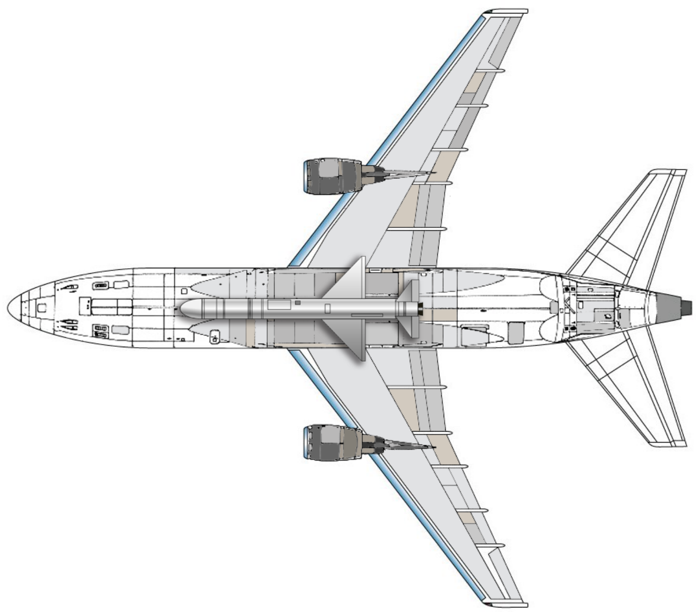
FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

FAA AST

Launch Vehicle Fact Sheet

Pegasus XL





Orbital ATK uses a modified L-1011 aircraft to carry and launch the Pegasus XL vehicle. The ground equipment necessary to launch the system is minimal, and the combination can be launched from almost any conventional runway.

Fairing	Length, m (ft)	Diameter, m (ft)
Standard Fairing	2.1 (6.9)	1.2 (3.9)

	1st Stage	2nd Stage	3rd Stage	4th Stage
Stage designation	Orion-50SXL	Orion-50XL	Orion-38	HAPS
Length, m (ft)	10.27 (33.7)	3.1 (10.2)	1.3 (4.3)	0.7 (2.3)
Diameter, m (ft)	1.3 (4.3)	1.3 (4.3)	1 (3.3)	1 (3.3)
Manufacturer	Orbital ATK	Orbital ATK	Orbital ATK	Orbital ATK
Propellant	Solid	Solid	Solid	Hydrazine
Propellant mass, kg (lb)	15,014 (33,105)	3,925 (8,655)	770 (1,697)	73 (161)
Total thrust, kN (lbf)	726 (163,247)	196 (44,171)	36 (8,062)	0.6 (135)
Engine(s)	--	--	--	3 x Rocket Engine Assemblies
Engine manufacturer	--	--	--	Orbital ATK
Engine thrust, kN (bf)	726 (163,247)	196 (44,171)	36 (8,062)	0.2 (45)

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

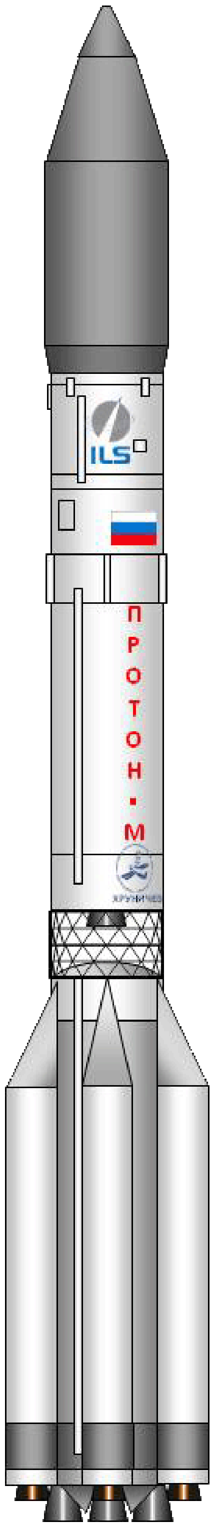
Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

Proton M



The Proton M is provided by International Launch Services (ILS) as a launch option for government and commercial operators of satellites in geosynchronous orbit. It is typically not used for missions to low Earth orbit (LEO).

The Proton M is built by the Khrunichev State Research and Production Space Center. The vehicle traces its lineage to the UR500 system developed by Vladimir Chelomei's OKB-52 design bureau in 1965. The Proton was originally intended to send cosmonauts to the Moon until Soviet leadership selected Sergei Korolov's N-1 vehicle instead. The Proton launched the Soviet Union's Almaz (Salyut) and Mir space stations, and two modules of the International Space Station (ISS).

Until December 2012, the Russian government used an earlier version of the Proton, often called the Proton K. It now uses the Proton M with either versions of the Block DM or the Breeze-M as the fourth stage or as a three-stage vehicle for LEO missions.

When introduced in 2001, the Proton M maintained a flawless record of 13 launches before a failure was encountered in 2006. Since then, there has been a Proton M failure each year except in 2009. The 2014 failure in May resulted in the loss of the Express AM4R satellite.

The Khrunichev-designed and built Angara series of vehicles is expected to gradually replace the Proton M beginning in 2015.

Launch service provider
VKS/Roscosmos/ILS

Organization Headquarters
Russia

Manufacturer
Khrunichev

Mass, kg (lb)
712,800 (1,571,400)

Length, m (ft)
53 (173)

Diameter, m (ft)
7.4 (24)

Year of First Launch
2001

Number of Launches
86

Reliability
91%

Launch sites
Baikonur (LC-81, LC-200)

GTO capacity, kg (lb)
6,920 (15,256)

LEO capacity, kg (lb)
23,000 (50,706)

SSO capacity, kg (lb)
N/A

Estimated Price per Launch
$65M

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

Proton M

A Proton M is poised from launch from Baikonur Cosmodrome in 2014. Source: ILS

Fairing	Length, m (ft)	Diameter, m (ft)
PLF-BR-13305 Fairing	13.3 (43.6)	4.4 (14.4)
PLF-BR-15255 Fairing	15.3 (50.2)	4.4 (14.4)

	1st Stage	2nd Stage	3rd Stage	4th Stage
Stage designation	1st Stage	2nd Stage	3rd Stage	Breeze-M
Length, m (ft)	21.2 (69.6)	17.1 (56.1)	4.1 (13.5)	2.7 (8.9)
Diameter, m (ft)	7.4 (24.3)	4.1 (13.5)	4.1 (13.5)	4 (13)
Manufacturer	Khrunichev	Khrunichev	Khrunichev	Khrunichev
Propellant	N_2O_4/UDMH	N_2O_4/UDMH	N_2O_4/UDMH	N_2O_4/UDMH
Propellant mass, kg (lb)	428,300 (944,239)	157,300 (346,787)	46,562 (102,651)	19,800 (43,651)
Total thrust, kN (lbf)	10,000 (2,248,089)	2,400 (539,541)	583 (131,063)	19.2 (4,411)
Engine(s)	6 x RD-276	3 x RD-0210	1 x RD-0123	1 x 14D30
Engine manufacturer	NPO Energomash	KB Khimavtomatika	KB Khimavtomatika	DB Khimmash
Engine thrust, kN (lbf)	1,667 (374,682)	800 (179,847)	583 (131,063)	19.6 (4,411)

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

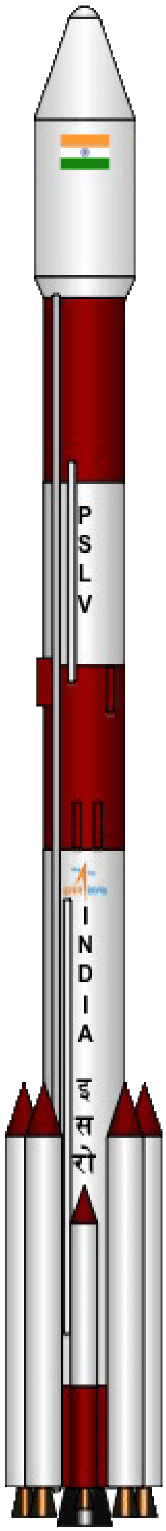
Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

PSLV



The Indian Space Research Organization (ISRO) has offered the Polar Satellite Launch Vehicle (PSLV) since 1993. The vehicle is used to launch small and medium payloads to low Earth orbit and, on occasion, to send small satellites to geosynchronous orbit. For missions to LEO, it is not uncommon for the PSLV to launch several satellites at a time.

The PSLV is available in three variants. The basic version is known as the PSLV-CA, for "Core Alone." The PSLV-G, or standard PSLV, is teh more common variant and features six solid strap-on motors attached to the first stage core. The PSLV-XL is similar to the standard PSLV, but the six solid boosters are longer to accomodate greater propellant mass and thus increasing buring time.

The PSLV has been used for four commercial launches. The latest was a 2014 launch that carried payloads for France (SPOT 7), Canada (Can-X4 and X5), Germany (AISAT), and Singapore (VELOX-1). SPOT 7 was sold to the government of Azerbaijan several moths later.

Launch service provider
ISRO/Antrix

Organization Headquarters
India

Manufacturer
ISRO

Mass, kg (lb)
320,000 (705,479)

Length, m (ft)
44 (144)

Diameter, m (ft)
2.8 (9.2)

Year of First Launch
1993

Number of Launches
30

Reliability
97%

Launch sites
Satish Dhawan (FLP, SLP)

GTO capacity, kg (lb)
1,425 (3,142)

LEO capacity, kg (lb)
3,250 (7,165)

SSO capacity, kg (lb)
1,750 (3,858)

Estimated Price per Launch
$33M

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

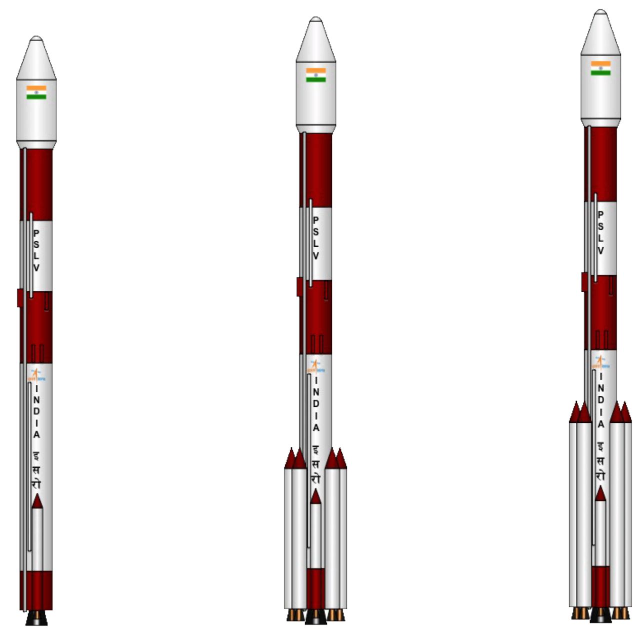
Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

PSLV

FAA AST



PSLV-CA PSLV-G PSLV-XL

Notable PSLV payloads include Chandrayaan-1, Mars Orbiter Mission (MOM), Space Capsule Recovery Experiment, and the Indian Regional Navigation Satellite System (IRNSS).

Fairing	Length, m (ft)	Diameter, m (ft)
PSLV Fairing	8.3 (27.2)	3.2 (10.5)

	Solid Boosters*	1st Stage	2nd Stage	3rd Stage	4th Stage
Stage designation	PSOM	PS1	PS2	PS3	PS4
Length, m (ft)	G: 10 (32.8) XL: 13.5 (44.3)	20.34 (66.7)	12.8 (42)	3.54 (11.6)	2.6 (8.5)
Diameter, m (ft)	1 (3.3)	2.8 (9.2)	2.8 (9.2)	2.02 (6.6)	2.02 (6.6)
Manufacturer	ISRO	ISRO	ISRO	ISRO	ISRO
Propellant	Solid	Solid	N_2O_4/UDMH	Solid	Solid
Propellant mass, kg (lb)	G: 9,000 (19,842) XL: 12,000 (26,455)	138,000 (304,238)	40,700 (89,728)	6,700 (14,771)	2,000 (4,409)
Total thrust, kN (lbf)	4,314 (969,828)	4,800 (1,079,082)	799 (179,622)	240 (53,954)	14.6 (3,282)
Engine(s)	--	--	1 x Vikas	--	2 x PS-4
Engine manufacturer	--	--	ISRO	--	ISRO
Engine thrust, kN (lbf)	719 (161,638)	4,800 (1,079,082)	799 (179,622)	240 (53,954)	7.3 (1,641)

** Figures are for each booster. Total thrust is sum of all boosters.*

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

Rockot

FAA AST

The three-stage Rockot is developed using refurbished missile components. The missile used as the basis for the commercially available vehicle is the UR100N (SS-19) intercontinental ballistic missile (ICBM) built by Soviet-era OKB-52. Production and launch of the Rockot is managed by Eurockot Launch Services GmbH, a joint company between Russia's Khrunichev State Research and Production Space Center and EADS Astrium.

The Rockot consists of three stages. The first two stages are composed of SS-19 booster segments. The first stage is powered by an RD-244 engine and the second by an RD-235 engine. The third stage is a newly manufactured Khrunichev Breeze-KM upper stage. A payload adapter and fairing complete the vehicle system.

Since 1990, the vehicle has launched 24 times, with 2 failures. The first three launches were with the initial version, the Rockot-K. In May 2000, the vehicle was upgraded to accommodate a larger payload, it became the Rockot-KM, which has launched 21 times with 2 failures. The Rockot-KM launches from Plesetsk Kosmodrome in Russia.

The Rockot is predominantly used for scientific Earth observation and climate research missions in LEO. Eleven flights have been performed by Eurockot Launch Services for international customers. Rockot-KM currently has a backlog of commercial customers until 2015 and Russian government flights to the end of the decade.

Launch service provider
VKS/Eurockot

Organization Headquarters
Russia

Manufacturer
Khrunichev

Mass, kg (lb)
107,000 (235,895)

Length, m (ft)
29.2 (95.8)

Diameter, m (ft)
2.5 (8.2)

Year of First Launch
2000

Number of Launches
27

Reliability
93%

Launch sites
Plesetsk (LC-133)

GTO capacity, kg (lb)
N/A

LEO capacity, kg (lb)
1,820-2,150 (4,012-4,740)

SSO capacity, kg (lb)
1,180-1,600 (2,601-3,527)

Estimated Price per Launch
$41.8M

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

FAA AST

Launch Vehicle Fact Sheet

Rockot

A Rockot vehicle is launched from Plestesk Cosmodrome. Source: Eurockot

Fairing	Length, m (ft)	Diameter, m (ft)
Standard Fairing	2.6 (8.5)	2.5 (8.2)

	1st Stage	2nd Stage	3rd Stage
Stage designation	1st Stage	2nd Stage	Breeze-KM
Length, m (ft)	17.2 (56.4)	3.9 (12.8)	2.5 (8.2)
Diameter, m (ft)	2.5 (8.2)	2.5 (8.2)	2.5 (8.2)
Manufacturer	OKB-52 (Khrunichev)	OKB-52 (Khrunichev)	Khrunichev
Propellant	N_2O_4/UDMH	N_2O_4/UDMH	N_2O_4/UDMH
Propellant mass, kg (lb)	71,455 (157,531)	10,710 (23,612)	4,975 (10,968)
Total thrust, kN (lbf)	1,870 (420,393)	240 (53,954)	19.6 (4,406)
Engine(s)	3 x RD-0233 1 x RD-0234	1 x RD-235	1 x S5.98M
Engine manufacturer	OKB-154 (KB Khimavtomatika)	OKB-154 (KB Khimavtomatika)	Khrunichev
Engine thrust, kN (lbf)	520 (116,901)	240 (53,954)	19.6 (4,406)

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

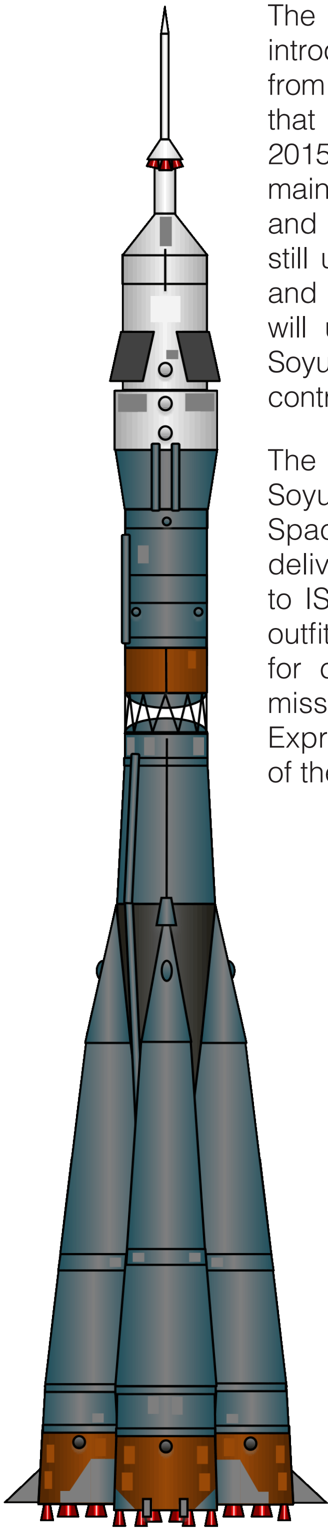
Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

Soyuz FG



The Soyuz FG vehicle (11A511FG), introduced in 2001, is an improvement from the Soyuz U (11A511U) vehicle that was in service from 1973 to 2015. The improvements focused mainly on upgrades to the RD-108 and RD-107 engines. The vehicle still uses an analog control system, and it is anticipated that the vehicle will ultimately be replaced by the Soyuz 2 series, which has a digital control system.

The vehicle is used for crewed Soyuz missions to the International Space Station (ISS). It is also used to deliver the Progess cargo modules to ISS. The Soyuz FG can also be outfitted with a Fregat upper stage for certain missions; examples of missions using Fregat include Mars Express and some replenishments of the Globalstar constellation.

Launch service provider
VKS/Roscosmos

Organization Headquarters
Russia

Manufacturer
TsSKB Progress

Mass, kg (lb)
305,000 (672,410)

Length, m (ft)
49.5 (162.4)

Diameter, m (ft)
10.3 (33.8)

Year of First Launch
2001

Number of Launches
49

Reliability
100%

Launch sites
Baikonur (LC-1, LC-31)

GTO capacity, kg (lb)
N/A

LEO capacity, kg (lb)
7,800 (17,196)

SSO capacity, kg (lb)
4,500 (9,921)

Estimated Price per Launch
$50M-$213M

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

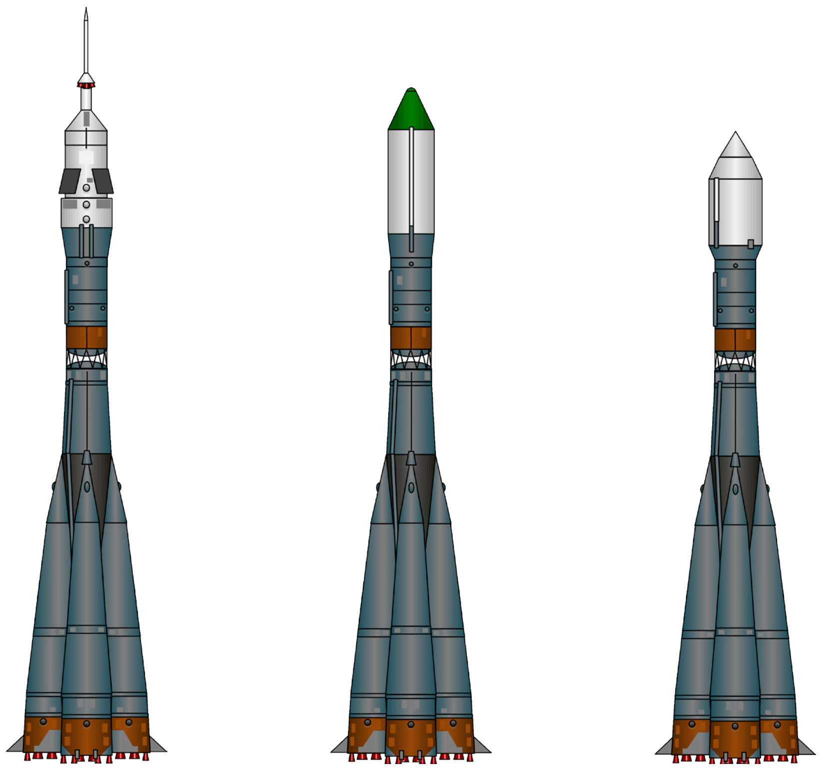
Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

Soyuz FG



Soyuz FG Crewed | Soyuz FG Progress | Soyuz FG Fregat

Fairing	Length, m (ft)	Diameter, m (ft)
Standard Fairing	11.4 (37.4)	4.1 (13.5)

	1st Stage	4 x Liquid Boosters	2nd Stage	3rd Stage
Stage designation	Core Stage	1st Stage	2nd Stage	Fregat
Length, m (ft)	27.1 (88.9)	19.6 (64.3)	6.7 (22)	1.5 (4.9)
Diameter, m (ft)	3 (9.8)	2.7 (8.9)	2.7 (8.9)	3.4 (11)
Manufacturer	TsSKB-Progress	TsSKB-Progress	TsSKB-Progress	NPO Lavochkin
Propellant	LOX/Kerosene	LOX/Kerosene	LOX/Kerosene	N_2O_4/UDMH
Propellant mass, kg (lb)	90,100 (198,636)	39,160 (86,333)	25,400 (55,997)	5,350 (11,795)
Total thrust, kN (lbf)	838.5 (188,502)	792.5 (178,161)	297.9 (66,971)	19.6 (4,406)
Engine(s)	1 x RD-108A	1 x RD-107A	2.1a: 1 x RD-0110 2.1b: 1 x RD-0124	1 x S5.92
Engine manufacturer	AO Motorostroitel	AO Motorostroitel	Voronyezh	KB KhIMMASH
Engine thrust, kN (lbf)	838.5 (188,502)	792.5 (178,161)	2.1a: 297.9 (66,971) 2.1b: 297.9 (66,971)	19.6 (4,406)

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

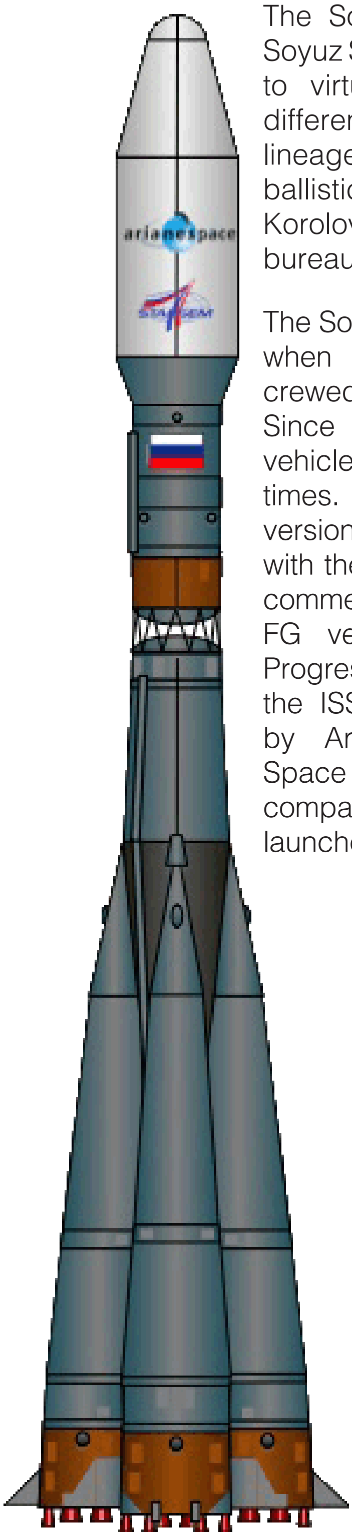
Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

Soyuz 2.1a/b



The Soyuz 2 (also referred to as Soyuz ST) is used to launch satellites to virtually any orbit from three different launch sites. It can trace its lineage to the R-7 intercontinental ballistic missile designed by Sergei Korolov and his OKB-1 design bureau in the mid-1950s.

The Soyuz received its current name when it was selected to launch crewed Soyuz spacecraft in 1966. Since that year, the R-7-derived vehicles have launched almost 1,800 times. There have been several versions of the Soyuz, culminating with the Soyuz 2 currently providing commercial service. The older Soyuz FG version continues to launch Progress and Soyuz missions to the ISS. The Soyuz 2 is operated by Arianespace at the Guiana Space Center. Arianespace's sister company, Starsem, manages Soyuz launches from Baikonur.

The Soyuz 2 is manufactured by TsSKB-Progress at the Samara Space Center and NPO Lavotchkin (the upper stage). The vehicle consists of a core stage powered by an RD-108A, four liquid strap on boosters powered by RD-107A engines, a second stage powered by an RD-0124 engine, and a Lavotchkin Fregat upper stage powered by an S5.92 engine. A payload adapter and standard 4-meter (13-foot) diameter fairing complete the vehicle system. TsSKB-Progress can produce about 20 Soyuz vehicles per year.

Launch service provider
VKS/Arianespace/Starsem

Organization Headquarters
Russia/France

Manufacturer
TsSKB Progress

Mass, kg (lb)
107,000 (235,895)

Length, m (ft)
29.2 (95.8)

Diameter, m (ft)
2.5 (8.2)

Year of First Launch
2000

Number of Launches
27

Reliability
93%

Launch sites
Plesetsk (LC-133)
Guiana Space Center (ELS)

GTO capacity, kg (lb)
N/A

LEO capacity, kg (lb)
1,820-2,150 (4,012-4,740)

SSO capacity, kg (lb)
1,180-1,600 (2,601-3,527)

Estimated Price per Launch
$80M

The Soyuz 2 variant has flown 38 times, with three failures. The 2014 failure, due to a fault in the Fregat upper stage, resulted in the loss of two Galileo navigation satellites.

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

FAA AST

Launch Vehicle Fact Sheet

Soyuz 2.1a/b

A Soyuz 2.1b launches two Galileo navigation satellites from the Guiana Space Center in 2015. Source: Arianespace

Fairing	Length, m (ft)	Diameter, m (ft)
Standard Fairing	11.4 (37.4)	4.1 (13.5)

	1st Stage	4 x Liquid Boosters	2nd Stage	3rd Stage
Stage designation	Core Stage	1st Stage	3rd Stage	Fregat
Length, m (ft)	27.1 (88.9)	19.6 (64.3)	6.7 (22)	1.5 (4.9)
Diameter, m (ft)	3 (9.8)	2.7 (8.9)	2.7 (8.9)	3.4 (11.2)
Manufacturer	TsSKB-Progress	TsSKB-Progress	TsSKB-Progress	NPO Lavotchkin
Propellant	LOX/Kerosene	LOX/Kerosene	LOX/Kerosene	N_2O_4/UDMH
Propellant mass, kg (lb)	90,100 (198,636)	39,160 (86,333)	25,400 (55,997)	6,638 (14,634)
Total thrust, kN (lbf)	838.5 (188,502)	792.5 (178,161)	297.9 (66,971)	19.9 (4,474)
Engine(s)	1 x RD-108A	1 x RD-107A	2.1a: 1 x RD-0110 2.1b: 1 x RD-0124	1 x S5.92
Engine manufacturer	AO Motorostroitel	AO Motorostroitel	Voronyezh	NPO Lavotchkin
Engine thrust, kN (lbf)	838.5 (188,502)	792.5 (178,161)	2.1a: 297.9 (66,971) 2.1b: 297.9 (66,971)	19.9 (4,474)

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

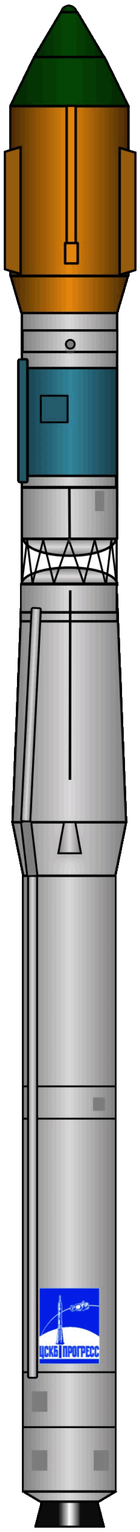
Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

Soyuz 2.1v



The Soyuz 2.1v (formerly described as the Soyuz 1) is similar to the Soyuz, but without the liquid strap-on boosters.

The first stage diamter is 2.7 m, compared to 2 m of a Soyuz. It is powered by a single engine, a modified version of the NK-33 once designated for use on the N-1 lunar rocket from the 1970s. In the long-term, the first stage will be powered by the RD-191 manufactured by NPO Enrgomash. The second stage is the same as that used for the Soyuz 2.1a/b.

A Volga upper stage may be employed for certain missions, such as insertion in orbits as high as 1,500 km (932 mi) in altitude.

The vehicle was originally conceived as a replacement for the small-class Rockot. It is expected to be available for launch from Russia's newest launch site, Vostochny, sometime after 2018.

The second launch of the Soyuz 2.1v, which took place in December 2015, is considered a success. According to Russian press reports, the Kanopus Earth observing satellite failed shortly after separation from the vehilce's upper stage.

Launch service provider
VKS/Roscosmos

Organization Headquarters
Russia

Manufacturer
TsSKB Progress

Mass, kg (lb)
157,000 (346,126)

Length, m (ft)
44 (144)

Diameter, m (ft)
2.95 (9.7)

Year of First Launch
2013

Number of Launches
2

Reliability
100%

Launch sites
Baikonur (LC-31 or LC-6)
Plesetsk (LC-43)

GTO capacity, kg (lb)
N/A

LEO capacity, kg (lb)
3,000 (6,614)

SSO capacity, kg (lb)
1,400 (3,086)

Estimated Price per Launch
Undisclosed

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

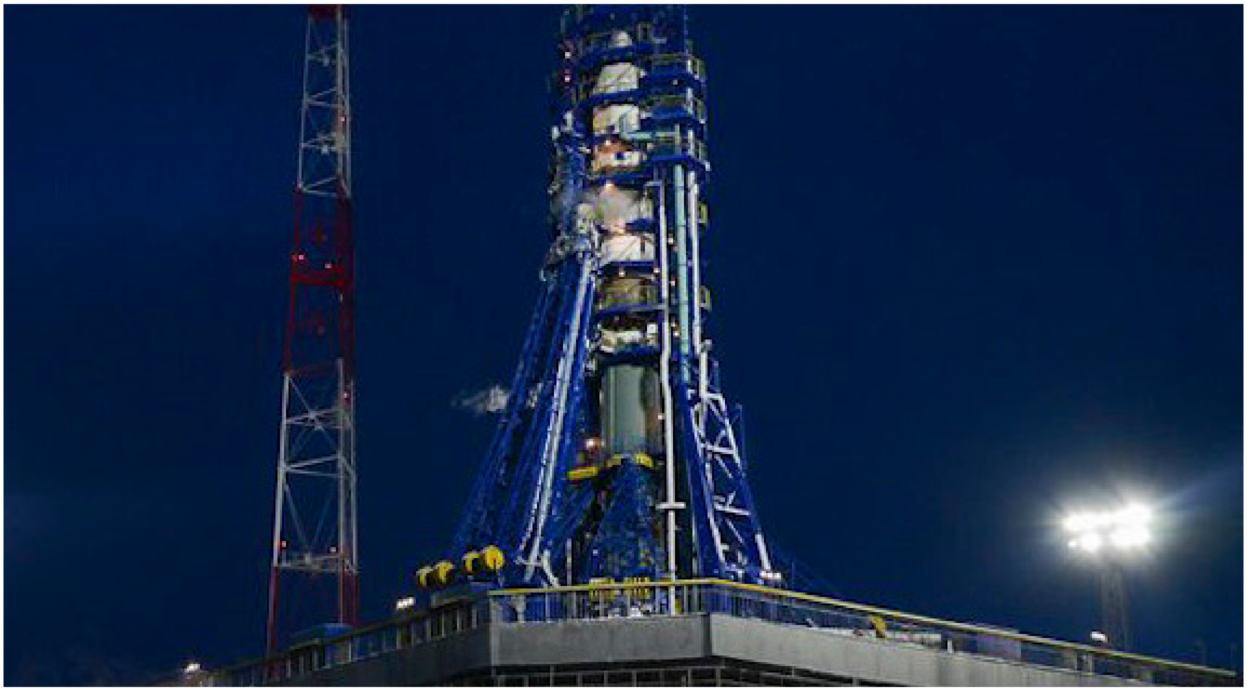
Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

Soyuz 2.1v

FAA AST



A Soyuz 2.1v is prepared for launch in December 2015. The launch, carrying a Kanopus remote sensing satellite, did not go entirely as planned - the payload did not fully separate from the upper stage due to a second stage latching problem. Source: Russian MoD

Fairing	Length, m (ft)	Diameter, m (ft)
Standard Fairing	7.7 (25.3)	3.7 (12.1)

	1st Stage	2nd Stage	3rd Stage
Stage designation	1st Stage	2nd Stage	Volga
Length, m (ft)	27.8 (91.2)	6.7 (22)	1.03 (3.4)
Diameter, m (ft)	2.95 (9.7)	2.7 (8.9)	3.1 (10.2)
Manufacturer	TsSKB Progress	TsSKB Progress	TsSKB Progress
Propellant	LOX/Kerosene	LOX/Kerosene	UDMH
Propellant mass, kg (lb)	119,700 (263,893)	25,400 (55,997)	900 (1,984)
Total thrust, kN (lbf)	1,510 (339,462)	297.9 (66,971)	2.94 (661)
Engine(s)	1 x 14D15 (NK-33)	1 x RD-0124	1 x main engine
Engine manufacturer	NK Engines Company	Voronyezh	TsSKB Progress
Engine thrust, kN (lbf)	1,510 (339,462)	297.9 (66,971)	2.94 (661)

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

SOAR

The Sub Orbital Aircraft Reusable, or SOAR, is a vehicle currently under development by Swiss Space Systems (S3) and its partners the European Space Agency (ESA), Kuznetsov NK Engines Company, RKK Energia, Thales Alenia Space, Dassault Aviation, and the Von Karman Institute. Dassault Aviation was previously involved with ESA's HERMES spaceplane project (1987 to 1992). The vehicle is intended as both a suborbital platform and a system for deploying small satellites. It is an air-launched vehicle designed to be released from an Airbus A300. The initial design features autonomous control capability, but in 2013, S3 announced its intention to produce a piloted version of the vehicle that may also be capable of carrying spaceflight participants.

The NK-39 engine being used to power the vehicle was scheduled for ground testing in late 2015, followed by an air drop test of a scaled-down version of SOAR sometime in 2016.

The company has an agreement with Space Florida to use the Shuttle Landing Facility at Kennedy Space Center (KSC) for operations, which are expected to commence in 2018 with scheduled deployment of CleanSpace One, a 30 kg (66 lb) satellite. S3 is also planning to fly SOAR from the United Arab Emirates.

Dimensions for SOAR include the Airbus A300 carrier aircraft.

Launch service provider
Swiss Space Systems

Organization Headquarters
Switzerland

Manufacturer
Swiss Space Systems

Mass, kg (lb)
109,500 (241,406)

Length, m (ft)
53.6 (175.9)

Wingspan, m (ft)
44.8 (147)

Year of Planned First Launch
2018

Launch sites
KSC (Runaway)
Payerne (Switzerland)
Udbina (Croatia)
Ras Al Khaimah (UAE)

GTO capacity, kg (lb)
N/A

LEO capacity, kg (lb)
250 (551.2)

SSO capacity, kg (lb)
Undisclosed

Estimated Price per Launch
$10.5M

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

SOAR

FAA AST

An artist's impression of SOAR and its Airbus A300 carrier aircraft in flight. Source: Swiss Space Systems

	1st Stage	2nd Stage
Stage designation	Airbus A300	SOAR
Length, m (ft)	53.6 (175.9)	Undisclosed
Wingspan/Diameter, m (ft)	44.8 (147)	Undisclosed
Manufacturer	Airbus	Swiss Space Systems
Propellant	Kerosene (Jet-A1)	LOX/Kerosene
Propellant mass, kg (lb)	50,449 (111,220)	Undisclosed
Total thrust, kN (lbf)	547.2 (123,016)	1,608 (361,493)
Engine(s)	2 x CF6-50C2	4 x NK-39
Engine manufacturer	General Electric	NK Engines Company
Engine thrust, kN (lbf)	273.6 (61,500)	402 (90,373)

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

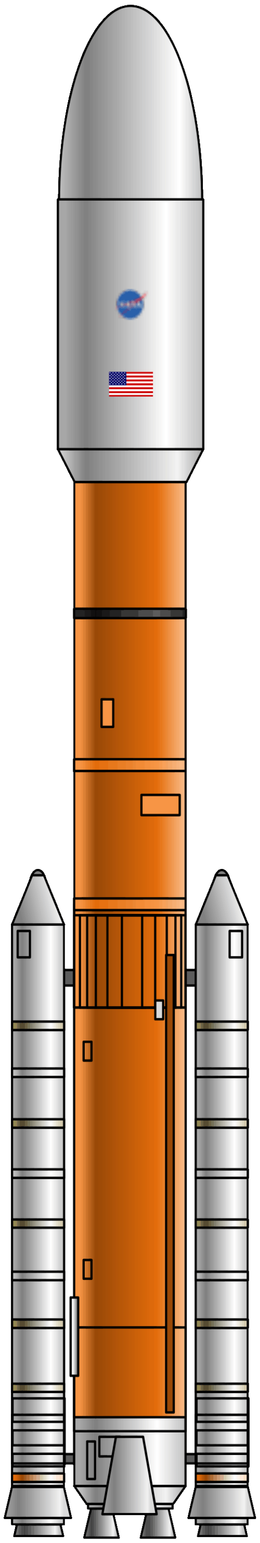
Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

Space Launch System



The Space Launch System (SLS) is a launch vehicle system being developed by NASA for the next era of human exploration beyond Earth's orbit. The vehicle will be used to send crews of up to four astronauts in an Orion spacecraft, cargo, or large robotic scientific missions to Mars, Saturn and Jupiter. Boeing is the prime contractor for SLS. Orbital ATK will provide the solid rocket boosters (SRB), United Launch Alliance (ULA) will provide the Interim Cryogenic Propulsion Stage (ICPS), and Aerojet Rocketdyne is the provider of liquid rocket engines.

SLS is designed to evolve into increasingly more powerful configurations using the same core stage throughout. The first SLS vehicle, called Block 1, has a maximum capacity of 70,000 kg (154,323 lb) to low Earth orbit (LEO). It will be powered by four RS-25 engines and two five-segment SRBs and include a modified version of an existing upper stage. The next versions, the Block 1B, will use a new, more powerful Exploration Upper Stage (EUS) to deliver 105,000 kg (231,485 lb) to LEO. A later evolution, the Block 2, would replace the SRBs with a pair of advanced solid or liquid propellant boosters to provide a LEO capacity of 130,000 kg (286,601 lb).

Two missions are envisioned for the SLS Block 1, including an uncrewed test of Orion in 2018 (EM-1) and a crewed mission to the vicinity of the Moon in 2021 (EM-2).

Launch service provider
NASA

Organization Headquarters
USA

Manufacturer
Boeing/ULA/Orbital ATK

Mass, kg (lb)
2,650,000 (5,842,250)

Length, m (ft)
111.3 (365)

Diameter, m (ft)
8.4 (27.8)

Year of Planned First Launch
2018

Launch sites
KSC (LC-39B)

GTO capacity, kg (lb)
N/A

LEO capacity, kg (lb)
70,000-130,000
(154,324-286,601)

SSO capacity, kg (lb)
N/A

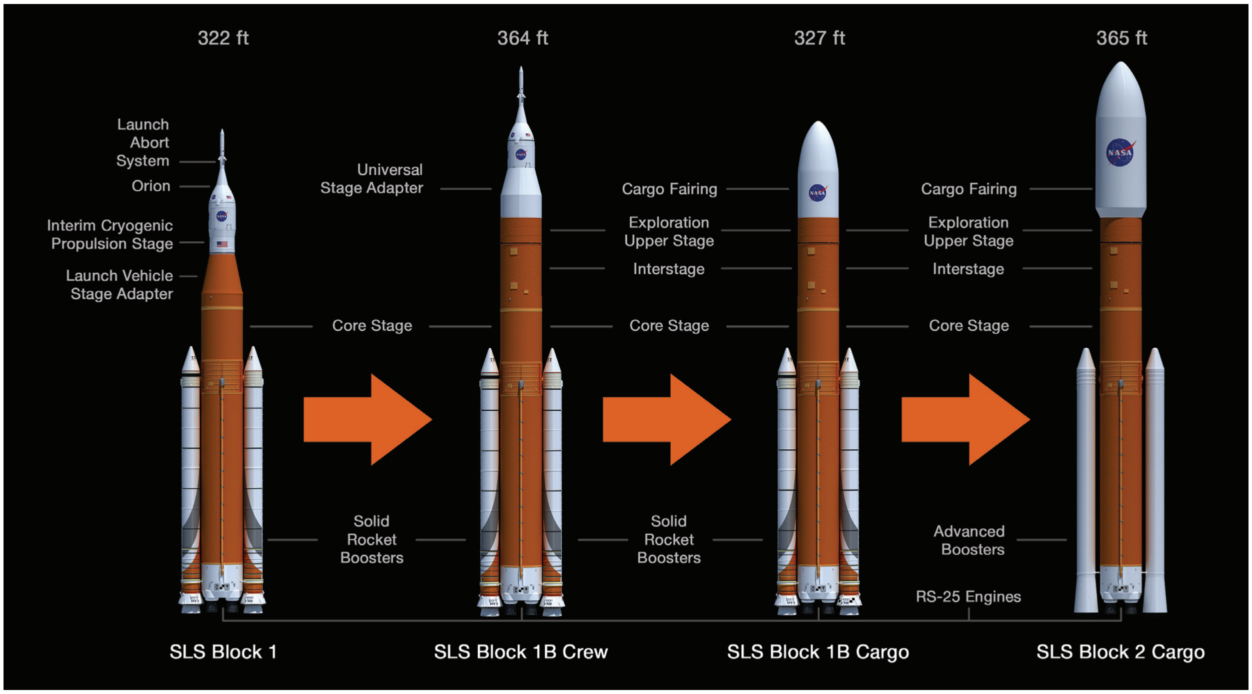
Estimated Price per Launch
N/A

The SLS Block 1B will be used to send astronauts and equipment on increasingly complex mission in cislunar space. Finally, the SLS Block 2 will be used for crewed missions to Mars by the 2030s.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

Space Launch System



A NASA diagram showing the evolution of the Space Launch System. Source: NASA

Fairing	Length, m (ft)	Diameter, m (ft)
Standard Fairing	12.5 (41)	8.4 (27.6)
Large Fairing	25 (82)	8.4 (27.6)

	Solid Boosters*	1st Stage	2nd Stage Option	2nd Stage Option
Stage designation	SRB	1st Stage	Interim Cryogenic Propulsion Stage	Exploration Upper Stage
Length, m (ft)	53.9 (177)	64.6 (212)	13.7 (45)	23 (75.5)
Diameter, m (ft)	3.7 (12)	8.4 (27.6)	5 (16.4)	8.4 (27.8)
Manufacturer	Orbital ATK	Boeing	ULA	Boeing
Propellant	Solid	LOX/H_2	LOX/H_2	LOX/H_2
Propellant mass, kg (lb)	631,495 (1,392,208)	894,181 (1,971,332)	26,853 (59,201)	206,020 (454,196)
Total thrust, kN (lbf)	16,014 (3,600,000)	1,859 (418,000)	110 (24,751)	110 (24,751)
Engine(s)	--	4 x RS-25E	1 x RL10B-2	4 x RL10B-2
Engine manufacturer	--	Aerojet Rocketdyne	Aerojet Rocketdyne	Aerojet Rocketdyne
Engine thrust, kN (lbf)	--	7,436 (1,671,679)	110 (24,751)	440 (98,916)

** Figures are for each booster. Total thrust is sum of all boosters.*

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

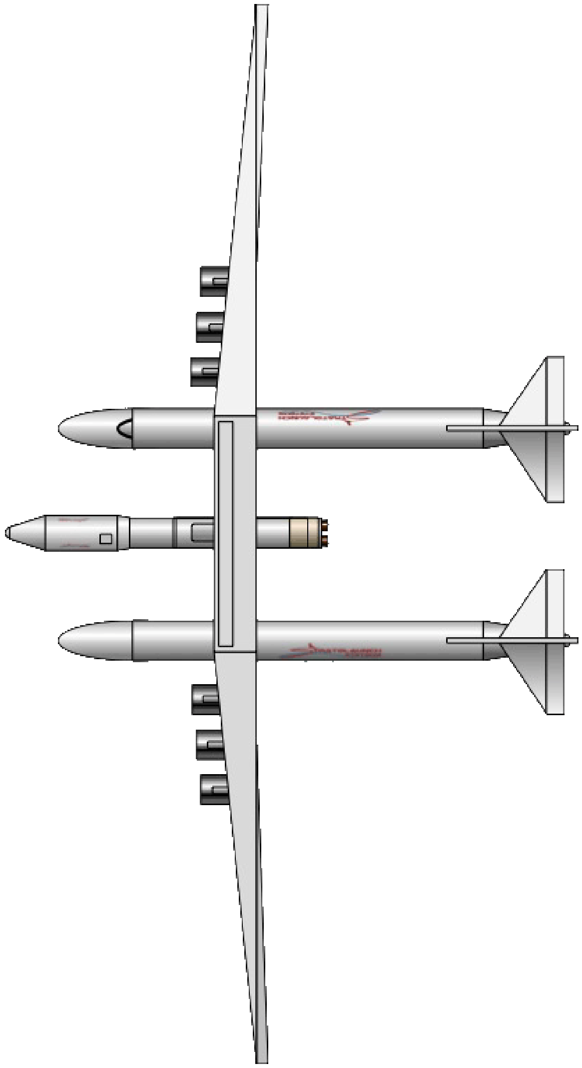
Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

Stratolaunch

FAA AST



Launch service provider
Stratolaunch Systems

Organization Headquarters
USA

Manufacturer
Scaled Composites/Dynetics

Mass, kg (lb)
TBD

Length, m (ft)
70.6 (231.6) *est*

Wingspan, m (ft)
117 (383.9) *est*

Year of Planned First Launch
2016

Launch sites
Mojave Air and Space Port
KSC (Runaway)

GTO capacity, kg (lb)
N/A

LEO capacity, kg (lb)
3,000 (6,614)

SSO capacity, kg (lb)
1,400 (3,086)

Estimated Price per Launch
Undisclosed

Stratolaunch is a system under development by Stratolaunch Systems and funded by owning company Vulcan Aerospace. The system will employ the largest airplane ever built to be a carrier vehicle for an orbital rocket. Initial plans called for a twin-boom Boeing 747, but this has been replaced with an original design by Scaled Composites. The original launch vehicle considered was a SpaceX Falcon 5, but SpaceX withdrew its association to focus on its various projects. The replacement, variously called Thunderbolt or Pegasus II, was to be provided by orbital ATK. This, too, has been tabled in favor of a new vehicle, and as of December 2015 this has not been defined publicly. Stratolaunch Systems is also reportedly working with Sierra Nevada Corporation (SNC) to consider plans for deploying SNC's Dream Chaser from the carrier aircraft.

A test flight of the carrier aircraft is planned for late 2016 from Mojave Air and Space Port in California.

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

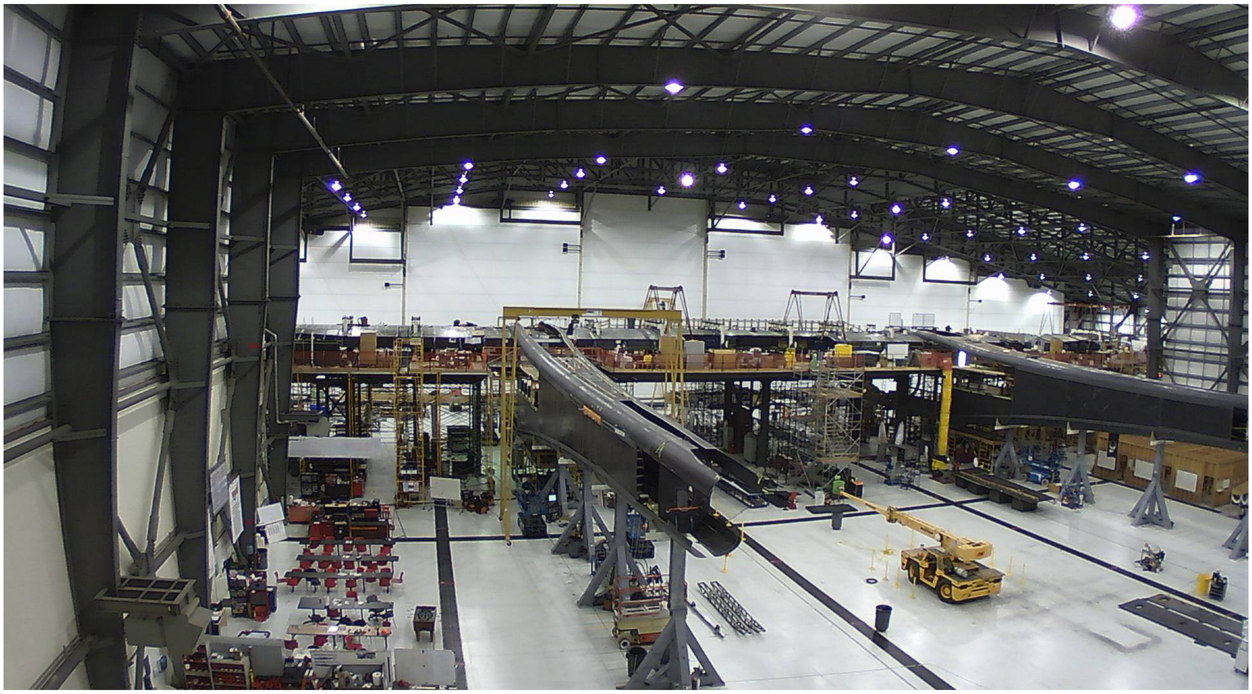
Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

FAA AST

Launch Vehicle Fact Sheet
Stratolaunch



The Stratolaunch system takes shape in the construction hangar located at Mojave Air and Space Port. Source: Stratolaunch Systems

Fairing	Length, m (ft)	Diameter, m (ft)
Standard Fairing	TBD	TBD

	1st Stage	2nd Stage	3rd Stage
Stage designation	StratoLauncher	TBD	TBD
Length, m (ft)	70.6 (231.6) est	TBD	TBD
Wingspan/Diameter, m (ft)	117 (383.9) est	TBD	TBD
Manufacturer	Boeing/Scaled Composites/Dynetics	TBD	TBD
Propellant	Kerosene (JP-4)	LOX/LH_2	TBD
Propellant mass, kg (lb)	Undisclosed	TBD	TBD
Total thrust, kN (lbf)	2,616 (588,100)	212.6 (47,794)	TBD
Engine(s)	6 x PW4056	2 x RL10C-1	TBD
Engine manufacturer	Pratt & Whitney	Aerojet Rocketdyne	TBD
Engine thrust, kN (lbf)	436 (98,017)	106.3 (23,897)	TBD

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

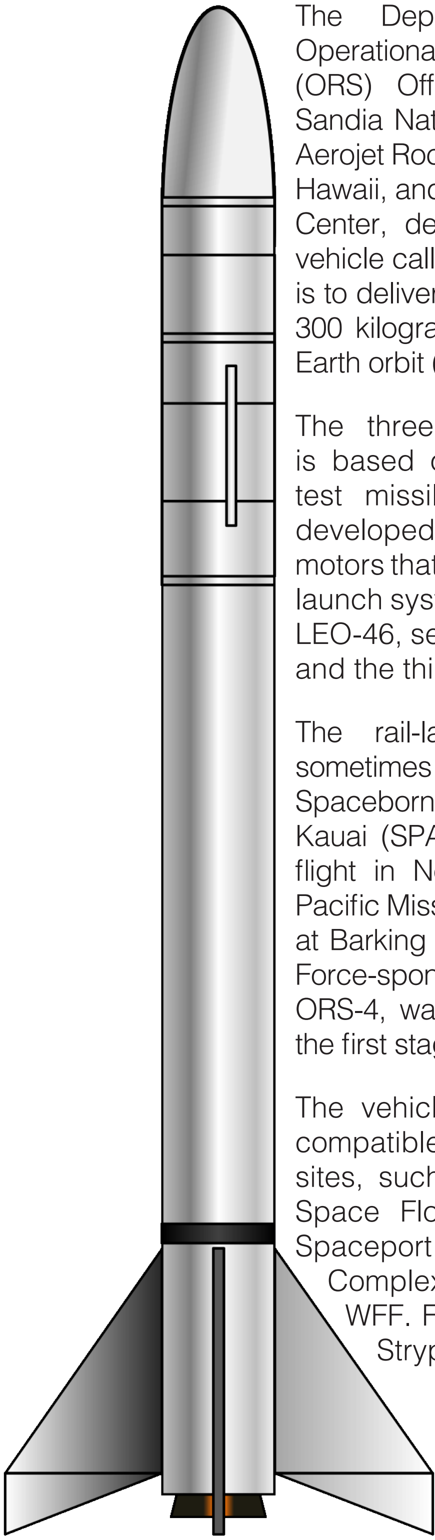
Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

Super Strypi



The Department of Defence's Operationally Responsive Space (ORS) Office, with support from Sandia National Laboratories (SNL), Aerojet Rocketdyne, the University of Hawaii, and NASA's Ames Research Center, developed a small launch vehicle called Super Strypi. The goal is to deliver payloads in the range of 300 kilograms (661 pounds) to low Earth orbit (LEO).

The three-stage all-solid vehicle is based on the 1960s-era Strypi test missile. Aerojet Rocketdyne developed three new solid rocket motors that support the Super Strypi launch system. The first stage is the LEO-46, second stage is the LEO-7 and the third stage is the LEO-1.

The rail-launched Super Strypi, sometimes also refered to as the Spaceborne Payload Assist Rocket Kauai (SPARK), made its inaugural flight in November 2015 from the Pacific Missile Range Facility (PMRF) at Barking Sands in Hawaii. The Air Force-sponsored mission, called ORS-4, was lsot following failure of the first stage.

The vehicle was designed to be compatible with other launch sites, such as, but not limited to, Space Florida's Cape Canaveral Spaceport, Kodiak Launch Complex in Alaska, and NASA's WFF. Future launches of Super Strypi appear unlikely.

Launch service provider
ORS Office
Sandia National Laboratory

Organization Headquarters
USA

Manufacturer
ORS Office
Sandia National Laboratory
Aerojet Rocketdyne

Mass, kg (lb)
505,846 (1,155,200)

Length, m (ft)
68.4 (224.4)

Diameter, m (ft)
3.7 (12)

Year of First Launch
2015

Number of Launches
1

Reliability
0%

Launch sites
PMRF (Pad 41)

GTO capacity, kg (lb)
N/A

LEO capacity, kg (lb)
320 (705)

SSO capacity, kg (lb)
275 (606)

Estimated Price per Launch
TBD

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

FAA AST

Launch Vehicle Fact Sheet

Super Strypi

The Super Strypi vehicle installed on its launcher rail system at PMRF in Hawaii. The inaugural launch on November 3, 2015 ended with a first stage booster failure. Source: U.S. Air Force

Fairing	Length, m (ft)	Diameter, m (ft)
Standard Fairing	1.5 (5)	1.5 (5)

	1st Stage	2nd Stage	3rd Stage
Stage designation	LEO-46	LEO-7	LEO-1
Length, m (ft)	11.3 (37)	2.7 (9)	1.5 (5)
Diameter, m (ft)	1.5 (5)	1.5 (5)	1.5 (5)
Manufacturer	Aerojet Rocketdyne	Aerojet Rocketdyne	Aerojet Rocketdyne
Propellant	Solid	Solid	Solid
Propellant mass, kg (lb)	20,413 (45,004)	3,233 (7,128)	643 (1,417)
Total thrust, kN (lbf)	1,265 (284,470)	195 (43,865)	50 (11,234)

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

Vega

The Vega launch vehicle, named after the second brightest star in the northern hemisphere, is operated by Arianespace and targets payloads to polar and low Earth orbits used by scientific and Earth observation satellites.

Development of the Vega began in 2003 led by the European Space Agency with contributions from the Italian space agency, the French space agency, and Italy-based Avio.

The Vega consists of four stages: a first stage P80 solid motor, a second stage Zefiro-23 solid motor, a third stage Zefiro-9 solid motor, and a liquid-fueled fourth stage called the Attitude and Vernier Upper Module (AVUM). The AVUM, powered by the RD-869, is produced by Yuzhnoye in the Ukraine. The payload adapter is affixed to the fourth stage and covered in a fairing during launch.

In December 2014, the European Space Agency agreed to pursue a replacement for the first stage called P120C, which will power an upgraded vehicle called Vega-C. The P120C will also serve as a strap-on booster for the Ariane 6 vehicle expected to be introduced in 2020. The inaugural flight of the Vega-C is planned for 2018.

Launch service provider
Arianespace

Organization Headquarters
France

Manufacturer
ELV SpA

Mass, kg (lb)
133,770 (294,912)

Length, m (ft)
29.9 (98.1)

Diameter, m (ft)
3 (9.8)

Year of First Launch
2012

Number of Launches
6

Reliability
100%

Launch sites
Guiana Space Center (ZLA)

GTO capacity, kg (lb)
N/A

LEO capacity, kg (lb)
1,963 (4,328)

SSO capacity, kg (lb)
1,430 (3,153)

Estimated Price per Launch
$37M

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

Vega

The second Vega mission, carrying the European Space Agency's (ESA) Proba-V and Vietnam's VNREDSat-1A, is prepared for launch from the Guiana Space Center in 2013. Source: Arianespace

Fairing	Length, m (ft)	Diameter, m (ft)
Standard Fairing	7.9 (25.9)	2.6 (8.5)

	1st Stage	2nd Stage	3rd Stage	4th Stage
Stage designation	P80FW	Zefiro 23	Zefiro 9	AVUM
Length, m (ft)	11.2 (36.7)	8.4 (27.6)	4.1 (13.5)	2 (6.6)
Diameter, m (ft)	3 (9.8)	1.9 (6.2)	1.9 (6.2)	2.2 (7.2)
Manufacturer	Europropulsion	Avio	Avio	Avio
Propellant	Solid	Solid	Solid	N_2O_4 (UDMH)
Propellant mass, kg (lb)	88,365 (194,811)	23,906 (52,704)	10,115 (22,300)	367 (809)
Total thrust, kN (lbf)	2,261 (508,293)	1,196 (268,871)	225 (50,582)	2.5 (562)
Engine(s)	--	--	--	1 x RD-869
Engine manufacturer	--	--	--	Yuzhnoye
Engine thrust, kN (lbf)	--	--	--	2.5 (562)

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

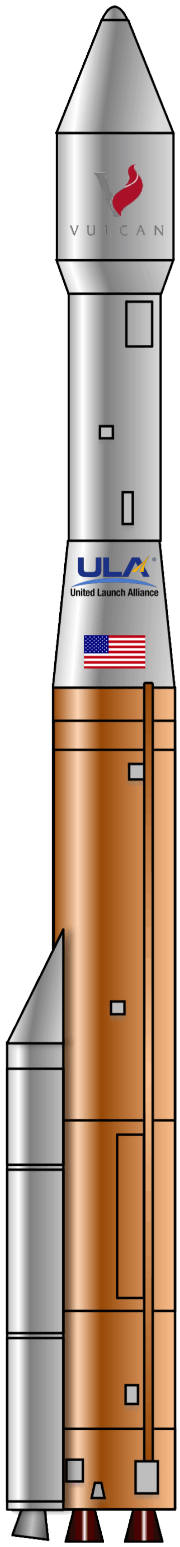
Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

Vulcan



The Vulcan family of launch vehicles was introduced by United Launch Alliance (ULA) in 2015 as an eventual replacement for the company's Atlas V and Delta IV. Formerly called the Next Generation Launch System (NGLS), the vehicle is expected to be introduced in 2019.

Leveraging technologies and processes from the Atlas V and Delta IV programs since 2002, and even earlier in terms of research and development time, the Vulcan will nevertheless feature a couple of unique capabilities. First is the use of a liquid oxygen (LOX)-liquified natural gas (LNG, or methane) engine called the BE-4. The BE-4, provided by Blue Origin, will power the vehicle's first stage. ULA is developing the capability to reuse the BE-4. Once the first stage is spent, the BE-4 subsystem will separate from the stage, deploy a reentry shield, deploy a parachute, and be recovered by an aircraft. The second is planned use of the Advanced Cryogenic Evolved Stage (ACES) as an upper stage, which will dramatically increase the vehicle's capacity to orbit. In addition, ACES, which will burn a LOX-liquid hydrogen mix, will be capable of remaining on-orbit for future use, allowing for a "distributed launch" capability. Until it is introduced in 2023, the Vulcan will use the proven Centaur upper stage.

The deployment strategy will take place in phases. First, the Delta IV Medium vehicles will be retired in 2018, except for the Delta IV Heavy. The first launch of Vulcan is expected in 2019. It will fly concurrently with the Atlas V for an undisclosed period of time. The Delta IV Heavy and the Atlas V will be retired following successful deployment of the Vulcan-ACES combination in 2023.

Launch service provider
ULA

Organization Headquarters
USA

Manufacturer
ULA

Mass, kg (lb)
432,000-1,280,000
(952,397-2,821,917) *est*

Length, m (ft)
58.3-63 (191-207) *est*

Diameter, m (ft)
3.8 (12.5)

Year of Planned First Launch
2019

Launch sites
CCAFS (SLC-41)
VAFB (SLC-3E)

GTO capacity, kg (lb)
4,750-8,900 (10,472-19,621)

LEO capacity, kg (lb)
9,370-18,510 (20,657-40,510)

SSO capacity, kg (lb)
7,724-15,179 (17,029-33,464)

Estimated Price per Launch
$85M-$260M

The ACES upper stage is currently under development. The final design and selection of an engine provider has not yet been decided.

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

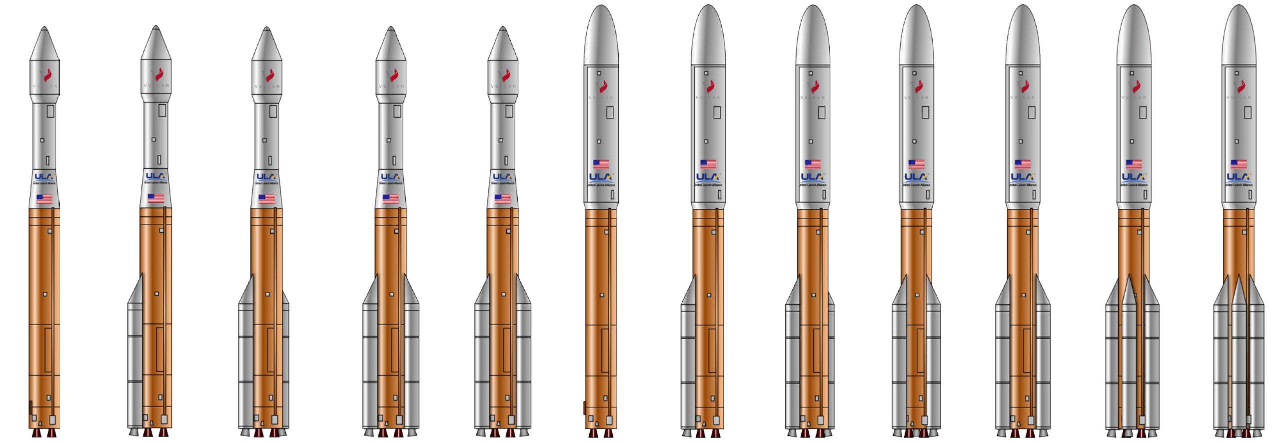
Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet
Vulcan

FAA AST



Vulcan 400 | Vulcan 401 | Vulcan 402 | Vulcan 403 | Vulcan 404 | Atlas V 500 | Atlas V 501 | Atlas V 502 | Atlas V 503 | Atlas V 504 | Atlas V 505 | Atlas V 506

Fairing	Length, m (ft)	Diameter, m (ft)
4m Large Payload Fairing	12 (39.3)	4 (13)
4m Extended Payload Fairing	12.9 (42.3)	4 (13)
4m Extra Extended Payload Fairing	13.8 (45.3)	4 (13)
5m Large Payload Fairing	20.7 (68)	5 (16.4)
5m Extended Payload Fairing	23.5 (77)	5 (16.4)
5m Extra Extended Payload Fairing	26.5 (87)	5 (16.4)

The Vulcan will feature a core stage and a combination of up to six solid rocket boosters, two Centaur upper stage options (and later ACES), and a 4- or 5-meter fairing. There will be five versions of the 400 series and seven versions of the 500 series.

	SRB*	1st Stage	2nd Stage Option	2nd Stage Option	2nd Stage Option
Stage designation	GEM-63XL	1st Stage	Single Engine Centaur	Dual Engine Centaur	ACES
Length, m (ft)	19.2 (63) *est*	32.5 (106.6) *est*	12.7 (41.7)	12.7 (41.7)	TBD
Diameter, m (ft)	1.6 (5.3)	5.1 (16.7) *est*	3.1 (10.2)	3.1 (10.2)	5.1 (16.7) *est*
Manufacturer	Orbital ATK	ULA	ULA	ULA	ULA
Propellant	Solid	LOX/CH_4	LOX/LH_2	LOX/LH_2	LOX/H_2
Propellant mass, kg (lb)	46,300 (102,074) *est*	368,000 (811,301) *est*	20,830 (45,922)	20,830 (45,922)	63,500 (139,994) *est*
Total thrust, kN (lbf)	1,833 (412,075) *est*	4,800 (1,079,083)	99.2 (22,300)	198.4 (44,600)	431 (96,893) *est*
Engine(s)	--	2 x BE-4	1 x RL10A-4-2	2 x RL10A-4-2	TBD
Engine manufacturer	--	Blue Origin	Aerojet Rocketdyne	Aerojet Rocketdyne	TBD
Engine thrust, kN (lbf)	--	2,400 (550,000)	99.2 (22,300)	99.2 (22,300)	TBD

** Figures are for each booster. Total thrust is sum of all boosters.*

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

XS-1

FAA AST

In 2013, the Defense Advanced Research Projects Agency (DARPA) announced it is pursuing development of a reusable spaceplan concept called Experimental Spaceplane-1 (XS-1). The primary objective of this program is to produce a vehicle capable of sending 2,267 kg to low Earth orbit (LEO). The XS-1 is being designed to handle a launch rate of 10 missions within ten days, with each launch costing about $5M.

DARPA selected three teams in 2014 to compete for the final development and manufacturing contract. The teams included Northrop Grumman (with Scaled Composites and Virgin Galactic), Masten Space Systems (with XCOR Aerospace), and Boeing (with Blue Origin). In August 2015, each company was awarded $6.5M under what is called Phase 1, in which XS-1 designs are matured further to include demonstration tasks. Completion of these tasks is expected in 2016. DARPA plans to select one of the three teams to move on to Phase 2 sometime in late 2016.

Test flights of the XS-1 are expected in 2018, with operational flights projected to begin in 2020.

Launch service provider
DARPA

Organization Headquarters
USA

Manufacturer
TBD

Mass, kg (lb)
TBD

Length, m (ft)
TBD

Diameter, m (ft)
TBD

Year of Planned First Launch
2018

Launch sites
TBD

GTO capacity, kg (lb)
N/A

LEO capacity, kg (lb)
2,267 (4,998)

SSO capacity, kg (lb)
TBD

Estimated Price per Launch
$5M

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

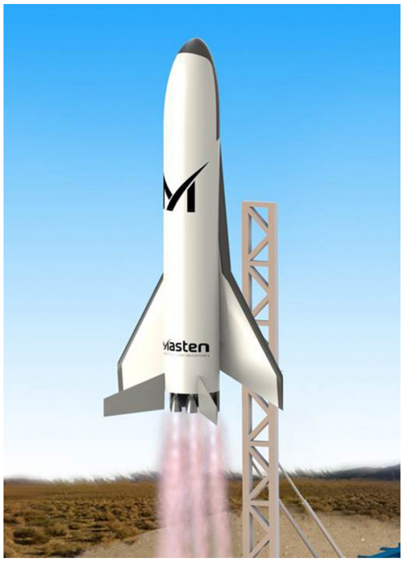
Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

XS-1

FAA AST



Masten Space Systems has been working on vertical takeoff, vertical landing (VTVL) technologies for about a decade. This effort has lead to the development of several test vehicles, including Xombie, Xoie, and Xaero. On several occassions, these systems have met DARPA's 10 flights within 10 days objective. Masten is developing the XS-1 design, including guidance, navigation, and control (GNC) systems. It's partner XCOR Aerospace is focusing on propulsion. Source: Masten Space Systems

Northrop Grumman's subsidiary, Scaled Composites, is developing this team's XS-1 concept. The concept includes a clean-pad approach using a transporter erector launcher with minimal infrastructure and ground crews, highly autonomous flight operations, and horizontal landing and recovery on standard runways. Virgin Galactic would manage operational missions. Source: Northrop Grumman

Boeing is the lead on the development of this team's XS-1 concept. Boeing is leveraging its extensive spaceflight experience, perhaps with emphasis on its X-37B spaceplane, which is owned and operated by the U.S. Air Force. Its concept is to deploy the XS-1 via an aircraft. The spaceplane would then deploy the payload and return to Earth as an airplane. Blue Origin is focusing on the propulsion system. Source: Boeing

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

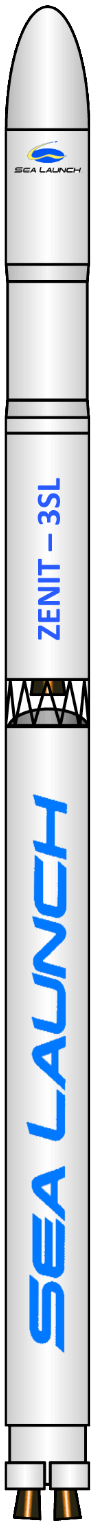
Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

Zenit



The Zenit 3SL can be traced to the 1980s when the Soviet government pursued a system that could be used as both a booster for the Energia launch vehicle and as a stand-alone vehicle. The first-generation Zenit 2 was introduced in 1985 and has been launched 37 times. The Zenit 3SL represents a second generation vehicle. It is provided by Sea Launch, a conglomerate entity with four major component providers: RSC Energia, PA Yuzhmash/Yuzhnoye, Aker Solutions, and Boeing.

The Zenit 3SL is a three-stage vehicle. Yuzhnoye provides both the first and second stages, which are powered by the RD-171M and the RD-120 engines, respectively. A specially modified Block-DM third stage is supplied by S.P. Korolev Rocket and Space Corporation Energia (RKK Energia). Boeing provides the payload fairing.

The Zenit 3SLB is a modernized version of the earlier generation of the two-stage Zenit featuring a Block-DM third stage, but marketed by Land Launch, a subsidiary of Sea Launch. Land Launch also includes the Zenit 2SLB, which is essentially the same as the Zenit 3SLB but without a third stage.

Due to increasing political tensions between Russia and Ukraine during 2014, and the resulting international sanctions against Russia, PA Yushmash, a key supplier of missiles and other hardware to the Russian military, has experienced considerable financial difficulties that may impact its product line.

Launch service provider
VKS/Sea Launch AG

Organization Headquarters
Russia

Manufacturer
PA Yuzhmash

Mass, kg (lb)
470,000 (1,036,173)

Length, m (ft)
59 (193.6)

Diameter, m (ft)
3.9 (12.8)

Year of First Launch
1985

Number of Launches
83

Reliability
88%

Launch sites
3SL: Pacific Ocean/*Odyssey*
2/3F/3SLB: Baikonur (LC-45/1)

GTO capacity, kg (lb)
3SL: 6,160 (13,580)
3SLB: 3,750 (8,267)

LEO capacity, kg (lb)
N/A

SSO capacity, kg (lb)
N/A

Estimated Price per Launch
$85M-$95M

Detailed information can be found in the Annual Compendium of Commercial Space Transportation(www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/).

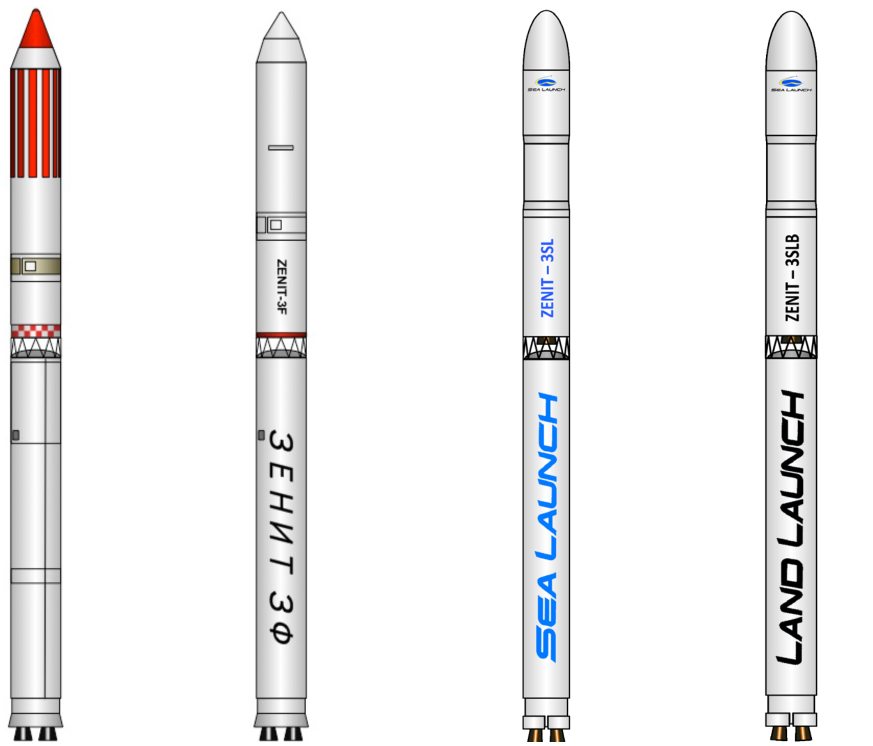
Data is maintained in FAA AST's Space Transportation Analysis and Research (STAR) database.

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast

Launch Vehicle Fact Sheet

Zenit



Zenit 2 | Zenit 3F | Zenit 3SL | Zenit 3SLB

The Zenit 3SL and Zenit 3SLB are provided commercially. The Zenit 2 was used for government missions, and has since retired. The Zenit 3F was used for a short period of time for government missions beginning in 2011.

The Zenit vehicles, which are built in Ukraine, appear unlikely to fly again.

Fairing	Length, m (ft)	Diameter, m (ft)
Standard Fairing	11.39 (37.4)	3.9 (12.8)

	1st Stage	2nd Stage	3rd Stage
Stage designation	1st Stage	2nd Stage	Block DM-SL
Length, m (ft)	32.9 (108)	10.4 (34)	4.9 (16.1)
Diameter, m (ft)	3.9 (12.8)	3.9 (12.8)	3.7 (12.1)
Manufacturer	Yuzhnoye	Yuzhnoye	RSC Energia
Propellant	LOX/Kerosene	LOX/Kerosene	LOX/Kerosene
Propellant mass, kg (lb)	322,280 (710,505)	81,740 (180,205)	15,850 (34,943)
Total thrust, kN (lbf)	7,256 (1,631,421)	992 (223,026)	79.5 (17,864)
Engine(s)	1 x RD-171M	1 x RD-120 1 x RD-8	1 x 11D58M
Engine manufacturer	NPO Energomash	NPO Energomash	RSC Energia
Engine thrust, kN (lbf)	7,117 (1,631,421)	RD-120: 912 (205,026) RD-8: 80 (18,000)	79.5 (17,864)

Publication produced for FAA AST by The Tauri Group under contract.

FAA Office of Commercial Space Transportation
800 Independence Avenue SW (AST)
Washington, DC 20591
202.267.5450 (fax)
http://www.faa.gov/go/ast