Federal Aviation Administration

2009 U.S. Commercial Space Transportation Developments and Concepts: Vehicles, Technologies, and Spaceports

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About the 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 49 United States Code, Subtitle IX, Chapter 701 (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 web site at http://www.faa.gov/about/office_org/headquarters_offices/ast/.

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INTRODUCTION

The year 2008 was one of steady progress in the commercial space transportation industry. Existing launch service providers performed 69 orbital launches in 2008, 28 of which were commercial. Both established companies and entrepreneurial ventures advanced new expendable and reusable launch vehicles currently under development. Companies exploring new markets, such as personal spaceflight, continued to sign up customers and furthered their plans to enter service in the near future. Additionally, these and other companies pursued innovative technologies needed to support new vehicles being designed, while spaceports strategized to create new infrastructure needed to support the industry.

While this steady progress may not seem much like change, in fact it is the basis for revolutionary improvements in commercial space transportation: increased reliability and safety, decreased costs, and new capabilities. Existing and new launch vehicles, the key technologies needed for these vehicles to operate successfully, and spaceports that these vehicles can operate from, are essential to the future of the U.S. commercial space transportation industry. This combination can help the industry more effectively serve existing customers while opening up new markets, such as personal spaceflight and commercial resupply of the International Space Station (ISS).

This report explores major developments and other events that defined U.S. commercial space transportation in 2008. It showcases current and planned U.S. commercial or commercially-oriented activities. It also addresses space competitions, reusable launch vehicles (RLVs), expendable launch vehicles (ELVs), reentry vehicles and in-space technologies, enabling technologies such as propulsion and launch configurations, the evolving array of U.S. spaceports, commercial human spaceflight training, and new developments in the regulatory arena.

Whether new developments are highly publicized occurrences or gradual changes, commercial space transportation remains a dynamic industry. Providing a broad understanding of today's commercial launch sector requires examining a wide range of topics. Information presented in this report was compiled from open sources and through direct communication with academic, federal, civil, and corporate organizations. Because many of the statements herein are forward-looking, the most current information should be obtained by directly contacting the organizations mentioned in this report.

Space Competitions

A major milestone in space competitions took place in 2008 when Armadillo Aerospace won first prize in Level One of the Northrop Grumman Lunar Lander Challenge (NG-LLC). Armadillo's vehicle, MOD-1, successfully carried out a pair of 90-second test flights to win the $350,000 Level One prize purse provided by NASA's Centennial Challenges program ($1.65 million in additional prize money remains to be won). For the first time in the competition's three-year history a

second team, TrueZer0, competed in the event. Several other teams made progress on vehicles they hope to fly in future competitions.

A number of other competitions under the Centennial Challenges umbrella are ongoing with events planned in 2009, including demonstrations of power beaming, tether strength, and regolith excavation. In the private sector, the Google Lunar X PRIZE gained momentum in 2008, with 16 teams registered by the end of the year to compete for $30 million in prize money.

Expendable Launch Vehicle Industry

The year 2008 was one of continued success and new progress for the ELV industry in the U.S. United Launch Alliance (ULA) and Orbital Sciences Corporation enjoyed a number of successful launches of their families of launch vehicles, including several commercial missions for government and commercial customers. Sea Launch returned its Zenit-3SL vehicle to flight in early 2008 and had an active year. The company also introduced a land-based version, the Zenit-3SLB, which had its successful inaugural flight from Kazakhstan in April 2008.

In the ELV development realm, SpaceX celebrated the successful launch of its Falcon 1 launch vehicle in September 2008. Less than two months previously a Falcon 1 launch attempt ended in failure. The company also made key progress on its larger Falcon 9 vehicle, including a series of static engine tests of the vehicle's first stage. Orbital Sciences Corporation, meanwhile, ramped up development of its Taurus II vehicle, winning a funded Space Act Agreement with NASA to help develop the vehicle for launching cargo spacecraft to the ISS.

Reusable Launch Vehicle Industry

As in the last few years, the most progress in the RLV industry has been in the development of suborbital RLVs designed principally to serve the emerging personal spaceflight market. Virgin Galactic and Scaled Composites rolled out in July 2008 the first WhiteKnightTwo aircraft, which will serve as the air launch platform for the SpaceShipTwo suborbital vehicle under development. In March 2008, XCOR Aerospace revealed its plans to develop a suborbital spaceplane, the Lynx. On the same day that Armadillo Aerospace won first prize in Level One of the NG-LLC, the company announced a partnership with Rocket Racing Inc. and the state of New Mexico to develop a vertical takeoff and landing vehicle to serve the personal spaceflight market.

Other companies continued work on suborbital RLVs. A particularly active area of work was in the development of vehicles to compete in the NG-LLC that could also serve as precursors of full-fledged suborbital RLVs.

Reentry Vehicles and In-Space Technology

The year saw continued progress in developing both government and commercial vehicles designed to carry cargo and crews to the ISS and potentially other destinations in low Earth orbit. NASA and its industry partners continued developing the Orion Crew Exploration Vehicle, including tests of the capsule's parachute system and the motors for its abort system. SpaceX worked on its Dragon capsule, supported by a Space Act Agreement under NASA's Commercial Orbital Transportation Services (COTS) program. The first Dragon demonstration mission is planned for 2009. SpaceX also announced plans to develop a free-flying version of Dragon, called DragonLab, that can be used for flying experiments or deploying small satellites. Orbital Sciences Corporation won a COTS Space Act Agreement in February 2008 to develop the Cygnus spacecraft and Taurus II launcher for delivering cargo to the ISS. The first Cygnus demonstration mission is planned for launch in late 2010. In December, both Orbital Sciences Corporation and SpaceX won NASA contracts to deliver cargo to the ISS through 2016.

Beyond the ISS, Bigelow Aerospace worked on a scaled-up version of the Genesis inflatable modules the company launched in 2006 and 2007. Sundancer, planned for launch in 2010, will be capable of supporting crews. It will also serve as the basis for a larger orbital habitat with the addition of more modules in the future. Bigelow let several contracts for Sundancer, including the spacecraft's attitude control and propulsion systems.

Enabling Technologies

The progress seen in the ELV and RLV industries rests on developing new technologies that provide improved operability, reliability, and performance at lower cost. Efforts continued in this arena in 2008, particularly in the area of engines. Several companies, from SpaceX and Garvey Spacecraft Corporation to Northrop Grumman and Pratt & Whitney Rocketdyne, demonstrated progress on a number of engines and thrusters of varying sizes, for uses ranging from main propulsion on launch vehicles to attitude control on piloted spacecraft. Other companies continued work on a diverse portfolio of technologies from composite propellant tanks to stage recovery systems.

Commercial Human Spaceflight Training

An emerging need for the U.S. commercial space transportation industry is training for those who will pilot the new generation of suborbital and orbital RLVs and spacecraft under development. A number of training providers, some of whom are focused exclusively on space, offer a wide range of services to prepare people for the rigors of spaceflight. The FAA published a listing of these training providers and the services they offer in February 2008. In the year since that initial report's publication, a number of developments have taken place in this field. Companies have enhanced their offerings and new companies have entered this field, providing services ranging from medical testing and physiological

training to high-performance jet flights and zero-gravity simulations. This updated information is included in this report.

Spaceports

The nation's commercial and federal spaceports had an active year, supporting ELV launches as well as laying the groundwork for supporting future commercial ELV and RLV missions. Space Florida reached an agreement with the U.S. Air Force to operate Launch Complex 36 at Cape Canaveral Air Force Station (CCAFS); Space Florida plans to convert the launch site into a facility that supports various classes of vertically-launched vehicles. The Mid-Atlantic Regional Spaceport (MARS) in Virginia reached an agreement with Orbital Sciences Corporation in June 2008 to host launches of Orbital's new Taurus II from a new launch facility at the spaceport.

Other spaceports are proceeding with their development plans. Spaceport America in New Mexico finalized its development plans and started construction of an access road to the site, and received its FAA launch site operator's license in December. Cecil Field, a former Naval Air Station in Florida, is also in the process of applying for an operator's license. Other spaceports have continued to make plans for future operations as well.

Regulatory

In December 2008, the FAA published a new amateur rocket rule. This rule provides a new definition of what is considered an "amateur rocket" by the FAA and codifies separation distances for amateur rocketry activities, air traffic control notice requirements, and other information required by the FAA to permit amateur rocket activities.

SIGNIFICANT 2008 EVENTS

January 15: A Sea Launch Zenit-3SL lifts off from the Odyssey Launch Platform on the Equator in the Pacific Ocean and places the Thuraya 3 satellite into geosynchronous orbit (GSO).

January 23: Virgin Galactic and Scaled Composites unveil the design of their suborbital piloted spacecraft, SpaceShipTwo, and its carrier aircraft, WhiteKnightTwo, at a press conference in New York City.

February 19: NASA signs a funded Space Act Agreement with Orbital Sciences Corporation as part of the agency's Commercial Orbital Transportation Services (COTS) project. The $170-million agreement will support development of the Cygnus cargo spacecraft and Taurus II launch vehicle.

February 21: The X PRIZE Foundation introduces the first ten teams registered in the $30-million Google Lunar X PRIZE competition. This competition will reward the first company to send a privately-developed rover to the Moon.

March 19: A Sea Launch Zenit-3SL lifts off from the Odyssey Launch Platform and places the DIRECTV 11 satellite into GSO.

March 19: Space Adventures acquires Zero Gravity Corporation (ZERO-G), a provider of parabolic flight services that simulate microgravity, for an undisclosed sum. ZERO-G will continue operations as a business unit of Space Adventures.

March 26: XCOR Aerospace announces plans to develop a suborbital piloted spacecraft, the Lynx. The two-seat vehicle, capable of flying to an altitude of over 60 kilometers, will be ready for test flights as early as 2010.

April 9: UP Aerospace signs a ten-year agreement with the New Mexico Spaceport Authority to conduct suborbital sounding rocket launches from Spaceport America.

April 12: Garvey Spacecraft Corporation (GSC) and its research partner, California State University Long Beach (CSULB), launched the Prospector 14 rocket on a low-altitude flight from the Mojave Desert in California. The launch tested a new liquid oxygen-methane engine developed by CSULB students.

April 14: A United Launch Alliance (ULA) Atlas V 421, operated by Lockheed Martin Commercial Launch Services, lifts off from Cape Canaveral Air Force Station (CCAFS) and places the ICO G1 satellite into GSO.

April 22: Voters in Sierra County, New Mexico, which includes the city of Truth or Consequences, approve a gross receipts tax increase to help fund development of Spaceport America.

April 28: A Zenit-3SLB rocket, operated by Land Launch, a joint venture of Sea Launch and Space International Services, lifts off from the Baikonur Cosmodrome in Kazakhstan and places the Amos 3 satellite into GSO. The launch is the first for Zenit-3SLB, a land-based version of the Zenit-3SL.

April 16: An Orbital Sciences Corporation Pegasus XL launches from its L-1011 carrier aircraft near Kwajalein Atoll in the central Pacific, carrying the Communications/Navigation Outage Forecasting System (C/NOFS) satellite for the U.S. Air Force (USAF). The launch is performed under an FAA/AST license.

May 21: A Sea Launch Zenit-3SL lifts off from the Odyssey Launch Platform and places the Galaxy 18 satellite into GSO.

June 9: Orbital Sciences Corporation announces that it will use the Mid-Atlantic Regional Spaceport (MARS) for its new Taurus II launch vehicle, with the first launch from there scheduled for late 2010.

June 11: Space Adventures announces that it has reached an agreement with the Russian Space Agency for the first private mission to the International Space Station (ISS), scheduled for the second half of 2011. The company also announces that Google co-founder Sergey Brin has invested in Space Adventures and will join its "Orbital Mission Explorers Circle," giving him preferential access to future spaceflight opportunities.

July 15: A Sea Launch Zenit-3SL lifts off from the Odyssey Launch Platform and places the EchoStar XI satellite into GSO.

July 28: Virgin Galactic and Scaled Composites roll out the first WhiteKnightTwo carrier aircraft, the VMS Eve, at Mojave Air and Space Port in California.

August 3: A SpaceX Falcon 1 rocket lifts off from Omelek Island, part of Kwajalein Atoll, carrying the Jumpstart payload for the Operationally Responsive Space (ORS) Office and two smaller satellites for NASA. The payloads fail to reach orbit when the rocket's first stage recontacts the second stage after stage separation.

August 7: The U.S. Air Force (USAF) agrees to license Launch Complex 36 at CCAFS to Space Florida, which plans to convert the facility into a multi-use vertical launch complex for commercial users.

August 22: An Alliant Techsystems (ATK) experimental launch vehicle, the ATK Launch Vehicle (ATV) X-1, lifts off from MARS on a suborbital flight carrying two NASA hypersonic flight experiments. The vehicle veers off course and is destroyed 27 seconds into the flight.

September 6: A ULA Delta II 7420, operated by Boeing Launch Services (BLS), launches from Vandenberg Air Force Base (VAFB) and places the GeoEye 1 satellite into orbit.

September 24: A Sea Launch Zenit-3SL lifts off from the Odyssey Launch Platform and places the Galaxy 19 satellite into GSO.

September 28: A SpaceX Falcon 1 rocket lifts off from Omelek Island and places a demonstration payload into orbit. The launch is the first successful flight of the Falcon 1.

September 30: Space Adventures announces that Charles Simonyi, who flew to the ISS as a space tourist in 2007, will make a return flight in spring of 2009, making him the first commercial customer to make a repeat trip to space.

October 12: A Soyuz rocket launches the Soyuz TMA-13 spacecraft on a mission to the ISS. The spacecraft's crew includes space tourist Richard Garriott, a computer game developer and son of former NASA astronaut Owen Garriott.

October 24: A ULA Delta II 7420, operated by BLS, launches from VAFB and places the COSMO-Skymed 3 satellite into orbit.

October 24: Armadillo Aerospace wins first prize in Level One of the Northrop Grumman Lunar Lander Challenge at Las Cruces International Airport in New Mexico with their MOD-1 vehicle. Armadillo receives $350,000 in prize money from NASA's Centennial Challenges prize program.

October 24: Armadillo Aerospace and Rocket Racing Inc. announce a joint venture to develop vertical takeoff and landing suborbital piloted vehicles. The state of New Mexico agrees to provide $3 million to help the joint venture establish development and test facilities in Las Cruces, New Mexico.

November 4: Voters in Otero County, New Mexico, which includes the city of Alamogordo, narrowly reject a gross receipts tax increase that would have helped fund development of Spaceport America.

November 22: SpaceX conducts a nine-engine "mission duty cycle" static test firing of the first stage of its Falcon 9 launch vehicle at its test facility in McGregor, Texas.

December 2: XCOR Aerospace announces its first customer for its Lynx vehicle, Danish investment banker Per Wimmer, and that tourism company RocketShip Tours will be selling tickets for Lynx flights.

December 2: SpaceX announces that it has added two missions to its manifest for DragonLab, a reusable free-flying laboratory developed by SpaceX for research and technology demonstration applications.

December 15: The FAA issues to the New Mexico Spaceport Authority a launch site operator license for Spaceport America. The license covers suborbital vertical launches from the planned facility.

December 23: NASA awards ISS Commercial Resupply Services contracts to Orbital Sciences Corporation and SpaceX. The contract with Orbital is for eight launches at a cost of $1.9 billion, while the contract for SpaceX is for 12 launches at a cost of $1.6 billion.

SPACE COMPETITIONS

Space prize competitions have become an effective method of promoting innovation and developing commercial spaceflight technology. The end goal of the competitions is to create available commercial space launch (and other commercial space capabilities) with lower cost, improved quality, and more efficient processes than the options currently available. The three sets of currently active prize competitions are the Google Lunar X PRIZE, America's Space Prize, and NASA's various Centennial Challenges.

Google Lunar X PRIZE

The Google Lunar X PRIZE is a fairly new international prize competition to reward the privately funded teams that can land a robotic craft on the surface of the Moon, roam about the surface for at least 500 meters, and collect and transmit digital data back to Earth in the form of images and videos (called "Mooncasts"). Active since September 2007, the Google Lunar X PRIZE is the joint effort of the X PRIZE Foundation and Google to encourage private enterprise and the exploration of the Moon. The largest prize amount is $20 million and is awarded to the first team to complete the mission by December 31, 2012. The prize money drops to $15 million if the competition is not won until 2013 or 2014. The second team to complete the mission by the end of 2014 is awarded $5 million. Additionally, a total of $5 million is available to win in bonus prizes by successfully completing additional tasks while exploring the lunar surface.[1]

Space Florida is offering an additional $2 million solely to the first place team if they successfully launch from the State of Florida. The Google Lunar X PRIZE has made significant developments since its announcement in 2007. The competition has received more than 560 expressions of interest from over 53 countries. The X PRIZE Foundation introduced the first 10 fully registered teams in February 2008, including teams from Romania, Italy, Texas, Southern California, and many more innovative and diverse organizations.[2] In December 2008, two new teams registered for the competition: Euroluna, from Denmark and Italy and SELENE, from China and Germany.[3]

Lunar rover mockup of the Google Lunar X PRIZE

America's Space Prize

Bigelow Aerospace has proposed a commercial spaceflight competition, America's Space Prize, to develop commercial human spacecraft. This prize challenges entities within the United States to design a reusable vehicle, without government funding, capable of carrying passengers into orbit, with the eventual goal of transporting humans to Bigelow Aerospace's expandable space modules. According to the rules, participants will be required to build a spacecraft capable of taking a crew of five people to an altitude of 400 kilometers (240 miles) and completing two orbits of

Armadillo Aerospace's module descends to a landing

the Earth at that altitude. They must then repeat that accomplishment within 60 days. The first flight attempt allows for just test pilots and an established mass for passengers, but the second flight must carry a crew of at least five. The spacecraft will have to demonstrate the ability to dock with Bigelow's inflatable space station and remain docked for a minimum of six months. Additionally, no more than 20% of the vehicle can be composed of expendable hardware.[4]

With the successful launch and ongoing operation of Genesis I and Genesis II and the proposed Sundancer, planned for launch early in the next decade, Bigelow Aerospace is continuing development towards future commercial space habitats.[5]

The competition deadline is January 10, 2010, with a cash prize of $50 million, funded fully by Bigelow Aerospace. To date, there has been very little in the way of publicly available information regarding the number of competition participants or if any progress has been made toward the competition.

Centennial Challenges

NASA's Innovative Partnerships Program Office uses the Centennial Challenges program to advance development of space technologies through prize competitions, bringing important government support to commercial spaceflight development. This program creates specialized competitions to further the exploration of space through specific technological development, using funding outlets beyond the standard procurement process.

There are seven currently funded Centennial Challenges, each of which is managed by an outside organization. Some of the competitions do not directly relate to commercial space transportation technologies, but all seven challenges develop technologies important to future commercial spaceflight.[6]

The Centennial Challenge that relates most directly with commercial spaceflight is the Northrop Grumman Lunar Lander Challenge (NG-LLC). This competition is managed for NASA by the X PRIZE Foundation, who received funding to cover administrative costs from Northrop Grumman. The NG-LLC was held as part of the X PRIZE Cup in 2006 and 2007. In 2008, the challenge was a stand-alone event that was not open to the general public but was broadcast live over the internet. This year's competition was the first time a competing team won a prize purse by successfully flying their vehicle.

The NG-LLC is divided into two levels that have separate prizes based on increasingly difficult requirements. Level 1 is completed if a team's constructed vehicle is able to take off vertically, reach an altitude of at least 50 meters and land precisely at the target landing area, having remained airborne for at least 90 seconds. They must complete a similar return trip and transport the vehicle back to the starting point within 50 minutes. The more difficult Level 2 requires the vehicle

to remain airborne for twice as long and land on a simulated lunar surface.[7] Each Level awards prizes for 1st and 2nd place.

On October 24, 2008 at the Las Cruces International Airport in Las Cruces, New Mexico, Armadillo Aerospace, a team that made attempts the previous two years of the NG-LLC, successfully completed Level 1 with its MOD-1 vehicle and earned $350,000 for first place in that level of the competition. The 2008 NG-LLC marks the first time a team successfully completed a part of the challenge and Armadillo's $350,000 win is the largest single prize awarded within any of the Centennial Challenges. The team competed unsuccessfully for Level 2 the following day. Although nine teams were registered to compete, only one other team participated in the competition. TrueZer0 team, new to the LLC this year, was unable to complete Level 1. The total unclaimed prize money, $1,650,000, reserved for Level 2 and second place for Level 1, will transfer to 2009 when the challenge will be held again.[8]

Aside from the General Aviation Technology Challenge managed by the Comparative Aircraft Flight Efficiency Foundation, the other five Centennial Challenges are space-related and promote further space mission technologies.

- The Astronaut Glove Challenge, conducted by Volanz Aerospace Inc., tests participants on the dexterity, flexibility, and overall development of a spacesuit glove. The Challenge will be held in 2009 and includes some variations to the 2007 competition. The teams must provide a complete glove including the thermal micrometeoroid garment (TMG), unpowered bladder and bladder-restraint sections.

- The Tether and Beam Power Challenges, conducted by the Spaceward Foundation, are tentatively scheduled for February – March 2009. The purpose of these challenges is to further the development of high strength-to-weight materials and wireless power distribution technologies. Since neither competition has awarded any prizes to date, the prize purse continues to rise; in 2009 it will be $2 million for each competition.

- Two other currently active space competitions are the Regolith Excavation Challenge, conducted in 2007 and 2008 with sixteen teams but no winner, and the Moon Regolith Oxygen Extraction Challenge (both organized by the California Space Education and Workforce Institute). These challenges award prizes of $750,000 and $1 million, respectively, for future lunar exploration excavation and oxygen extraction technologies.

Whether prize purses are awarded or not, the Centennial Challenges Program is considered a success in meeting NASA's goals of promoting private space technology development and encouraging innovation in private enterprise.[9]

The President's Fiscal Year (FY) 2009 Budget Request asks for $4 million per year for the Centennial Challenges for FY 2009 through FY 2012 as a part of the IPP.[10] Although the program's budget was zeroed out in FY 2008, funding of the purses

for the competitions mentioned above was obligated using FY 2005 funds. If new funding is appropriated, NASA plans to introduce new Centennial Challenges competitions.

EXPENDABLE LAUNCH VEHICLES

This survey of U.S. Expendable Launch Vehicles (ELVs) is divided into four sections. The first reviews the ELVs currently available to serve a wide range of commercial and government payloads. The second reviews a number of proposed commercial ELVs under study or development—many of which are designed to launch small satellites at lower costs, greater responsiveness, and with shorter turnaround times than existing vehicles. The third discusses the new launch vehicles being developed exclusively to support NASA's Vision for Space Exploration. Finally, the fourth section reviews suborbital sounding rockets manufactured and operated by U.S. companies.

Current Expendable Launch Vehicle Systems

Table 1 on the next page lists the ELV systems available in the United States today for commercial or government missions. The Minotaur is restricted to government payloads. The Delta IV, while available to both US government and commercial customers, has thus far been mainly used by the government. The Atlas V, Delta II, Pegasus, and Taurus vehicles are available for commercial and U.S. government launches. The Zenit-3SL is available only to commercial customers.

Atlas V – United Launch Alliance

Atlas V

The Atlas V is one of two launch vehicles developed as part of the U.S. Air Force's Evolved Expendable Launch Vehicle (EELV) program in the late 1990s. The Atlas V was developed by the Lockheed Martin Corporation; since December 2006 it has been produced by United Launch Alliance (ULA), a joint venture between The Boeing Company and Lockheed Martin. The Atlas V is made available for commercial launches by Lockheed Martin Commercial Launch Services.

The Atlas V is available in the 400 and 500 series and accommodates 4-meter (13.1-foot) and 5.4-meter (17.6-foot) fairings and up to five strap-on solid rocket motors. The Atlas 400 series can place payloads between 4,950 and 7,640 kilograms (10,910 and 16,843 pounds) into geosynchronous transfer orbit (GTO). The Atlas 500 series can place payloads between 3,970 and 8,670 kilograms (8,750 and 19,120 pounds) into GTO. The Atlas V launches from Cape Canaveral Air Force Station (CCAFS) in Florida and Vandenberg Air Force Base (VAFB) in California.[1]

Since its introduction in 2002, the Atlas V has performed 14 launches. In 2008, two Atlas V launches took place, including the commercial launch of the ICO G1 satellite.

Up to five Atlas V launches are planned for 2009.

	SMALL				MEDIUM	INTERMEDIATE		HEAVY	
									
Vehicle	Falcon 1	Minotaur	Pegasus XL	Taurus XL	Delta II	Atlas V	Delta IV	Delta IV Heavy	Zenit-3SL
Company	SpaceX	Orbital Sciences	Orbital Sciences	Orbital Sciences	ULA	ULA	ULA	ULA	Sea Launch
First Launch	2008	2000	1990	1994	1990	2002	2002	2004	1999
Stages	2	4	3	4	3	2	2	2	3
Payload Performance (LEO)	420 kg (925 lb)	640 kg (1,410 lb)	440 kg (970 lb)	1,590 kg (3,505 lb)	6,100 kg (13,440 lb)	12,500 kg (27,560 lb) (Atlas V 402) 20,520 kg (45,240 lb) (Atlas V 552)	9,150 kg(20,170 lb)(Delta IV M) 13,360 kg (29,440 lb) (Delta IV M+ (5,4))	22,560 kg (49,740 lb)	N/A
Payload Performance (LEO polor)	420 kg (925 lb)	640 kg (1,410 lb)	190 kg (420 lb) (SSO)	860 kg (2,000 lb) (SSO)	3,600 kg (7,930 lb)	7,095 kg (15,640 lb) (Atlas V 402) 14,095 kg (31,075 lb) (Atlas V 552)	7,510 kg (16,550 lb) (Delta IV M) 11,300 kg (24,920 lb) (Delta IV M+ (5,4))	22,560 kg (49,740 lb)	N/A
Payload Performance (GTO)	N/A	N/A	N/A	430 kg (950 lb)	2,170 kg (4,790 lb)	4,950 kg (10,910 lb) (Atlas V 401) 8,670 kg (19,120 lb) (Atlas V 551)	4,300 kg (9,480 lb) (Delta IV M) 7,020 kg (15,470 lb) (Delta IV M+ (5,4))	12,980 kg (28,620 lb)	6,100 kg (13,500 lb)
Launch Sites	RTS, CCAFS	VAFB, Wallops	VAFB, Wallops, CCAFS	VAFB	CCAFS, VAFB	CCAFS, VAFB	CCAFS, VAFB	CCAFS, VAFB	Pacific Ocean

Table 1: Currently Available Expendable Launch Vehicles

Delta II – United Launch Alliance

Delta II

The Delta II launch vehicle, in service since 1989, traces its heritage to the Thor missile program of the 1950s. Since December 2006, the Delta II has been produced by ULA and is marketed commercially by Boeing Launch Services (BLS). The Delta II has the capability to launch payloads of 900 to 2,170 kilograms (1,980 to 4,790 pounds) to GTO, and 2,700 to 6,100 kilograms (5,960 to 13,440 pounds) to low Earth orbit (LEO). The vehicle can launch from either CCAFS or VAFB.[2]

There were five Delta II launches in 2008, including the commercial launches of GeoEye 1 and Cosmo-Skymed 3. As many as seven Delta II launches, including one commercial mission, are planned for 2009.

Delta IV – United Launch Alliance

Delta IV

The Delta IV is one of two launch vehicles developed for the EELV program in the 1990s. The Delta IV was designed by Boeing, and since December 2006 has been produced by ULA. Originally developed for both commercial and government applications, the Delta IV is currently only available to government customers.

The Delta IV is available in five versions: four medium-class versions, with varying payload fairing sizes and number of strap-on boosters, and one heavy-class version, which uses three common booster core stages instead of one. The vehicle's payload launch capacities to LEO range from 9,150 kilograms (20,170 pounds) for the Delta IV Medium to 22,560 kilograms (49,740 pounds) for the Delta IV Heavy. Geosynchronous transfer orbit capacities range from 4,300 to 12,980 kilograms (9,480 to 28,620 pounds). The Delta IV operates from CCAFS and VAFB.[3]

The Delta IV has flown seven times since its introduction in late 2002. Up to four Delta IV launches, including Delta IV Heavy launch of the National Reconnaissance Office (NRO) satellite NRO L-26 as well as one FAA-licensed mission, are planned for 2009.

Falcon 1 – Space Exploration Technologies Corporation

SpaceX of Hawthorne, California, has developed the partially reusable Falcon 1 launch vehicle, which can place up to 475 kilograms (1,050 pounds) into LEO for about $7 million. The first stage of this vehicle is designed to parachute into the ocean. It can then be recovered, refurbished, and reused. SpaceX privately developed the entire two-stage vehicle from the ground up, including the engines,

Falcon 1

cryogenic tank structure, and guidance system. The first stage engine, known as Merlin, uses pump-driven LOX and kerosene. The second stage engine, called Kestrel, uses a pressure-fed LOX and kerosene system.

The Falcon 1 performed three launches before achieving success. The first, in March 2006, suffered an engine failure 29 seconds into flight due to a fuel leak. The second, in March 2007, failed to reach orbit. The third, in August 2008, experienced a stage separation problem. However, on September 28, 2008, Flight 4 of the Falcon 1 achieved total success. It is now in full operation, and is expected to perform at least two launches of commercial payloads in 2009.[4]

The Falcon 1e, an enhanced version of the Falcon 1 with a stretched first stage and larger payload fairing, is also slated to enter service in 2009; it will be able to place up to 725 kilograms (1,600 pounds) into LEO for $8.5 million.[5]

Minotaur I – Orbital Sciences Corporation

Orbital Sciences Corporation developed the Minotaur family of launch vehicles under the U.S. Air Force's Orbital/Suborbital Program (OSP). The first vehicle of the series, Minotaur I, is used to launch small government payloads. The Minotaur I booster uses a combination of rocket motors from decommissioned Minuteman II ICBMs and upper stages from Orbital's Pegasus launch vehicle. The first two stages of the Minotaur I are Minuteman II M-55A1 and SR-19 motors, while the upper two stages are Orion 50 XL and Orion 38 motors from the Pegasus XL.

Minotaur I

The Minotaur I entered service in 2000 and has performed seven launches to date. No Minotaur I missions took place in 2008, but the vehicle did launch the NFIRE satellite in 2007 from the Mid-Atlantic Regional Spaceport (MARS) in Virginia. A Minotaur I is scheduled to launch the TacSat-3 satellite in 2009, also from MARS. The Minotaur I has previously performed launches from VAFB, and can operate from CCAFS and Kodiak Launch Complex, Alaska.

Pegasus XL – Orbital Sciences Corporation

The Pegasus XL is an air-launched booster designed for small payloads, primarily to low Earth and sun-synchronous orbits. Introduced in 1994, the Pegasus XL is a derivative of the original Pegasus rocket, with stretched first and second stages. (The original Pegasus, first launched in 1990, was retired in 2000.) The Pegasus XL, with three solid-propellant stages and an optional hydrazine monopropellant upper

stage, is deployed from an Orbital Sciences L-1011 aircraft named "Stargazer." One advantage of the fact that the Pegasus XL is air-launched is the flexibility to stage missions from a variety of sites, including Edwards Air Force Base (EAFB) and VAFB in California; CCAFS and Kennedy Space Center (KSC) in Florida; NASA Wallops Flight Facility (WFF) in Virginia; Kwajalein Missile Range, Marshall Islands; and Gando Air Force Base (GAFB), Canary Islands.

The Pegasus XL performed two launches in 2008: the FAA-licensed launch of the U.S. Air Force (USAF) C/NOFS satellite, and the launch of NASA's Interstellar Boundary Explorer (IBEX). At least one Pegasus XL mission is scheduled for 2009.

A Pegasus XL rocket is air-launched

Taurus – Orbital Sciences Corporation

Taurus

The Taurus is a ground-launched vehicle based on the air-launched Pegasus. Orbital Sciences developed the Taurus under the sponsorship of the Defense Advanced Research Projects Agency (DARPA). The goal was to develop a standard launch vehicle that could be set up quickly in new locations to launch small satellites that exceed the lift capacity of the Pegasus XL. The Taurus uses the three stages of a Pegasus XL (without wings or stabilizers) stacked atop a Castor 120 solid rocket motor. The Castor 120 serves as the first stage of the Taurus. The Taurus has successfully completed six of seven launch attempts since entering service in 1994. No Taurus launches took place in 2008, but at least two are scheduled for 2009.

Zenit-3SL – Sea Launch Company, LLC

The Zenit-3SL is a Ukrainian-Russian launch vehicle operated by Sea Launch Company, LLC, a multinational venture of four partners. Ukrainian sister companies SDO Yuzhnoye and PO Yuzhmash provide the first two stages, the same as those used on the Zenit 2 launch vehicle. A Russian company, RSC Energia, provides the third stage, a Block DM-SL upper stage. The Norwegian shipbuilding company, Aker, designed and built the two Sea Launch vessels and contracts marine operations. The Boeing Company provides the payload fairing and interfaces, as well as operations and business management.

The Zenit-3SL launches from the *Odyssey* Launch Platform, which travels from its Sea Launch Home Port in Long Beach, California, to a position on the Equator in the Pacific Ocean for each mission. Launch operations are remotely controlled from a separate vessel, the *Sea Launch Commander*, which is positioned approximately 6.5 kilometers (about 4 miles) uprange from the platform during launch operations.

After a first-stage engine explosion destroyed the Zenit-3SL just after ignition on January 30, 2007, no further launches took place in 2007. On January 15, 2008, the Zenit-3SL returned to flight with the successful launch of the communications satellite Thuraya 3. In all, five Zenit-3SL launches took place in 2008. At least three Zenit-3SL launches are planned in 2009.

Zenit 3SL lifts off from Odyssey launch platform

In addition to the Zenit-3SL, Sea Launch offers the Zenit-3SLB through its Land Launch service. The Zenit-3SLB is designed to lift commercial satellites in the 2,000 to 3,600-kilogram (4,410 to 7,940-pound) range to GTO and heavier payloads to inclined or lower orbits. The three stages on the Zenit-3SLB are the same as those on the Sea Launch Zenit-3SL; the fairing is the only significant difference between the two vehicles. A two-stage configuration of the same rocket, the Zenit-2SLB, is also available for launching heavy payloads, or groups of payloads, to LEO.

Payloads and vehicles for the Land Launch Zenit-3SLB are processed and launched from existing Zenit facilities at the Baikonur launch site. Following its single launch in 2008, the Zenit-3SLB vehicle is scheduled to perform up to four launches in 2009.[6]

ELV Development Efforts

A number of efforts by both established corporations and startups are currently in progress to develop new ELVs. Many of these designs focus on the small payload sector of the launch market, with the goal of placing payloads as small as a few hundred pounds into LEO.

ATK Launch Vehicle – Alliant Techsystems

In October 2006, ATK of Edina, Minnesota, announced it was developing a small launch vehicle, the two-stage ATK Launch Vehicle (ALV). The ALV is based on existing rocket stages developed by the company. ATK carried out a successful "pathfinder" for the ALV by assembling the vehicle on the pad at MARS in 2006.

Vehicle	ATK Launch Vehicle
Developer	Alliant Techsystems (ATK)
First Launch	TBD
Number of Stages	2
Payload Performance	1,360 kg (3,000 lb) suborbital
Launch Site	MARS
Markets Served	Responsive launches of small satellites for civil, commercial, and military customers

The first launch of the ALV, a suborbital flight designated ALV X-1 carrying two NASA hypersonic flight experiments, took place on August 22, 2008. The vehicle lifted off as expected from MARS in Virginia, but veered off course 17 seconds into flight, prompting range safety officials to trigger the self-destruct mechanism. The vehicle

ATK Launch Vehicle

achieved an altitude of between 3,300 and 3,600 meters (11,000 and 12,000 feet) before the flight was terminated.[7] In January 2009, an investigation panel released preliminary findings that the likely cause of the failure was a software problem.[8]

While the failure of the suborbital test destroyed the ALV prototype, ATK plans to continue development of a larger orbital version of the ALV that would serve government and commercial customers seeking responsive launches of small satellites.[9]

Athena III – PlanetSpace

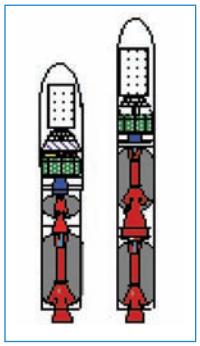
Vehicle	Athena III
Developer	Planetspace with ATK, Boeing, and Lockheed Martin
First Launch	TBD
Number of Stages	3
Payload Performance	TBD
Launch Site	CCAFS
Markets Served	ISS resupply

In late 2007, PlanetSpace announced a partnership with Lockheed Martin and ATK to design a new launch vehicle in pursuit of the NASA ISS Commercial Resupply Services (CRS) contract. In 2008, this group of companies added a fourth member, Boeing, to their team. Together, the PlanetsSpace-led consortium proposed the development of the Athena III booster.

The Athena III design centers around a 2.5-segment first-stage propulsion system derived from the Space Shuttle's 4-segment solid-rocket booster system. The vehicle's seconds stage design would employ the ATK Castor 120 engine currently used on the Taurus I launch vehicle. The third stage of the vehicle would use an ATK Castor 30 engine, atop with there would be a liquid-propelled Orbit Adjust module and the Boeing/Lockheed Martin Orbital Transfer Vehicle designed to ferry cargo to the ISS.

In November 2008, the PlanetSpace team submitted its ISS CRS proposal, which called for 10 to 12 flights to the ISS from 2009 to 2015. In December 2008, NASA announced that the ISS CRS contract had been awarded to Orbital Sciences Corporation and Space Exploration Technologies Corporation (SpaceX), rather than to the PlanetSpace team.[10] Nevertheless, PlanetSpace announced earlier in 2008 it planned to proceed with the Athena III design regardless of the outcome of the CRS bid process.[11]

Eagle S-series – E'Prime Aerospace Corporation



Cutaway view of Eaglet and Eagle

E'Prime Aerospace of Colorado is developing a family of launch vehicles named the Eagle S-series, based on the LGM-118A Peacekeeper Intercontinental Ballistic Missile (ICBM) design. The Eagle S-series concept dates back to 1987 when the company signed a commercialization agreement with the U.S. Air Force to use Peacekeeper technology for commercial launch vehicles. Like the Peacekeeper, Eagle S-series vehicles would be ejected from a ground-based silo, using a compressed gas system. At an altitude of 61 meters (200 feet), the engines will ignite. The smallest vehicle, the Eaglet, could launch 580 kilograms (1,280 pounds) into LEO. A somewhat larger version, the Eagle, could put 1,360 kilograms (3,000 pounds)

Vehicle	Eaglet/Eagle/S1/S2
Developer	E'Prime Aerospace
First Launch	TBD
Number of Stages	2 (Eaglet and Eagle); 3 (S1 and S2)
Payload Performance	580 kg (1,280 lb) to LEO (Eaglet); 1,360 kg (3,000 lb) to LEO (Eagle); 2,948 kg (6,500 lb) to LEO (S1); 4,535 kg (10,000 lb) to LEO (S2)
Launch Site	MARS
Markets Served	Small satellite launch

into LEO. Planned follow-on vehicles, the S1 and S2, would be medium-lift boosters with launch capability of 2,948 kilograms (6,500 pounds) and 4,536 kilograms (10,000 pounds) to LEO. E'Prime has also proposed larger hot pad vehicles, designated S-3 through S-7, with the ability to place larger payloads into LEO and to add a geosynchronous Earth orbit (GEO) lift capability.

The Eagle-S series would use solid propellant lower stages and liquid propellant upper stages. E'Prime is exploring upgrading the solid propulsion systems to use safer, more storable, and higher-performance microcellular solid fuels.

In August 2007, E'Prime Aerospace announced that it had selected MARS as its primary launch site and will develop infrastructure there to support its vehicles. In November 2007, the company was notified that its proposed vehicle had cleared an interagency policy review, removing government obstacles to its use of its Peacekeeper-derived motors.[12] Development of the Eagle S-series continued in 2008 as E'Prime Aerospace underwent a change in management.[13]

Falcon 9 – Space Exploration Technologies Corporation

Quarter section of Falcon 9 fairing

The two-stage Falcon 9 vehicle is designed to launch large spacecraft as well as cargo and crew resupply missions to the ISS. The first stage uses nine Merlin 1C engines, the same engine as used on the first stage of the Falcon 1. The second stage, a shortened version of the first stage, uses a single Merlin engine. Both stages are designed to be recovered and reused. The Falcon 9 can place up to 9,900 kilograms (21,820 pounds) into LEO and 4,900 kilograms (10,800 pounds) into GTO.

Vehicle	Falcon 9
Developer	Space Exploration Technologies Corporation
First Launch	2009; Heavy version first launch in 2010
Number of Stages	2
Payload Performance	Up to 9,900 kilograms (21,820 pounds) to LEO and 4,900 kilograms (10,800 pounds) into GTO; for Heavy version, up to 27,500 kg (60,600 lb) to LEO, 12,000 kg (26,500 lb) to GTO
Launch Site	Kwajalein Atoll, CCAFS
Markets Served	Launch of medium and large satellites, ISS crew and cargo resupply

The first Falcon 9 launch, a demonstration mission, is scheduled for 2009.[14] In addition to the demonstration flight, four other Falcon 9 launches are planned for 2009. Two are NASA COTS demonstration missions, in which SpaceX will used its Dragon reusable spacecraft to demonstrate the Falcon 9's ability to ferry cargo to and from the ISS. The other two are on behalf of the commercial customers MacDonald, Dettwiler and Associates Ltd. of Canada and Avanti Communications—which signed the first contract for the Falcon 9 launch of a commercial communications satellite in September 2007.[15] Falcon 9 will launch from Space Launch Complex 40, a former Titan IV launch pad at CCAFS.[16]

In 2008, SpaceX also announced plans to develop the Falcon 9 Heavy. With a capacity of over 28,000 kilograms (62,000

pounds) to LEO, and over 12,000 kg (26,000 pounds) to GTO, the Falcon 9 Heavy will be among the largest commercial launchers available. The design of the Falcon 9 heavy features a standard Falcon 9 with two additional Falcon 9 first stages serving as liquid strap-on boosters. The first launch of the Falcon 9 Heavy is slated for 2010.[17]

Launch cost estimates for the Falcon 9 range from $35 million for the medium version to $95 million for the heavy version.[18]

FALCON SLV – Lockheed Martin Michoud Operations

Vehicle	FALCON SLV
Developer	Lockheed Martin Michoud Operations
First Launch	TBD
Number of Stages	2
Payload Performance	840 kg (1,855 lb) to LEO
Launch Site	TBD
Markets Served	Small satellite launch, responsive space operations

Lockheed Martin Michoud Operations of New Orleans, Louisiana, was awarded one of four Defense Advanced Research Projects Agency (DARPA) Force Application and Launch from CONUS (FALCON) contracts in September 2004. This $11.7 million contract tasked Lockheed Martin to develop concepts for a low-cost operationally responsive launch vehicle. Lockheed Martin's FALCON Small Launch Vehicle (SLV) approach featured environmentally friendly hybrid propulsion and a mobile launch system able to launch from an unimproved site with limited infrastructure on 24 hours notice, placing up to 840 kilograms (1,855 pounds) into LEO.

Artist conception of Falcon SLV

In 2005, Lockheed conducted two successful test firings of the SLV second stage hybrid rocket motor. The second test lasted 120 seconds and confirmed the motor port design and the combustion stability technology. Though Lockheed did not win a Phase 2B Falcon contract from DARPA in late 2005, since then company has continued to mature the FALCON SLV and remains in discussions about the vehicle with potential customers.[19]

Nanosat Launch Vehicle – Garvey Spacecraft Corporation

Vehicle	Nanosat Launch Vehicle
Developer	Garvey Spacecraft Corporation
First Launch	TBD
Number of Stages	2
Payload Performance	10 kg (22 lb) to LEO (polar orbit)
Launch Site	TBD
Markets Served	Nanosatellite launch

Garvey Spacecraft Corporation (GSC), based in Long Beach, California, is a small research and development (R&D) company, focusing on the development of advanced space technologies and launch vehicle systems. As part of the California Launch Vehicle Initiative (CALVEIN), GSC and California State University, Long Beach (CSULB) jointly conduct preliminary R&D tasks to establish the foundation for development of a two-stage, liquid propellant, Nanosat Launch Vehicle (NLV). Capable of delivering 10 kilograms (22 pounds) to a 250-kilometer (155-mile) polar orbit, the NLV will provide low-cost, dedicated launch services to universities and other research organizations that traditionally depend on secondary payload opportunities to access space. Their current work builds upon flights

Prospector-11A test flight

that the team conducted using several of its LOX/ethanol Prospector research vehicles. The company's most visible accomplishments include the first-ever flight of a composite LOX tank, conducted in partnership with Microcosm, Incorporated; the first-ever powered flights of a liquid-propellant aerospike engine; and the launch and 100 percent recovery of several prototype reusable test vehicles.

As a preliminary step in developing the NLV, GSC and its research partner, CSULB, is continuing development of the P-9 and two other vehicles, Prospectors 10 and 12.[20] On April 12, 2008, the GSC and CSULB team jointly staged a test flight of the Prospector 14 (P-14LM) vehicle. The P-14LM airframe is a refurbished version of the original Prospector 1 prototype flown in 2001. It features a 4,500-newton (1000-pounds-force) LOX-methane engine developed by CSULB students as part of their senior design course.[21]

GSC conducted three other test flights in 2008. In June 2008, GSC launched a prototype of the Prospector 11A (P-11A) under a Phase 1 SBIR contract for NASA Ames. In August 2008, GSC performed a test launch of Prospector 9A (P-9A) as part of a demonstration program for the Air Force Research Laboratory (AFRL). Finally, in October 2008, GSC flew the Prospector 12A (P-12A)–a refurbished version of P-11A—as a demonstration test for the California Space Authority and U.S. Department of Labor. In addition to testing technologies planned for eventual use on the NLV, a primary project objective of these missions was to provide mentoring opportunities for future launch vehicle engineers and also show the vehicle's capacity to carry academic payloads.

Minotaur IV and V – Orbital Sciences Corporation

Under a contract with the USAF Space and Missile Systems Center, Orbital Sciences Corporation is currently developing the Minotaur IV launch vehicle for U.S. government payloads. The Minotaur IV is derived from the Peacekeeper ICBM, using three Peacekeeper solid-propellant stages and an Orion 38 motor for the fourth stage. The Minotaur IV uses a standard 234-centimeter (92-inch) payload fairing also used on Orbital's Taurus rocket. The first Minotaur IV launch is scheduled for 2009, when it will launch the Space-Based Surveillance System (SBSS) satellite for the USAF. As of the end of 2008, Orbital had finalized eight publicly announced Minotaur IV launch contracts.[22]

Vehicle	Minotaur IV and V
Developer	Orbital Sciences Corporation
First Launch	2009 (Minotaur IV), TBD (Minotaur V)
Number of Stages	4 (Minotaur IV), 5 (Minotaur V)
Payload Performance	1,750 kg (3,860 lb) to LEO (Minotaur IV), 678 kg (1,495 lb) to GTO (Minotaur V)
Launch Site	MARS, VAFB
Markets Served	Small satellite launch and responsive space operations for U.S. government-sponsored payloads

Minotaur IV

Orbital is also developing a derivative

of the Minotaur IV, called the Minotaur V, for payloads launched to orbits beyond LEO. The Minotaur V features the same three Peacekeeper-based lower stages, but uses a Star 48 fourth stage and Star 37 fifth stage, allowing it to put 678 kilograms (1,495 pounds) into GTO and 440 kilograms (970 pounds) on a translunar injection trajectory. The Minotaur V shares many of the same subsystems as the Minotaur IV, requiring only an additional $10 million in non-recurring engineering expenses to complete its development.[23]

QuickReach – AirLaunch LLC

Vehicle	QuickReach
Developer	AirLaunch LLC
First Launch	2010
Number of Stages	3 (including the launch aircraft)
Payload Performance	450 kg (1,000 lb) to LEO
Launch Site	Air launched
Markets Served	Small satellite launch, responsive space operations

AirLaunch LLC, based in Kirkland, Washington, is developing the QuickReach™ vehicle, a small, low-cost, air-launched rocket for defense and other applications. The vehicle is being developed with assistance from the DARPA/Air Force FALCON SLV program. The two-stage rocket is carried aloft inside a cargo aircraft, such as a C-17A or other large cargo aircraft. The rocket is released from the aircraft at an altitude of 7,600 to 10,700 meters (25,000 to 35,000 feet) and fires its liquid-propellant engines to ascend to orbit. The vehicle is designed to place a 450-kilogram (1,000-pound) payload into LEO for less than $5 million.

Horizontal Test Stand (HTS-2)

On February 5, 2008, AirLaunch announced it had achieved a major hardware milestone as part of Phase 2C of the FALCON program: completion of the upgraded Horizontal Test Stand (HTS-2). The HTS-2 features new hardware and additional sensors and instrumentation systems. Upon completion, AirLaunch received approval from the FALCON program to proceed with its series of engine tests on the HTS-2. AirLaunch conducted 30 test firings on the new horizontal test stand during July and August 2008.[24]

DARPA and the Air Force collectively invested approximately $38 million in AirLaunch during the course of the FALCON SLV Program, covering Phases 1, 2A, 2B and 2C. Although the Falcon SLV program concluded on November 3, 2008, development of the QuickReach™ vehicle for commercial use remains ongoing.[25]

Taurus II – Orbital Sciences Corporation

Vehicle	Taurus II
Developer	Orbital Sciences Corporation
First Launch	2010
Number of Stages	2 (with optional third stage)
Payload Performance	5,400 kg (11,900 lb) to LEO
Launch Site	WFF, VAFB, CCAFS
Markets Served	Medium-class payloads for government and commercial customers

In 2007, Orbital Sciences Corporation announced that it had begun study of a new launch vehicle, the Taurus II, designed to serve medium-class payloads for U.S. government and commercial customers. On February 19, 2008, NASA awarded Orbital a three-year cooperative agreement. Under the agreement, NASA will invest $170 million in Orbital Sciences Corporation, while Orbital will contribute

Taurus II

$150 million to the Commercial Orbital Transporation Services (COTS) initiative. The $150 million investment by Orbital also represents an investment by the company in its own Taurus II vehicle. The agreement provides for the Taurus II vehicle to perform a LEO flight demonstration of its commercial cargo delivery capacity. This initial demonstration flight is planned for 2010.[26]

The Taurus II's first stage will be powered by a pair of Aerojet AJ26-58 engines, a version of the NK-33 engine developed for the Soviet Union's N-1 lunar rocket in the 1960s. The second stage of the vehicle will use an ATK Castor-30 solid motor with thrust vectoring; its design will be based on the Castor-120 motor. The Taurus II will also allow for an optional third stage that includes an Orbital Raising Kit (ORK) integrated into the 3.9-meter (12.8-foot) payload fairing. The ORK will feature a helium-pressure regulated bi-propellant system fueled by nitrogen tetroxide and hydrazine; its design heritage will be based on the Orbital STAR bus.[27]

The Taurus II would be able to place 5,400 kilograms (11,900 pounds) into LEO. While the initial Taurus II demonstration flight is slated to launch from Wallops Flight Facility (WFF), the vehicle will also be compatible with facilities at VAFB and CCAFS.[28]

Upper Stage – SpeedUp

Vehicle	Upper Stage
Developer	SpeedUp
First Launch	TBD
Number of Stages	0
Payload Performance	50 kg (110 lb) to 2600 m/s delta-v
Launch Site	TBD
Markets Served	unmanned sounding rocket payloads

In addition to its Laramie Rose prototype (discussed in the reusable launch vehicles section), SpeedUp is developing a modular expendable upper stage to increase the altitude or payload mass capability of other launch providers' unmanned sounding rockets. The rocket is powered by a hybrid engine using 98-percent concentration hydrogen peroxide as oxidizer. Prototype construction is underway, and SpeedUp plans to perform static engine firings in 2009 and captive carry tests on other launch providers' rockets beginning in 2010.[29]

NASA Exploration Launch Vehicles

On September 19, 2005, NASA announced its planned mission architecture for crewed lunar missions. The plan calls for developing two new launch vehicles, the Crew Launch Vehicle (since renamed the Ares I) and the Cargo Launch Vehicle (renamed the Ares V). Both vehicles are designed to leverage Shuttle and even Apollo-era technologies to launch crewed and uncrewed spacecraft required to carry out the Vision for Space Exploration.

Ares I

The Ares I Crew Launch Vehicle is a two-stage vehicle designed principally to launch NASA's Orion CEV into LEO and may also be used to launch cargo spacecraft to the ISS. The first stage of the Ares I is a five-segment reusable solid

rocket motor (RSRM) derived from the four-segment boosters used in the Space Shuttle program. The second stage is a new design powered by a single J-2X engine, based on the J-2S engine developed at the end of the Apollo program in the early 1970s; it uses LOX and liquid hydrogen propellants. The Orion spacecraft, along with an escape rocket, will be mounted on top of the second stage development of the Ares I is currently in progress. In July 2007, NASA awarded Pratt & Whitney Rocketdyne a $1.2-billion contract for the J-2X engine.[30] In August 2007, NASA selected Boeing to build the upper stage of the Ares I.[31] NASA also awarded Boeing a contract in December 2007 for the instrument unit avionics for the Ares I, the last major component of the launch vehicle to be assigned to a contractor.[32]

Vehicle	Ares I
Developer	NASA
First Launch	2014
Number of Stages	2
Payload Performance	22,700 kg (50,044 lb) to LEO
Launch Site	KSC
Markets Served	Crew launches for exploration and ISS missions

Artist conception of Ares I

In November 2008, the J-2X engine successfully completed its critical design review.[33] Also in November, the Upper Stage Simulator for the first test flight of the Ares I rocket, designated Ares I-X, arrived at KSC from Glenn Research Center (GRC).[34] A suborbital test launch of the vehicle with an inert second stage, the Ares I-X flight, is planned in the third or fourth quarter of 2009.[35] The operational orbital version of the Ares I vehicle is scheduled to enter service no later than 2014.

Ares V

The Ares V Cargo Launch Vehicle is a two-stage, heavy-lift vehicle that NASA will use to carry out human missions to the Moon and other destinations. The Ares V uses two five-and-a-half segment RSRMs similar to those developed for the Ares I vehicle, attached to either side of a core propulsion stage. The core stage features six RS-68 engines, the same LOX and liquid hydrogen engines as those used currently on the Delta IV family of vehicles. Under the current exploration architecture, an Ares V vehicle would place a lunar module and Earth departure stage into LEO, where the module would dock with an Orion spacecraft launched separately by an Ares I. The combined vehicle would then leave Earth orbit for the Moon.

Vehicle	Ares V
Developer	NASA
First Launch	2018
Number of Stages	2
Payload Performance	131,500 kg (289,904 lb) to LEO
Launch Site	KSC
Markets Served	Cargo launches for exploration missions

Artist conception of Ares V

Detailed development of the Ares V is not expected to begin until the end of this decade. The first test flight of the vehicle is scheduled to take place around 2018.[36]

Sounding Rockets

In addition to orbital launch vehicles, a number of suborbital ELVs, or sounding rockets, are in use today. These vehicles, which primarily use solid propellants, differ from amateur rockets in that they typically climb to higher altitudes and primarily carry out missions on behalf of specific commercial, government, or non-profit (including scientific missions and academic) clients. Sounding rockets support a variety of applications, including astronomical observations, atmospheric research, and microgravity experiments.

Black Brant – Bristol Aerospace Limited

Black Brant sounding rocket

Over 1,000 Black Brant rockets have been launched since 1962, when manufacturing of the vehicle began. Versions of the Black Brant can carry payloads ranging from 70 to 850 kilograms (154 to 1,874 pounds) to altitudes from 150 to more than 1,500 kilometers (93 to 932 miles), and can provide up to 20 minutes of microgravity time during a flight. The Black Brant and Nikha motors used on some Black Brant versions are manufactured in Canada by Bristol Aerospace Limited (a Magellan Aerospace Company). Terrier, Talos, and Taurus motors used on other Black Brant versions are built in the United States. The launch operator integrates these vehicles. In the United States, NASA has been a frequent user of Black Brant vehicles.

The smallest version of the Black Brant family is the single-stage Black Brant V, which is 533 centimeters (210 inches) long and 43.8 centimeters (17.24 inches) in diameter. The rocket produces an average thrust of 75,731 Newtons (17,025 pounds-force). The Black Brant V motor is used as the second or third stage in larger, multi-stage versions of the Black Brant. The most powerful of the line, Black Brant XII, is a four-stage vehicle that uses the Black Brant V motor as its third stage. This vehicle can launch a 113-kilogram (250-pound) payload to an altitude of at least 1,400 kilometers (870 miles), or a 454-kilogram (1,000-pound) payload to an altitude of at least 400 kilometers (250 miles).[37]

Oriole – DTI Associates

SPACEHAB's Astrotech Space Operations developed the Oriole sounding rocket in the late 1990s to provide launch services for commercial and scientific payloads. Oriole was both the first privately-developed sounding rocket in the United States and the first new U.S. sounding rocket in 25 years. The Oriole is a single-stage vehicle with a graphite-epoxy motor manufactured by Alliant Missile Products Company of Rocket Center, West Virginia. It is 396 centimeters (156 inches) long, 56 centimeters (22 inches) in diameter, and generates an average thrust of 92,100 Newtons (20,700 pounds-force). The vehicle provides payloads with six to nine minutes of microgravity during

Oriole sounding rocket

flight. Additionally, it can be combined with other motors to create two-stage sounding rockets, with the Oriole serving as the second stage.

The first Oriole launch took place from NASA WFF on July 7, 2000. That launch used a two-stage configuration, with the Oriole serving as the second stage and a Terrier Mk 12 motor serving as the first stage. The Oriole sounding rocket reached a peak altitude of 385.6 kilometers (229 miles) 315 seconds after launch during the ten-minute test flight. In July 2001, SPACEHAB's Astrotech Space Operations sold the Oriole program to DTI Associates of Arlington, Virginia, which integrates the vehicle and offers it commercially.

Terrier-Orion – DTI Associates

Terrier Orion sounding rocket

The Terrier-Orion is a two-stage, spin-stabilized sounding rocket, which uses a Terrier Mk 12 Mod 1 engine for its first stage and an improved Orion motor for its second stage. The Terrier Mk 12 Mod 1 is a surplus U.S. Navy missile motor; Orion is a surplus U.S. Army missile motor. The Terrier-Orion is 10.7 meters (35.1 feet) long. The Terrier stage is 46 centimeters (18 inches) in diameter, and the Orion is 36 centimeters (14 inches) in diameter. The Terrier-Orion can loft payloads weighing up to 290 kilograms (640 pounds) to altitudes up to 190 kilometers (118 miles).

A more powerful version of the Terrier-Orion rocket uses the Terrier Mk 70 motor as its first stage. This version was used for two FAA-licensed suborbital launches performed by Astrotech Space Operations/DTI at the Woomera Instrumented Range in Australia in 2001 and 2002. The second flight, in July 2002, successfully flew the HyShot scramjet engine experiment. DTI Associates of Arlington, Virginia, now markets and offers integration services for the Terrier-Orion after purchasing all intellectual property rights to the rocket from SPACEHAB.

SpaceLoft XL – UP Aerospace, Inc.

UP Aerospace, Incorporated, headquartered in Farmington, Connecticut, with business and engineering offices in Highlands Ranch, Colorado, has developed the SpaceLoft XL sounding rocket for research and commercial applications. The rocket, 6 meters (20 feet) tall and 25 centimeters (10 inches) in diameter, can carry up to 50 kilograms (110 pounds) of payload to an altitude of 225 kilometers (140 miles). A smaller version, the SpaceLoft, can carry 9 kilograms (20 pounds) to an altitude of 130 kilometers (80 miles). UP Aerospace is marketing the SpaceLoft family of vehicles to serve educational and research markets, such as microgravity and atmospheric sciences experiments, as well as commercial applications, including product marketing and novelty promotion.

Spaceloft XL

The first successful SpaceLoft XL launch took place on April 28, 2007, from Spaceport America in New Mexico.[38] The rocket reached a peak altitude of 117.5 kilometers (72.7 miles), landing in a mountainous region of the approved landing zone at White Sands Missile Range, New Mexico. The rocket carried over 50 experiments created by high school students from across America as well as commercial payloads from several companies.[39]

No SpaceLoft XL launches took place in 2008. At least one SpaceLoft XL launch is planned for 2009.[40]

REUSABLE LAUNCH VEHICLES

This section describes active and emerging reusable launch vehicle (RLV) programs in the United States. It is divided into two subsections. The first features vehicles developed by private companies without government assistance—many of which are developing space hardware for the first time. The second discusses government RLV programs, with particular focus on the Space Shuttle, which is considered a first-generation RLV. The flight experience of the Space Shuttle, in operation for nearly 30 years, has helped highlight and resolve problems with implications not only for that vehicle, but for other RLVs as well.

Commercial RLV Development Efforts

Tiger & Cardinal – Acuity Technologies

Vehicle	Tiger & Cardinal
Developer	Acuity Technologies
First Launch	TBD
Number of Stages	1
Payload Performance	25 kg (55 lb) to 50 m (165 ft)
Launch Site	TBD
Markets Served	Lunar Lander Challenge competition

Acuity Technologies of Menlo Park, California, has been developing the Tiger and Cardinal vehicles to compete in the two levels of the Northrop Grumman Lunar Lander Challenge (NG-LLC) competition. Both vehicles feature vertical takeoff and landing designs powered by methanol and a 59-percent concentration of hydrogen peroxide. The vehicles are designed to maneuver autonomously and can also be controlled from the ground via a standard remote control aircraft radio link.

Tiger prototype

Although test prototypes of the Tiger and Cardinal vehicles—"Hop" and "Hover"—were entrants in the 2008 NG-LLC competition, neither vehicle flew in the competition.[1] The vehicles may participate in future competitions.

QUAD & MOD-1 – Armadillo Aerospace

Armadillo Aerospace, a former competitor for the Ansari X PRIZE, is developing a set of vehicles designed for suborbital and, eventually, orbital flight opportunities: QUAD and MOD-1.

MOD-1 in flight

QUAD is a four-tank vertical takeoff and landing vehicle. On October 25, 2008, Armadillo flew a prototype of QUAD, named Pixel, in an effort to win Level Two of the NG-LLC. Level Two requires a vehicle to hover for twice as long as in Level One (180 seconds versus 90 seconds) before landing precisely on a simulated rugged lunar surface. Shortly after ignition, when Pixel was commanded from hovering to full throttle for liftoff, the fuel valve moved slower than the oxygen valve, resulting in a very hot engine.

Vehicle	Pixel (QUAD Prototype) and MOD-1
Developer	Armadillo Aerospace
First Launch	2007
Number of Stages	1
Payload Performance	25 kg (55 lb) to 50 m (165 ft)
Launch Site	Oklahoma Spaceport; Holloman Air Force Base; Las Cruces International Airport
Markets Served	Lunar Lander Challenge competition, future suborbital and orbital launch applications

The additional heat caused the side of the engine to melt and diverted some of the thrust sideways causing the Pixel vehicle to overturn. Armadillo opted to withdraw from the Level Two competition, with plans to re-compete at the 2009 Lunar Lander Challenge.[2]

In 2007, Armadillo developed a variant of the QUAD vehicle, the MOD-1 vehicle, for competition in Level One of the NG-LLC. The MOD-1 consists of a single pair of propellant tanks (the QUAD design featured two pairs of tanks) above a LOX/ethanol engine, with payload and electronic boxes on top of the tanks. The vertical-takeoff, vertical-landing vehicle is supported by four large landing legs.

In 2007, Armadillo received an experimental permit for MOD-1 from the Federal Aviation Administration (FAA) Office of Commercial Space Transportation (AST). To date, Armadillo has conducted eight launches of the MOD-1 vehicle in pursuit of the NG-LLC cash prize.

The MOD-1 narrowly fell short of the prize in 2007. After diagnosing and resolving the engine problems it experienced during the 2007 NG-LLC, Armadillo continued developing the MOD-1 throughout 2008. On October 24, 2008, MOD-1 flew again at Las Cruces International Airport in New Mexico, where it successfully achieved the NG-LLC Level One competition rules by performing two 90-second flights between pads 100 meters apart. The first 2008 flight failed to remain in the air for the required 90 seconds. The second launch, flown in the morning, was deemed a successful first leg of the competition; however, the required return flight was interrupted by airspace restrictions at the airport. Judges allowed Armadillo to complete the return leg with the remaining 64 minutes of their allotted two-and–a-half hour competition time in the afternoon. By completing this third flight, Armadillo won the $350,000 first prize for NG-LLC Level One.[3]

Armadillo expects MOD-1 to provide the basis for a series of increasingly-powerful modular vehicles. In August 2008, Armadillo announced that its engines would be used in vehicles participating in the Rocket Racing League, a proposed competition featuring races between rocket-powered aircraft. Armadillo also plans to collaborate with the Rocket Racing League to develop a vertical takeoff, vertical landing suborbital vehicle. Additional future plans call for testing vehicles that use two or more MOD-1 vehicles in combination. A "six-pack" variant using six modules, MOD-6, with the ability to higher suborbital altitudes, is also being considered.[4]

New Shepard – Blue Origin

Blue Origin is developing the New Shepard Reusable Launch System, a suborbital, vertical-takeoff, vertical-landing RLV for commercial passenger spaceflights. The vehicle will consist of a conical crew capsule, capable of carrying three people, mounted on top of a propulsion module. Engines using high-test peroxide (HTP)

and kerosene will power the vehicle. The flights would take place from a private facility operated by Blue Origin in Culberson County, Texas.

Blue Origin's Goddard prototype vehicle

As part of the New Shepard development process, Blue Origin has several prototype vehicles for flight testing at the company's Texas facility. The first such vehicle, named Goddard, is powered by an HTP monopropellant engine and is intended to perform flights to altitudes of about 600 meters (2,000 feet) and lasting no longer than 1 minute. In September 2006, the FAA granted Blue Origin an experimental permit to perform those flight tests. The first permitted flight took place on November 13, 2006, followed by flights on March 22 and April 19, 2007. All three test flights of the Goddard prototype were successful.[5]

Vehicle	New Shepard
Developer	Blue Origin
First Launch	2010
Number of Stages	2
Payload Performance	3 120-kg (265-lb) passengers or cargoes to 100 km (62 mi)
Launch Site	Culberson County, Texas
Markets Served	Suborbital space tourism

In 2008, Blue Origin continued to develop the New Shepard vehicle. The company aims to perform its first launch no later than 2010.[6]

Sea Star – Interorbital Systems

Sea Star

Interorbital Systems of Mojave, California, is developing the Sea Star for microsatellite payloads weighing up to 26 kilograms (58 pounds) and as a testbed for its larger Neptune orbital launch vehicle. The vehicle is aimed at launching multi-manifested missions of between 12 and 15 microsatellites at a price of approximately $500,000 per mission. To attract this market of academic microsats, Interorbital in November 2008 unveiled its new launch service, "Broad Operational Opportunity for Space Transport of University Payloads (BOOST UP)."[7]

Vehicle	Sea Star
Developer	Interorbital Systems
First Launch	4th quarter 2009
Number of Stages	2.5
Payload Performance	26 kg (58 lb) to LEO
Launch Site	Pacific Ocean west of Long Beach, California
Markets Served	Microsatellite launches

The Sea Star is constructed for design simplicity. The vehicle consists of a recoverable half-stage booster module with four rocket engines, a sustainer module with four additional engines as well as propellant tanks and guidance control systems, and a satellite module that contains the payload and one small rocket engine. All the engines use a combination of storable hypergolic propellants: white fuming nitric acid (WFNA) and "Hydrocarbon X" (HX), a company-proprietary fuel. The main structures of the rocket, including the outer shell and propellant tanks, will use aluminum and carbon composite materials.

Sea Star does not require land-based launch infrastructure. If a customer requires a land launch, a mobile truck-based tilt-up launch unit carries the rocket to the desired launch location. The vehicle is designed to launch primarily from the ocean using a minimal infrastructure that includes a launch tube and a ballast unit that enables the rocket to float vertically in the ocean. The ballast unit is dropped following liftoff, then recovered for reuse.[8]

In 2008, Interorbital Systems completed construction of the Sea Star flight demonstrator's propellant tankage, and readied for Sea Star flight tests slated for 2009. The company expects commercial launch of the vehicle will begin in late 2009.[9]

Neptune – Interorbital Systems

Neptune is a proposed scaled-up version of Interorbital Systems' partially reusable Sea Star rocket, and is designed to feature the same recoverable/reusable half-stage booster unit as its counterpart. Neptune would be much larger than Sea Star, and would be designed to carry passengers into orbit. In February 2008, Interorbital Systems publicly unveiled the design of the Neptune. The vehicle features a modular design similar to that of the Sea Star, with a booster module that includes four high-thrust rocket engines and a sustainer module with four smaller engines.[10] The vehicle is designed to place 3,175 kilograms (7,000 pounds) into a 51-degree, 400-kilometer (250-mile) orbit.

Neptune design concept

A unique aspect of the Neptune is that a portion of the main rocket structure, once in orbit, could act as a small space station or an orbital station module (OSM). The main "room" of the OSM would consists of the adaptively reused pressurant tank of the Neptune rocket. The OSM is planned to measure 4.2 meters (14 feet) in diameter and 6.1 meters (20 feet) in length. It would be purged of any remaining pressurant gases and then re-pressurized and outfitted to serve as a large habitation module with both private and public zones. A conical crew module attached to the top of the rocket, carrying up to six people, would be capable of serving as an orbiting hotel. The module would also serve as the crew's return vehicle.

Vehicle	Neptune
Developer	Interorbital Systems
First Launch	TBD
Number of Stages	2.5
Payload Performance	3,175 kg (7,000 lb) to LEO
Launch Site	Pacific Ocean west of Long Beach, California; Pacific Ocean adjacent to Kingdom of Tonga for equatorial launches
Markets Served	Orbital space tourism

In 2008, Interorbital Systems completed a mockup of its planned six-person crew module measuring 5.2 meters (17 feet) in diameter. The module is outfitted for crew and passenger training at the company's Mojave, California, facility.[11]

XA-1.0 – Masten Space Systems

Vehicle	XA-1.0
Developer	Masten Space Systems
First Launch	TBD
Number of Stages	1
Payload Performance	100 kg (220 lb) to 100 km (62 mi)
Launch Site	Mojave Air and Space Port
Markets Served	Suborbital research payloads

Masten Space Systems of Mojave, California, is developing the eXtreme Altitude (XA) series of suborbital RLVs, initially designed to carry small research payloads. The first in the series, the XA-1.0, is a vertical-takeoff, vertical-landing vehicle powered by LOX and isopropyl alcohol engines. The XA-1.0 is designed to carry a 100-kilogram (220-pound) payload to an altitude of at least 100 kilometers (62 miles), performing several such flights per day at a cost per flight of $20,000 to $30,000. The company plans to sell payload space on the vehicle for as little as $99 for a 350-gram (12-ounce) "SODAsat." Beyond the XA-1.0, the company has proposed the XA-1.5, which would be capable of carrying a 200-kilogram (440-pound) payload to 500 kilometers (310 miles), and the XA-2.0, which would be able to carry 2,000 kilograms (4,400 pounds) or five people to 500 kilometers.

XA-1.0 design concept

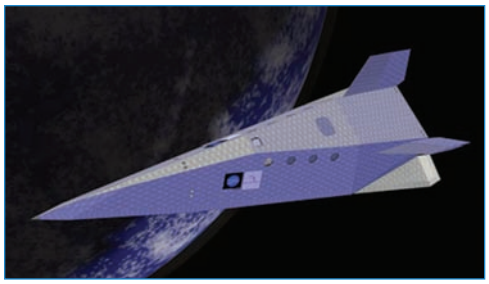
As part of the development of the XA-1.0, Masten is building several prototype vehicles. The first, the XA-0.1, began tethered flight tests in 2007. However, the vehicle was destroyed during one such test flight in December 2007.[12] Several follow-on prototypes, including the XA-0.1B, are currently in development. Tethered flights of these prototypes were facilitated by a 2008 FAA/AST license waiver providing for the company to perform vehicle tests.[13]

Masten Space Systems opted not to participate in the 2008 NG-LLC. The company plans to focus on further testing of the XA-0.1B as a stepping stone toward development of the XA-1.0.[14] In September 2008, Masten resumed hot testing of the XA-0.1B engines, successfully verifying the operability of two of its four engines.[15]

Silver Dart – PlanetSpace

Vehicle	Silver Dart
Developer	PlanetSpace
First Launch	TBD
Number of Stages	3 (1-stage vehicle deployed by 2-stage rocket)
Payload Performance	TBD
Launch Site	Cape Breton Space Port, Nova Scotia, Canada
Markets Served	Passenger and cargo missions to LEO

PlanetSpace, headquartered in Chicago, Illinois, is developing the Silver Dart reusable spacecraft for missions to LEO. The Silver Dart is based on the FDL-7 hypersonic glider design originally proposed by the U.S. Air Force Flight Dynamics Laboratory in the late 1950s. The vehicle design features an all metal thermal protection system to enable flight in all weather conditions.[16] The



Silver Dart

Silver Dart is planned to have a glide range of 40,000 kilometers (25,000 miles) and a cross range of over 6,400 kilometers (4,000 miles), allowing the vehicle to leave LEO at any time and still land in the continental U.S. PlanetSpace proposes to launch the Silver Dart with a two-stage expendable rocket called Nova, also under development, from a proposed spaceport in Cape Breton, Nova Scotia.[17]

Rocketplane XP – Rocketplane Global

Rocketplane Global, a subsidiary of Rocketplane Inc. of Oklahoma City, Oklahoma, is developing the Rocketplane XP suborbital RLV. The vehicle will take off under jet power. At an altitude of at least 12,200 meters (40,000 feet), it will ignite a single AR-36 rocket LOX and kerosene rocket engine provided by Polaris Propulsion for a 70-second burn. The Rocketplane XP will fly to an altitude of at least 100 kilometers (62 miles) before reentering and landing, either under jet power or unpowered, at the same site as takeoff.

RocketPlane XP concept

In late 2007, Rocketplane Global unveiled a new design for the Rocketplane XP. The previous design, based on a highly-modified Learjet fuselage, was replaced with a larger cabin capable of carrying one pilot and five passengers. The jet engines were upgraded to the more powerful J-85 version. The V-tail of the previous design has been replaced with a T-tail, and the landing gear with a model based on the gear used for the F-5 aircraft. Rocketplane Global estimates that over 200,000 person-hours went into developing the new design.

Vehicle	Rocketplane XP
Developer	Rocketplane Global
First Launch	2011
Number of Stages	1
Payload Performance	6 people to 100 km (62 mi)
Launch Site	Oklahoma Spaceport
Markets Served	Suborbital space tourism, microgravity research

In 2008, Rocketplane Global continued conceptual work on the Rocketplane XP while seeking capital for its construction.[18] The company anticipates beginning flight tests in 2011, contingent on raising sufficient funds for vehicle development.

SpaceShipTwo – The SpaceShip Company

Scaled Composites, LLC, and Virgin Galactic, LLC a subsidiary of the Virgin Group of Companies, announced the formation of a joint venture, called The Spaceship Company (TSC), LLC, in July 2005. The purpose of TSC is to oversee development and production of SpaceShipTwo (SS2), a commercial suborbital spacecraft based on technology developed for SpaceShipOne (SS1). TSC is producing the first five SS2 vehicles for Virgin Galactic, which will put them into commercial service once test flights are completed, offering suborbital

WhiteKnightTwo

space flights for private individuals, science research, and payload. The venture is also developing a carrier aircraft, WhiteKnightTwo (WK2), that will be used to air-launch SS2 in much the same manner that the original White Knight aircraft air-launched SS1.

Vehicle	SpaceShipTwo
Developer	The SpaceShip Company (Virgin Galactic and Scaled Composites)
First Launch	2010
Number of Stages	2
Payload Performance	8 people to minimum of 100 km (62 mi)
Launch Site	Spaceport America
Markets Served	Suborbital space tourism

In January 2008, Virgin Galactic and Scaled Composites unveiled the designs for WK2 and SS2.[19] Production of the two craft continued throughout 2008. In March 2008, senior officials from Virgin Galactic and the Kiruna Spaceport in Sweden announced plans to use "Spaceport Sweden" as a second site for SS2. In July 2008, Sir Richard Branson, Virgin Group founder, publicly rolled-out the WK2, named "Eve" after his mother. In September 2008, representatives from Virgin Galactic and NOAA announced discussions to launch NOAA climatology instruments aboard SS2 and WK2.[20] Finally, on December 21, 2008, WK2 made its maiden test flight, reaching the altitude of 4,880 meters (16,000 feet) as planned.[21]

As of year-end 2008, Virgin Galactic had signed up 284 customers for its first suborbital space tourism flights, scheduled to begin by 2010. Rollout of SS2 is expected in April 2009.[22]

Dream Chaser – SpaceDev

DreamChaser concept

Dream Chaser is an RLV under development by SpaceDev to serve suborbital and orbital applications. The design of this vehicle is based on the NASA HL-20 spaceplane concept from the early 1990s, which was itself inspired by the successfully launched Soviet BOR-4 spaceplane from the early 1980s. Dream Chaser has been expanded from the original HL-20 by 10 percent to an overall length of 9.6 meters (31.5 feet) and wingspan of 8 meters (26.2 feet). The Dream Chaser is designed to transport 6-9 passengers, compared to the original HL-20's capacity of 6-10. For suborbital flights, the vehicle will launch vertically, using hybrid engines. On orbital flights, the vehicle will launch on top of existing launch vehicles. In both scenarios, the vehicle will glide back to a runway landing.

Vehicle	Dream Chaser
Developer	SpaceDev
First Launch	4th quarter 2009 (suborbital), 2nd quarter 2011 (orbital)
Number of Stages	2 (suborbital), 3 (orbital)
Payload Performance	6-9 people
Launch Site	Spaceport America (suborbital), CCAFS (orbital)
Markets Served	Suborbital space tourism, ISS crew and cargo resupply, orbital space tourism, military missions

The Dream Chaser concept was one of the finalists in the original round of NASA's COTS competition, and was resubmitted as a bid for the COTS-2 competition. However, the vehicle was not selected for a funded COTS agreement. In June 2007, NASA and SpaceDev signed an unfunded Space Act agreement (SAA) where NASA will provide technical support and other information to SpaceDev to aid in the ongoing development of Dream Chaser.[23]

With NASA's October 2008 certification that SpaceDev had successfully performed its Internal Space Vehicle Propulsion Module Preliminary Design Review (PDR), SpaceDev has completed three technical milestones to date under the unfunded SAA. SpaceDev has also signed a memorandum of understanding (MoU) with United Launch Alliance (ULA) in April 2007 to study the use of the Atlas V to launch the Dream Chaser on orbital missions, and is collaborating with ATK to study the integration of the Dream Chaser on an Ares I-derived launch vehicle.[24]

Skyhopper™ – SPACE ACCESS®, LLC

Vehicle	Skyhopper
Developer	Space Access, LLC
First Launch	2012 (suborbital); 2015 (orbital)
Number of Stages	1
Payload Performance	TBD
Launch Site	Near Corpus Christi, Texas
Markets Served	Suborbital space tourism

In December 2007, SPACE ACCESS®, LLC, of Miami, Florida announced its plans to develop a suborbital RLV called Skyhopper™. The vehicle would take off and land horizontally on a conventional runway, and use ejector ramjet engines with liquid hydrogen fuel—as opposed to conventional rocket engines—to reach suborbital altitudes. SPACE ACCESS® anticipates Skyhopper™ will reach speeds of up to Mach 5 and altitudes in excess of 100 kilometers (62 miles). The company plans on building up to eight Skyhopper™ vehicles and operate up to 15 flights per day. Suborbital flight operations are scheduled to begin in 2013 from facilities to be developed in Florida and Texas. Orbital flights, using a variant of Skyhopper™, are projected to begin as soon as 2016. In 2008, SPACE ACCESS® announced plans to construct a fleet of up to eight vehicles for the suborbital flights.[25]

Skyhopper concept

Laramie Rose – SpeedUp

Vehicle	Laramie Rose
Developer	SpeedUp
First Launch	TBD
Number of Stages	1
Payload Performance	25 kg (55 lb) to 50 m (165 ft)
Launch Site	TBD
Markets Served	Lunar Lander Challenge competition

SpeedUp of Laramie, Wyoming, is developing the Laramie Rose vehicle to compete in the NG-LLC. The vehicle, being built in partnership with Frontier Astronautics of Chugwater, Wyoming, is a vertical takeoff and vertical landing design powered by an engine using 90-percent concentration hydrogen peroxide. The vehicle is also designed to be a technology testbed for future rocket-powered recreational vehicles planned by the company. SpeedUp chose not to compete at the 2008 NG-LLC; however, the Laramie Rose vehicle did perform its first tethered hover test in April 2008, and development

Laramie Rose

continues.[26] In July, 2008, SpeedUp announced plans to sell peroxide-compatible propellant tanks that are part of its plan to develop an expendable upper stage.[27]

M.I.C.H.E.L.L.E.-B – TGV Rockets, Inc.

Vehicle	M.I.C.H.E.L.L.E.-B
Developer	TGV Rockets
First Launch	TBD
Number of Stages	1
Payload Performance	1,000 kg (2,200 lb) to 100 km (62 mi)
Launch Site	TBD
Markets Served	Remote sensing; science, including microgravity research; national security applications

TGV Rockets, Inc. (TGV) is developing the Modular Incremental Compact High Energy Lowcost Launch Example (M.I.C.H.E.L.L.E.)-B, a fully reusable, remotely-piloted suborbital vehicle, designed to carry up to 1,000 kilograms (2,200 pounds) to an altitude of 100 kilometers (62 miles). This vehicle is designed to perform vertical take-off and landing, with a drag shield to assist in deceleration during landing. M.I.C.H.E.L.L.E.-B will provide up to 200 seconds of microgravity, while not exceeding 4.5 Gs during any phase of flight. Using existing optical packages, the vehicle is designed to provide 60-centimeter (24-inch) oblique imagery. Six pressure-fed LOX and JP-8 engines for use on ascent and landing power the vehicle. TGV's design is intended to enable high reusability, require minimal ground support, and allow the vehicle to return to flight within a few hours of landing. The company has completed a preliminary design review of the M.I.C.H.E.L.L.E.-B and, in the second quarter of 2007, performed three tests of its "workhorse" engine for the vehicle. In 2008, the company continued work to complete a prototype engine based on the lessons learned from those tests.[28]

M.I.C.H.E.L.L.E.-B concept

Ignignokt – TrueZer0

Vehicle	Ignignokt
Developer	TrueZer0
First Launch	2008
Number of Stages	1
Payload Performance	25 kg (55 lb) to 50 m (165 ft)
Launch Site	Las Cruces International Airport
Markets Served	Lunar Lander Challenge competition

TrueZer0 of Chicago, Illinois is a four-person team that developed the Ignignokt vehicle to compete in the 2008 NG-LLC. The Ignignokt is a 215-kilogram (475-pound) vertical takeoff, vertical landing vehicle that produces 2,900 Newtons (650 pounds-force) of thrust fueled by hydrogen peroxide and nitrogen. The Ignignokt was the only vehicle besides Armadillo Aerospace's MOD-1 to attempt a flight in the 2008 Level 1 NG-LLC. The vehicle crashed 18.8 seconds after takeoff in its only flight attempt.[29] As of year-end 2008, the TrueZer0 team was examining the causes of the crash. The TrueZer0 team had not decided whether

Ignignokt and team

to continue its vehicle development efforts, but was awaiting new rules from the X PRIZE Foundation regarding the 2009 Lunar Lander Challenge.[30]

Burning Splinter – Unreasonable Rocket

Burning Splinter prototype

Unreasonable Rocket of Solana Beach, California, is a father-son team developing the Burning Splinter vehicle to compete in the NG-LLC. The vertical takeoff, vertical landing vehicle is powered by four engines using liquid oxygen and ethanol propellants. The team completed the vehicle hardware and performed several tethered launches. The Unreasonable Rocket team was not satisfied with the peroxide decomposition and demonstrated thrust levels during testing and chose not to compete in the 2008 NG-LLC. Unreasonable Rocket continues to test potential vehicle modifications including the use of a solid peroxide catalyst and the use of peroxide and RP-1 for a larger Level Two bi-propellant vehicle.[31]

Vehicle	Burning Splinter
Developer	Unreasonable Rocket
First Launch	TBD
Number of Stages	1
Payload Performance	25 kg (55 lb) to 50 m (165 ft)
Launch Site	TBD
Markets Served	Lunar Lander Challenge competition

Lynx – XCOR Aerospace

Lynx concept

In March 2008, XCOR Aerospace unveiled the design of a suborbital RLV known as Lynx. The Lynx will be a two-seat suborbital plane designed to take off horizontally from a runway under rocket power and fly to an altitude of 100 kilometers (62 miles) before returning for a horizontal landing. The Lynx will enable participants to experience weightlessness, obtain a clear view of the stars, and see the curvature of the Earth below. The firm's previous concept for a suborbital vehicle was known as the Xerus, but the significant technical and aerodynamic changes made during the launcher design process resulted in a new vehicle designation: the Lynx.[32]

Vehicle	Lynx
Developer	XCOR Aerospace
First Launch	2010
Number of Stages	1
Payload Performance	Two passengers to suborbital altitude
Launch Site	Mojave Air and Space Port
Markets Served	Suborbital space tourism

Since 2006, XCOR has performed fundraising and technical development for its suborbital launch vehicle. It was awarded a Phase II SBIR from the USAF in connection with the Lynx and in August 2008, the company received its first institutional investor, Desert Sky Holdings.[33] In early December 2008, the firm announced a partnership with RocketShip Tours to begin selling suborbital space tourism tickets for $95,000 a flight. Also in December 2008, XCOR successfully performed its first

hot fire of the 5K18 kerosene-LOX engine that will be used on the Lynx. XCOR anticipates filing a new FAA launch license application, and expects to perform the first Lynx flight by mid-2010.[34]

Government RLV Development Efforts

Throughout the 1980s and 1990s, the DoD and NASA conducted several joint and independent programs to produce experimental RLVs. These vehicles were intended to improve reliability, minimize operating costs, and demonstrate "aircraft-like" operations. However, none of these concepts resulted in a fully operational vehicle. In recent years, these technology development efforts diminished. The U.S. Department of Defense focused on operating its large EELV vehicles and developing small responsive launch vehicles, although it is devoting some resources to technology development that is relevant to RLVs. NASA has shifted its emphasis to developing large ELVs designed to implement the Vision for Space Exploration.

Space Shuttle

Consisting of an expendable external tank, two reusable solid rocket boosters, and a reusable Orbiter, NASA's Space Transportation System (STS), commonly referred to as the Space Shuttle, has conducted 124 launches since its introduction in 1981.

Vehicle	Atlantis, Discovery, and Endeavour
Developer	Rockwell International (now Boeing); fleet is managed, operated, and maintained on the ground by United Space Alliance, a joint venture between Boeing and Lockheed Martin
First Launch	1981
Number of Stages	1.5
Payload Performance	24,900 kg (54,890 lb) to LEO
Launch Site	KSC
Markets Served	Non-commercial payloads, ISS access

The three remaining orbiters—Atlantis, Discovery, and Endeavour—returned to flight in July 2005 after the loss of Columbia in February 2003. Today, the Space Shuttle is the only available means for completing assembly of the ISS. Intending to use the Shuttle until 2010, NASA is committed to investing in the Space Shuttle fleet to maintain safety and reliability and extend orbiter service life until its role in constructing the ISS is complete. As of January 1, 2009, nine Space Shuttle flights, including one mission to service the Hubble Space Telescope, are planned before the fleet is retired in 2010. The Space Shuttle's day-to-day operations are managed by United Space Alliance, a Boeing-Lockheed Martin joint venture in operation since 1996.

Space Shuttle from above

Fully-Reusable Access to Space Technology Program

The Fully-Reusable Access to Space Technology (FAST) program is an effort by the Air Force Research Laboratory (AFRL) to develop technologies for use in RLVs capable of "aircraft-like" operations. FAST calls for the methodical development of these key technologies initially through ground experiments and later in flight

tests, with the ultimate goal of flying a ground-launched suborbital vehicle capable of flying to speeds of Mach 4 to 7, as well as being capable of reentering at Mach 25 if launched as the upper stage of another vehicle. This experimental vehicle could be later scaled up to larger, operational vehicles. Current plans call for ground-based technology tests to continue through 2011, with first flights of the experimental suborbital vehicle slated for 2013.[35]

AFRL has issued contracts with several companies to work on elements of the FAST program. In March 2007, AFRL awarded Andrews Space a contract to develop the program requirements for a series of technology experiments that will be part of the overall effort.[36] In November 2007, Lockheed Martin Michoud Operations won a $14-million contract to work on airframe technologies, including composite structures and thermal protection systems, as a part of the FAST program.[37] In December 2007, AFRL awarded Northrop Grumman a 39-month, $5.2-million contract to study responsive ground operations and perform experiments and simulations to support the development of a future operations control center.[38]

On December 12, 2008, in support of the FAST Airframe Ground Experiment, Lockheed Martin successfully tested an unlined LOX-compatible composite tank with a demonstrated cryogenic containment of up to 5,000 micro-strain (250 pounds-force per square inch gauge, or psi) of pressure.[39]

REENTRY VEHICLES AND IN-SPACE TECHNOLOGIES

A number of new orbital transportation systems are being developed by U.S. entities. These systems range from government reusable crewed and cargo vehicles to commercial habitats. These developments will provide critical manned and unmanned orbital operations and transportation in the post-Shuttle era after 2010. A number of technologies have been demonstrated for these systems during the past year and show progress towards planned operational capability.

NASA has development contracts for the Orion crew exploration vehicle and two active awards for commercial ISS crew and cargo demonstrations through the Commercial Orbital Transportation Services (COTS) program. NASA awarded additional contracts for ISS Cargo Resupply Services in December of 2008. Additionally, the U.S. Air Force is developing a military-use X-37B Orbital Transfer Vehicle (OTV) that will carry payloads into orbit. Finally, Bigelow Aerospace is in the process of developing commercial orbital habitat.

Orion Crew Exploration Vehicle

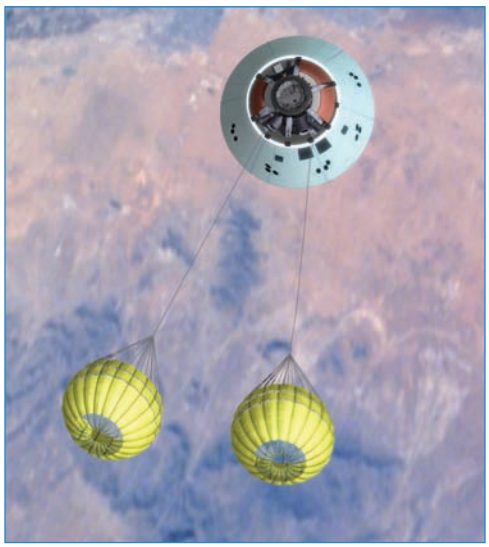
The U.S. plan for space exploration calls for continued missions to LEO and later missions to the Moon, Mars, and beyond. To maintain this mission capability after retiring the Shuttle in 2010, NASA is developing a new Crew Exploration Vehicle (CEV), the Orion, as part of the Constellation Program. The current Orion design has the capacity to transport up to six crew members to the ISS or four people on missions to the Moon. Orion's first crew transport to the ISS is planned for no later than 2015, while the first lunar flight is currently scheduled for 2020.[1]

Artist rendition of the Orion CEV approaching the ISS

The spacecraft will consist of a combined pressurized crew module and service module launched into orbit by the Ares I crew launch vehicle. For missions to the Moon and Mars, NASA will precede the Ares I launch with an Ares V cargo launch vehicle. Ares V, the "heavy lifter" of the fleet, that will deliver the Altair lunar lander and the Earth departure stage to LEO. Orion will then dock with these "parked" payloads, and the Earth departure stage will propel Orion and its crew and the Altair lander to the Moon.

Once in lunar orbit, Altair will undock from Orion and carry the astronauts to the Moon's surface. At the end of the mission, a lunar ascent module will return the crew to the orbiting Orion craft. The crew will then use the service module main engine to break out of lunar orbit and return to Earth, where Orion's crew module will reenter the atmosphere and parachute to the surface.

The spacecraft's conical shape is similar to the Apollo capsules that predated the Shuttle, but Orion will incorporate 21st century technology in computers, electronics, life support, propulsion, landing technology, and a newly developed thermal protection system for Earth re-entry. A powered system for launch abort will sit atop the Orion capsule, and is designed to pull the crew module away from the Ares I launch vehicle in an emergency situation on the launch pad or during the first 91,400 meters (300,000 feet) after launch. In addition, Orion's 5-meter (16.5-foot) diameter will allow for more than twice the volume—doubling crew capacity and increasing interior space—of Apollo-era modules.



Artist rendition of Orion during parachute landing

Lockheed Martin is the prime contractor for the Orion CEV. NASA selected Lockheed Martin in August of 2006, awarding them a seven-year base contract worth just under $4 billion. The contract contains an option worth another $4 billion for production and operational engineering activity up to 2019. Lockheed Martin's contracting team includes Honeywell, Orbital Sciences, United Space Alliance, and Hamilton Sundstrand. Contracts for the Altair lunar lander and earth departure stage have not yet been awarded. NASA is developing conceptual designs for Altair and is currently seeking input from industry experts towards that effort. Hardware and test concepts are targeted for the 2009 - 2011 timeframe.

The overall Constellation Program is managed out of the Johnson Space Center in Houston, Texas. Every other NASA center has a role in the mission, and many have been actively involved in testing the Orion and Ares vehicles and their subsystems. For instance, the Ames Research Center in Moffett Field, California leads the development of Orion's thermal protection systems. Langley Research Center is the lead for integrating the launch abort system. In October of 2008, the Dryden Flight Research Center in Edwards, California conducted mass properties tests on the Orion test crew module, in preparation for the launch abort system flight tests scheduled for 2009.[2] In November of 2008, ATK successfully conducted the first full-scale test fire of the abort system's motor at their launch systems facility in Promontory, Utah.[3]

Additional testing in 2008 included a failed parachute test conducted by NASA in July. A mock-up of the Orion crew module was dropped from 7,600 meters (25,000 feet) by a C-17 aircraft above the U.S. Army's Yuma Proving Grounds. A test set-up parachute — which was only used to orient the mock-up for the drop and would not be part of the overall re-entry system — did not inflate properly, resulting in failure of the entire parachute system.[4] Test milestones for 2009 include the launch abort system flight test in White Sands New Mexico, and the first test flight of the Ares I (the Ares I-X).[5]

International Space Station Crew and Cargo Transport

The decision to finish constructing the ISS by the end of the decade and maintain its operation with a six-person crew reinforces the demand for continual transport flights to and from the station. Several government systems are either operational or planned to fill this demand. Until it is retired in 2010, the Space Shuttle will be the primary American system for bringing new station components, crew, and cargo to the ISS. Orion will start providing crew transport by 2015.

This five-year gap can be filled by using the services of existing and developing international ISS transport vehicles. Russia's Soyuz crew and Progress cargo vehicles are frequently used to support the station and are currently the most robust international ISS supply systems. However, other international systems are making progress to fill that role as well. In March of 2008, the European Space Agency conducted the maiden voyage of their Automated Transfer Vehicle (ATV) for ISS cargo supply. The "Jules Verne" ATV delivered supplies, fuel, and oxygen to the crew and remained docked with the ISS for six months and performed orbital reboosts. The ATV eventually offloaded 2½ tons of waste from the ISS before returning to Earth in a controlled destructive re-entry.[6] The ESA has contracted industry to produce four more ATVs to be flown through 2015.[7] Additionally, the Japan Aerospace Exploration Administration (JAXA) is currently developing the H-2 Transfer Vehicle (HTV), with plans to conduct a test flight in 2009.[8]

American commercial vehicles are planned to supplement these government systems for crew and cargo transport to the ISS. To that end, NASA established the Commercial Crew & Cargo Program Office (C3PO) at the Johnson Space Center. This office will help stimulate the U.S. commercial space transportation industry through technical assistance as well as direct investment through the COTS demonstrations project. In August 2006, NASA announced the signing of two funded Space Act Agreements with U.S. companies under Phase 1 of the COTS program. Space Exploration Technologies (SpaceX) and Rocketplane/Kistler (RpK) collectively received nearly $500 million in funding to develop and demonstrate the ability to provide transportation services to the ISS. However, the agreement with RpK was terminated and re-competed in 2007 due to RpK's failure to meet required financial and technical milestones related to developing its K-1 vehicle. In February of 2008, NASA selected Orbital Sciences Corporation as a new funded partner and awarded them approximately $170 million in funding.[9]

In Phase One of the COTS program, the bidding companies were required to demonstrate one or more of four capabilities:

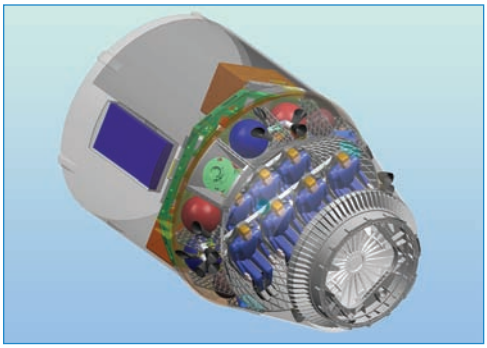
- external, unpressurized cargo delivery and disposal;
- internal, pressurized cargo delivery and disposal;
- internal, pressurized cargo delivery and return;
- an option for crew transportation.

Fixed payments will be made to the winning companies as they achieve milestones for design and development, including conducting three vehicle flights before 2010.

Phase Two of the program culminated in the December 2008 awarding of two ISS Cargo Resupply (ISS-CRS) contracts, which went to SpaceX and Orbital Sciences. The contracts call for the delivery of a minimum of 20 metric tons of upmass cargo to the space station, with flights taking place between 2010 and 2016. NASA initially ordered 12 flights valued at about $1.6 billion from SpaceX, and eight flights valued at about $1.9 billion from Orbital Sciences.[10]

Dragon – SpaceX

Initiated internally by SpaceX in 2005, the Dragon spacecraft will be used for the commercial transportation of cargo and crew to and from LEO. The 4-meter (13-foot) diameter Dragon consists of an unpressurized trunk module and the capsule itself. The trunk module carries the solar arrays and thermal radiators, and can also store any unpressurized cargo. The Dragon capsule comprises three elements: the nosecone, which protects the vessel and docking adaptor during liftoff; the pressurized crew and cargo section; and the service section, which contains support infrastructure such as avionics, parachutes, and the reaction control system (RCS).



Concept of SpaceX's Dragon vehicle crew version

The structural design of Dragon will be identical for cargo and crew missions, providing a capacity of over 2,500 kilograms (5,500 pounds) for launch and return in either configuration. In crew mode, the vehicle can carry up to seven people, and will be able to remain attached to the ISS for six months at a time, providing emergency return capability for the entire ISS crew. SpaceX has constructed full-scale engineering models of the capsule pressure vessel, heat shield, and other systems.[11]

The initial plan for NASA funding under COTS Phase One includes $278 million, which could change as the demonstration process continues. In 2008, SpaceX reached several COTS milestones, including two firings of the Falcon 9 with its full complement of nine Merlin 1C engines at its Texas test facility.[12] That was followed in November by a successful "mission-length" test firing lasting 178 seconds. SpaceX plans to conduct two COTS demo flights of the Falcon 9 in 2009, and a full cargo mission in 2010, which will include an actual berthing of an empty Dragon vehicle with the ISS, and return to Earth via water landing. All flights are scheduled for launch from SpaceX's Space Launch Complex 40 at Cape Canaveral, Florida.[13] NASA also has the option to extend the agreement with SpaceX to include three demonstrations of crew transport to and from the ISS. Those demonstrations would be conducted 18-24 months after the execution of that option.[14]

Depiction of the Dragon vehicle berthed with the ISS

SpaceX is also pursuing the commercial market with the DragonLab spacecraft. Introduced in November of 2008, DragonLab's potential uses include small spacecraft

deployment, recovery of pressurized and some unpressurized payloads, and in-space experimentation and research projects. SpaceX is marketing the DragonLab system as able provide for all aspects of in-orbit operation and re-entry, including propulsion, power, environmental control, avionics, communications, thermal protection, flight software, navigation and control, entry, landing and recovery.[15] Based on the positive response from prospective customers at DragonLab's unveiling, SpaceX immediately added two DragonLab missions to its launch manifest, scheduled for 2010 and 2011.[16]

Taurus II/Cygnus – Orbital Sciences Corporation

On February 18, 2008, Orbital Sciences Corporation of Dulles, Virginia won the re-competed RpK COTS agreement. NASA and Orbital Sciences signed a funded Space Act Agreement worth approximately $170 million in federal funds to supplement Orbital's private funding for the Taurus II launch vehicle and the Cygnus advanced maneuvering spacecraft.

The Taurus II will have a payload capacity of 4,750 to 6,250 kilograms (10,470 to 13,780 pounds) to LEO. The Cygnus spacecraft will be capable of delivering up to 2,300 kilograms of pressurized or unpressurized cargo to the ISS, and will be capable of returning up to 1,200 kilograms of cargo from ISS to Earth. Orbital will also develop several interchangeable modules for pressurized and unpressurized cargo. The development, production, and integration of Cygnus and these cargo modules will take place at Orbital's facilities in Dulles as well as Greenbelt, Maryland. The first COTS demonstration is scheduled to take place in late 2010 from Wallops Flight Facility, and Orbital is preparing to conduct several operational COTS missions in 2011 and as many as eight operational ISS cargo flights a year in 2012.[17]

Artist rendition of Orbital's Cygnus spacecraft approaching the ISS

Other Commercial Crew and Cargo Transport Concepts

NASA currently has signed unfunded Space Act Agreements with three companies to help them develop various vehicles and technologies that could lead to orbital crew and cargo missions in the future. While these companies do not receive funding for their projects, NASA does provide them technical assistance in order to facilitate compatibility with ISS and future programs. These systems potentially could provide transport to the ISS and other orbital locations.

- PlanetSpace has teamed with Lockheed Martin Space Systems, ATK, and Boeing to develop, produce, launch, and operate modular Orbital Transfer Vehicles (OTV's) that can serve as the cargo carriers to the ISS.[18] In 2008, the PlanetSpace team proposed this vehicle to NASA as part of the COTS Phase-2 funding for the ISS-CRS project.

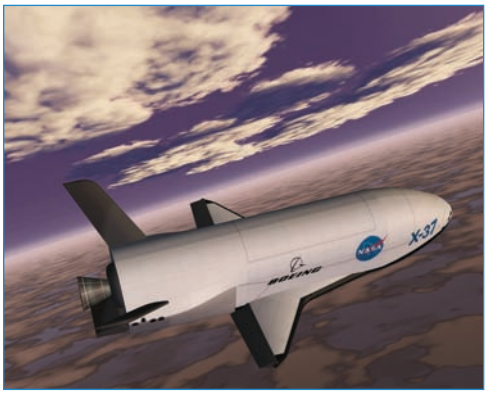
- SpaceDev's Dream Chaser Space Transportation System is a lifting body RLV based on the NASA HL-20 lifting body spaceplane. The vehicle conceptually will launch on a man-rated Atlas V rocket.

- Transformational Space (t/Space) is developing the CXV Crew Transfer Vehicle, a transport and reentry vehicle based on Discoverer and Corona capsule design.

Another unfunded partner, SPACEHAB, had proposed its Advanced Research and Conventional Technology Utilization Spacecraft (ARCTUS) for orbital transport during the COTS Phase 1 process. In 2008, they allowed their Space Act Agreement partnership expire.

X-37B Orbital Test Vehicle

The U.S. Air Force Rapid Capabilities Office is leading development of an unmanned reusable space vehicle designated the X-37B Orbital Test Vehicle (OTV). This new capability will serve as a platform for science and technology demonstration and testing. Experiments will be carried in a payload bay, which can open and expose its contents to the space environment. This vehicle leverages previous work NASA, DARPA, AFRL, and Boeing completed for the X-37 program. As it was for the original X-37 vehicle, Boeing is the prime contractor for the OTV.



Artist's concept of an X-37 vehicle, similar to the X-37B in development

The OTV will launch vertically into orbit on an expendable rocket and have the ability to de-orbit on command and land horizontally for reuse. The first OTV test flight is scheduled to take place in February of 2009, using an Atlas V rocket to be launched from Cape Canaveral.[19] During the test, the OTV is to deploy a gallium arsenide solar array to power its flight, then de-orbit and land on a runway at Vandenberg AFB. Other flights for the X-37B will be for testing advanced thermal protection materials, autonomous approach and landing schemes, and orbital and ground operations.[20]

Commercial Orbital Habitat Development

Bigelow Aerospace is developing next-generation, expandable space habitat technology intended to support a future, robust, private-sector-driven commercial space industry. The company manufactured and launched two technology demonstration spacecraft called Genesis I and Genesis II. These spacecraft are currently being used to validate the fundamental engineering concepts necessary to construct an expandable orbital habitat. Currently, Bigelow Aerospace is constructing a larger and more complex spacecraft designed to support a crewed presence in LEO.

The Genesis II spacecraft was launched on June 28, 2007, less than one year after the Genesis I launch on July 12, 2006. Both of these spacecraft were successfully orbited by an ISC Kosmotras Dnepr rocket launched from facilities at the Yasny Cosmodrome in the Orenburg region of the Russian Federation. The two spacecraft are externally similar although internally different; Genesis II was outfitted with additional sensors, cameras, and unique interior payloads. The size of the demonstrators is approximately 4.4 meters (15 feet) in length and 1.6 meters (5.3 feet) in diameter at launch, expanding to 2.54 meters (8 feet) in diameter after full deployment in orbit. Both Genesis spacecraft have a usable volume of 11.5 cubic meters (406 cubic feet). Bigelow Aerospace uses its mission control facility in North Las Vegas, Nevada for operating these spacecraft, both of which have performed as planned, validating Bigelow Aerospace's basic concepts and capabilities.

External view of Bigelow's Genesis II spacecraft in Earth orbit

Because of the success of the Genesis technology demonstrators, Bigelow Aerospace has decided to proceed directly with developing the larger Sundancer spacecraft. Sundancer will be the company's first attempt at producing a habitat capable of supporting a human presence on orbit. The spacecraft is currently anticipated to weigh around 8,600 kilograms (19,000 pounds) and offer roughly 180 cubic meters (6,350 cubic feet) of usable volume. The technologies to be demonstrated and deployed on Sundancer include environmental control and life support systems; guidance, navigation, and attitude control; propulsion; power generation; and windows, among others.

In May of 2008, Bigelow Aerospace awarded a $4.8 million contract to Orion Propulsion, Inc. to supply the attitude control system for the forward end of Sundancer. Also in May, Bigelow Aerospace completed a $23 million deal with Aerojet to supply the propulsion system for the aft end of Sundancer.[21]

ENABLING TECHNOLOGIES

Organizations from industry and the government have been working to develop launch vehicle components that are substantially simpler, more flexible and reliable, and less costly than those based on legacy technologies. These efforts research projects in the areas of air launch technologies, composite cryogenic fuel tanks, propulsion systems, thermal protection systems, and vehicle recovery systems. This chapter reviews some of the accomplishments made in 2008 with emphasis given to those organizations and technologies that have achieved significant testing milestones.

Friction Stir Welding – Space Exploration Technologies Corporation

Falcon 9 propellant tanks

Space Exploration Technologies Corporation (SpaceX) uses friction stir welding during the construction of the Falcon 9 launch vehicle. The Falcon 9's first and second stage walls use a high-performance aluminum-lithium alloy. Friction stir welding forms a metal-to-metal joint without melting, using only friction and pressure. Thus, the alloy composition remains unaffected and retains its strength. This allows for the creation of some of the lightest and strongest possible metal alloy tanks. Since friction stir welding does not melt the metal being worked on, but rather, through heat and pressure, plastically deforms the metal of a joint and blends it together, metallurgical problems that occur with aluminum-lithium alloys featuring fusion welding do not occur.[1] In early 2008, SpaceX successfully completed fabrication of the first all-stir-welded first stage propellant tanks for the Falcon 9. This tank, featuring both longitudinal and circumferential stir welding, was the first launch vehicle pressurized structure ever completely assembled with stir welding.[2]

Composite Tanks – Microcosm, Inc.

Family of all-composite propellant and pressure tanks

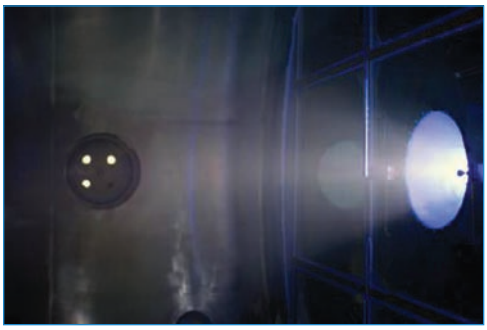
In 2008, Microcosm, Inc. (MI) and Scorpius Space Launch Company (SSLC) of Hawthorne, California, continued developing cryogenic composite LOX tanks for a variety of applications and customers. The companies have successfully tested a 106.7 cm (42 in.) diameter, all-composite LOX tank to four times its operating pressure of 38.7 Kg/cm^2 (550 PSI). Testing occurred at cryogenic temperatures using liquid nitrogen. New materials and production methods are now incorporated in a family of cryogenic and ambient propellant tanks as well as higher pressure tanks extending the application of all-composite tank structures. Microcosm successfully completed the final qualification tests on the full-scale, all-composite cryogenic LOX tank for the Sprite Small Launch Vehicle (SLV) and is now proceeding with the design of lower mass cryogenic tanks. MI's tank design and SSLC's manufacturing method

prevents gas permeation/leakage, and manages the typical micro-cracking that has always been a problem with all-composite tanks at cryogenic temperatures. The tank design allows for reducing the weight of the propellant tanks for Sprite and increases the mass to orbit by over 30 percent. MI/SSLC offers these tanks in a range of sizes as well as custom-made pressure vessels for industrial applications where ultra-high, strength-to-weight ratio is important. MI and SSLC continue to provide these new technology tanks that are stronger and lower mass to others in the aerospace community, as well as customers with other applications.[3]

High Performance Pressurization System (HPPS) – Microcosm, Inc.

Through 2008, Microcosm has continued developing the HPPS the company's family of launch vehicles and upper-stages for other customer applications. The HPPS is a Tridyne-based method of using high pressure cold gas. By using a specialized catalytic converter, it provides hot gas pressure to use on the propellant tanks while also providing heat to replace the normal cooling of the cold gas as the gas is used. Microcosm has tested the system in large-scale implementations. The HPPS reduces in half the comparable gas required for the typical pressure-fed system, thus lowering the cost and mass of launch vehicles and upper stages using the system.[4]

VASIMR Engine – Ad Astra Rocket Co.



VASIMR first stage test-fire

The Variable Specific Impulse Magnetoplasma Rocket (VASIMR) is an electro-magnetic thruster for spacecraft propulsion. The VASIMR engine is not intending to launch a vehicle into space from ground-level. Rather, it would be an efficient method of propulsion for interplanetary craft. It uses radio waves to ionize a propellant and magnetic fields to accelerate the resulting plasma to generate thrust. The method of heating plasma used in VASIMR was originally developed as a result of research into nuclear fusion. VASIMR is intended to bridge the gap between high-thrust, low-specific impulse propulsion systems and low-thrust, high-specific impulse systems. VASIMR is capable of functioning in either mode. Scientist and former astronaut Franklin Chang-Diaz created the VASIMR concept and has been working on its development since 1979.

On October 28, 2008, Ad Astra announced that the VASIMR engine had reached a major milestone in its development. The VASIMR's Helicon first stage, which generates the plasma that is later accelerated by the drive, achieved its full rated power of 30 kilowatts on a test stand. This paves the way for further testing.[5] On December 8, 2008, an agreement was signed between Ad Astra and NASA to test the VASIMR engine aboard the International Space Station at an unspecified date in the future.[6]

Solid Rocket Motors - Alliant Techsystems, Inc.

ATK was named the prime contractor by NASA for the development of the Ares I first stage in December 2005. The design of the Ares I first stage will primarily use existing Space Shuttle solid rocket motor technology; however, ATK is developing new components to increase performance. The core tooling used to achieve the new propellant shape is being manufactured.[7] Two mockups of a section located at the top of the motor between the first and second stages, called the forward skirt, have been constructed. The forward skirt mockups will simulate the physical space available for the avionics and will be used to determine the optimal required space and placement of the electronics.

ATK's December 4, 2008 test of the reusable solid rocket motor

In 2008, a series of tests were completed. X-ray imaging of an inert test article intended for the Ares I-X was done to verify integrity. Also, a series of test firings were conducted using intentionally weakened exhaust nozzles to aid in developing failure warning sensors. These intentional failures helped assess the best methods for designing and locating error warning sensors.[8] The flight test scheduled in 2009, designated Ares I-X, will use a modified four-segment Space Shuttle Solid Rocket Booster with a fifth segment simulator. Five ground tests of a new five-segment Ares I rocket motor are scheduled in 2009-2011. Three Ares I flight tests using the new five-segment first stages are scheduled in 2012 and 2013.[9]

Liquid Engines – AirLaunch LLC

AirLaunch LLC, of Kirkland, Washington, is developing Vapor Pressurization (VaPak) LOX- and propane-powered upper stage engines for its QuickReach Small Launch Vehicle (SLV) as part of the Falcon SLV program. AirLaunch LLC's QuickReach booster is designed to deliver 450 kilograms (1,000 pounds) to low Earth orbit for $5 million per launch, with a response time of less than 24 hours.

AirLaunch's March 28, 2008 test of the Vapak engine

AirLaunch LLC conducted a 191-second engine test in March 2007, the longest VaPak engine burn in history. As of November 2007, AirLaunch had conducted 55 test firings of its propulsion system, all using VaPak. Fifty of these tests were performed on the original Horizontal Test Stand (HTS), and five test fires, totaling 315.5 seconds, have been performed on the Vertical Test Stand (VTS) with the QuickReach Integrated Second Stage (IS2), in addition to several propellant loading and conditioning tests.[10] The IS2 firings incorporated ground propellant loading operations and flight-type avionics, software, and systems. Transition of liquid oxygen to gaseous oxygen, a feature of VaPak, has been observed in test firings on both the HTS and VTS.

During 2008, in Phase 2C of the testing cycle, AirLaunch conducted 30 additional test firings of the second stage engine on a new and more sophisticated horizontal

test stand. These tests produced the consistent, repeatable test data desired by the Falcon SLV program office. AirLaunch also matured its technical and safety procedures to enable multiple tests per day. Over the course of the Falcon SLV program, the QuickReach propulsion system was fired 82 times, for a total of 1227.3 seconds of run time.[11]

Liquid Rocket Engines and associated technologies – Garvey Spacecraft Corporation

Garvey Aerospace's August 23, 2008 launch of the P-9

Garvey Spacecraft Corporation (GSC) is a small aerospace R&D company, formed in 1993, that is focusing on the development of advanced space technologies and launch vehicle systems. GSC conducts research and development in partnership with a variety of organizations. The most notable of these partnerships has been the California Launch Vehicle Education Initiative (CALVEIN) with California State University, Long Beach (CSULB). Since getting started in early 2001, the CALVEIN work has resulted in numerous static fire tests and 15 flight tests, including development of the CSULB aerospike rocket engine as well as the more recent missions involving a prototype RLV test bed and the first-ever flight test of a LOX/methane rocket (the P-14) in April 2008 that featured an engine developed by CSULB students.

In May of 2008, Garvey Spacecraft supported CSULB in conducting a static fire test of a next generation multi-chamber aerospike engine with the P-10. In June of 2008, the Prospector 11A (P-11A) was launched as a testbed for wireless sensors and networking technologies, under a Phase 1 SBIR contract for NASA Ames Research Center. In August of 2008, the Prospector 9A (P-9A) was launched as part of Garvey Spacecraft's RLV demonstration program for AFRL/RZ and SMC. The vehicle featured two composite propellant tanks, procured from Microcosm, as well as a number of wireless sensor experiments provided by NASA JSC. This was the first such flight of a liquid propulsion rocket with two such composite tanks of this design.[12] The team then wrapped up the year by reflying the refurbished P-11 as the P-12 in October with a series of academic payloads recruited and managed by Stanford University.

Liquid Rocket Engines – Northrop Grumman Corporation

Northrop Grumman successfully tested a new type of rocket engine specifically designed to use oxygen and methane propellants that range from all-gas to all-liquid at injection to the combustion chamber. The new engine design was developed under contract to NASA Glenn Research Center's Cryogenic Reaction Control Engine program. The engine, named the TR408, ensures that the fuel and oxidizer fully vaporize by passing the propellants through cooling passages located in the thrust chamber wall before injecting them into the chamber for combustion. This technique ensures consistent performance and combustion

stability. Previous rocket engine designs using propellant to cool the chamber do not vaporize any of the propellant or may only vaporize one of the propellants, typically the fuel. The TR408 uses a simple design consisting of only two propellant valves, no moving parts other than the valves, and contains a built-in spark igniter to initiate combustion of the injected propellants.

In October of 2008, Northrop Grumman announced that it had completed manufacture and integration of the TR408 and that testing could commence. Upcoming tests will attempt to operate the engine at a steady-state specific impulse of 340 seconds.[13]

Northrop Grumman's completed TR408 LOX-methane engine

Liquid Rocket Engines – Pratt & Whitney Rocketdyne, Inc.

NASA awarded Pratt & Whitney Rocketdyne, Inc. (PWR) a $1.2 billion contract in July 2007 to design, develop, and test the J-2X engine that will power the upper stage of the Ares I and Ares 5 launch vehicles. Powered by liquid oxygen and liquid hydrogen, the J-2X is an evolved variation of two historic predecessors: the J-2 upper stage engine, that propelled the Apollo-era Saturn 1B and Saturn 5 rockets to the Moon in the 1960s and 1970s, and the J-2S, a simplified version of the J-2 developed and tested in the early 1970s but never flown. The J-2S turbopumps and related machinery were demonstrated in the 1990s on the X-33 aerospike engine. The J-2X main injector hardware, a major component of the engine, is similar to the J-2 engine injector.[14] In December 2007, NASA began testing core components of the J-2X on the A-1 Test Stand at NASA's John C. Stennis Space Center near Bay St. Louis, Mississippi. The tests focused on the engine's turbopumps. During the test, engineers ran liquid oxygen and liquid hydrogen through the turbopumps, monitoring their ducts, valves, and lines to verify the tightness of seals in the oxidizer lines and pumps. All test objectives were met with no anomalies noted.[15] By November of 2008, the J-2X had passed its critical design review and was on track to commence full-scale testing in 2010.[16]

The J-2X engine

The J-2X will provide an estimated 1,308,000-Newtons (294,000-pounds-force) of thrust to power the Ares vehicles. The contract includes ground and test flight engines and extends through December 31, 2012.[17]

Liquid Rocket Engines – Space Exploration Technologies Corporation

In 2006, SpaceX began working on the Merlin 1C engine, a regeneratively-cooled successor to the ablatively-cooled Merlin 1A engine. The regeneratively-cooled Merlin 1C uses rocket propellant grade kerosene (RP-1), a refined form of jet fuel, to cool the combustion chamber and nozzle before combining the fuel with

liquid oxygen to create thrust. This cooling allows for higher performance without significantly increasing engine mass.[18]

During 2007, 125 hot fire tests were conducted on the Merlin 1C engine for a combined run time exceeding 3,000 seconds. In November 2007, SpaceX announced that it had completed development of the Merlin 1C.[19] In its current Falcon 9 first-stage configuration, the Merlin 1C has a thrust at sea level of 423,000 Newtons (95,000 pounds-force), a vacuum thrust of over 480,000 Newtons (108,000 pounds-force), vacuum specific impulse of 304 seconds and sea level thrust-to-weight ratio of 92. In generating this thrust, the Merlin 1C consumes 159 kilograms per second (350 pounds per second) of propellant. The chamber and nozzle are cooled by 45 kilograms per second (100 pounds per second) of kerosene. A planned turbopump upgrade in 2009 will improve the thrust by over 15 percent.[20]

Full Mission-length tests of nine Merlin 1-C engines on November 22, 2008.

The Merlin 1C engine powered SpaceX's two Falcon 1 missions in 2008, with a partially successful launch on August 3 and a completely successful launch on September 28. SpaceX's far larger Falcon 9 rocket, now in development, will employ nine Merlin engines on its first stage. A vacuum version of the Merlin 1C, with a larger bell nozzle and some additional features, will be used on the Falcon 9's upper stage.[21]

Testing of the Merlin 1 C 9-engine installation for the Falcon 9 took place through 2008. Multi-engine testing began on January 18 and culminated on July 30 with the first nine-engine firing of its Falcon 9 launch vehicle at its Texas Test Facility outside McGregor. A second firing, conducted on August 1, completed a major NASA Commercial Orbital Transportation Services (COTS) milestone almost two months early. SpaceX reported that all phases of integration and testing went smoothly and that all nine engines worked perfectly in concert, generating a total of over 3,700,000 Newtons (832,000 pounds force) of thrust.[22] On November 22, 2008, SpaceX conducted a successful full-mission length burn of all nine engines working in concert at their test-stand facility in Central Texas.[23]

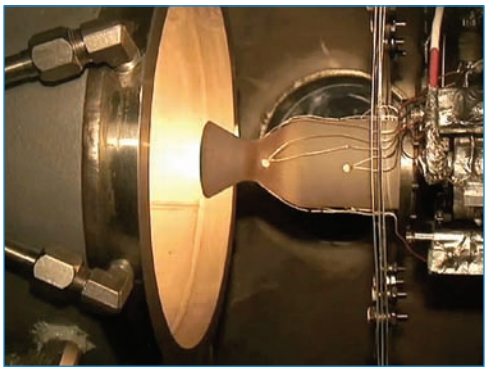
20,000 pounds force ablative engine under test

Ablative Engines – Microcosm, Inc.

Microcosm has continued enhancing its line of low-cost ablatively-cooled pressure fed engines. The 22,000-Newton (5000-pounds force) engines have now been successfully flown on suborbital vehicles, and the newer 88,900-Newton (20,000-pounds force) engines have passed preliminary test firings. Microcosm will continue to develop both the sea level version engines along with related upper-stage configurations.[24]

Liquid RCS Thruster – Space Exploration Technologies Corporation

SpaceX is developing a spacecraft thruster called Draco that generates 400 Newtons (90 pounds-force) of thrust. The Draco thruster is fueled by a common aerospace bipropellant combination, monomethyl hydrazine and nitrogen tetroxide (MMH/NTO). The SpaceX Dragon crew and cargo spacecraft will have a total of 18 Draco thrusters for both attitude control and orbital maneuvering. Draco thrusters will also be used on the Falcon 9 second stage for maneuvering and deorbiting. In 2007, SpaceX's propulsion team completed the first Draco development engine.[25]



Test of the Draco thruster

In 2008, SpaceX's propulsion team conducted atmospheric and vacuum level testing of Draco thrusters at their new MMH/NTO test facilities in central Texas, successfully meeting another milestone in its COTS program to demonstrate resupply of the ISS. On March 12, 2008, SpaceX successfully test fired the Draco thruster in fulfillment of a NASA COTS program milestone.[26] By late 2008, the Draco thruster had achieved several thousand seconds of testing, including a 10-minute continuous burn with a hot restart.[27]

Launch Abort System – Orbital Sciences Corporation

Orbital Science Corporation announced in September 2006 that it will build the Launch Abort System (LAS) for the NASA Orion CEV. Orbital is a member of the Lockheed Martin-led team selected to construct the Orion CEV and will receive approximately $250 million under subcontract to Lockheed Martin to construct the LAS.[28] The LAS will be composed primarily of solid rocket motors, separation mechanisms, canards, and an adapter structure. The LAS will provide escape capability for the Orion crew from pad operations through ascent. The new design, using Orbital's small launch vehicle technology, will improve flight crew safety as compared to current human space flight systems. The contract called for a five-year development program, including several planned abort demonstration flights beginning in late 2008.[29]

The November 20, 2008 test-firing of the Lauch Abort System

On November 14, 2007, NASA broke ground on a new test launch pad at the U.S. Army's White Sands Missile Range, New Mexico, that will be the site of a series of tests of a launch abort system for the Orion CEV.[30] The first full-scale test fire took place on November 20, 2008 at the ATK Launch Systems facility in Promontory, Utah. This is the first time such a test was conducted since the Apollo Program tested its launch escape system in the 1960s. The demonstration was the culmination of a series of motor and component

tests conducted earlier in 2008 in preparation for a test with a mock-up of the Orion crew capsule scheduled for the spring of 2009.[31]

Scramjet Propulsion – Pratt & Whitney Rocketdyne, Inc.

By year-end 2007, Pratt & Whitney Rocketdyne, Inc. (PWR), along with its X-51A team members, including the U.S. Air Force, DARPA, NASA, and the Boeing Company, demonstrated operation and performance of the X-1 scramjet engine in the first simulated flight at Mach 5 of the X-51A. The X-1 demonstrator, designated the SJX61-1, is a hydrocarbon-fueled scramjet featuring X-51A flight hardware. The X-51A flight test program plans to demonstrate scramjet engine technology within the Mach 4.5-6.5 range with four flight tests beginning in 2009. According to PWR, the program will set the foundation for several hypersonic applications including access to space.[32] By the end of October 2008, the X-2 scramjet engine, a developed version of the X-1, had complete ground testing. Flight testing is on track to commence in October of 2009.[33]

Wind tunnel testing of the X-1 demonstrator engine

Air Launch Method – AirLaunch LLC

In July 2006, AirLaunch LLC demonstrated the safe release of a dummy rocket from an Air Force C-17 cargo airplane. A full-scale simulated AirLaunch QuickReach rocket, weighing almost 33,000 kilograms (72,000 pounds) and measuring 20 meters (66 feet) in length, was dropped as part of the DARPA/Air Force Falcon SLV Program. The unmodified C-17A aircraft released the test article at an airspeed of 600 kilometers/hour (330 knots) from an altitude of 9,700 meters (32,000 feet). The drop was third in a series of envelope expansion tests to verify the ability of the C-17 safely to deliver AirLaunch's full-scale, full-weight QuickReach rocket to its operational launch altitude. Previous tests took place in June 2006 and in September 2005. Each test set a new record for the longest and heaviest single item dropped from the C-17 aircraft.[34] The initial test in 2005 demonstrated the QuickReach release technology, including proof that the nose of the booster does not hit the roof of the C-17A as the rocket leaves the carrier aircraft. In 2007, AirLaunch did not conduct any further tests of the unique air launch system but instead focused efforts on developing propulsion systems for the QuickReach as detailed earlier in this chapter.[35]

Test drop of Quickreach test model

In March of 2008, AirLaunch received a patent on its Gravity Air Launch air drop methodology. A second patent is forthcoming for its "trapeze lanyard" capability, originally demonstrated for t/space. DARPA and the Air Force collectively invested approximately $38 million in AirLaunch during the course of the Falcon SLV Program, covering Phases 1, 2A, 2B, and 2C. The Falcon SLV program concluded on November 3, 2008.[36]

Stage Recovery System – Alliant Techsystems, Inc. & United Space Alliance, LLC

ATK and United Space Alliance successfully tested the world's largest rocket stage recovery parachute system. In September and November 2007, the 46 meter (150 foot) diameter, 900 kg (2,000 pound) parachute carried a 19,000 kilogram (42,000 pound) weighted test unit safely to the Earth.[37] The parachute is derived from the 41 meter (136 foot) main parachute currently used on the Space Shuttle Solid Rocket Boosters. The larger parachute will be used by the new five-segment solid rocket booster being developed for the Ares I first stage. In July 2008, the drogue parachute system was successfully tested, attached to a 10,800-kg (24,000-pound) test article.[38] The first Ares test flight, Ares I-X, a full-scale launch vehicle with inert upper stage, will use the new parachute.[39] Ares I-X is currently scheduled to launch in June 2009.[40]

The July 24, 2008 test of the Ares drogue parachute

SPACEPORTS

Launch and reentry sites – sometimes referred to as "spaceports" – are the nation's gateways to and from space. Although individual capabilities vary, these facilities may house launch pads and runways as well as the infrastructure, equipment, and fuels needed to process launch vehicles and their payloads before launch. The first such facilities in the United States emerged in the 1940s when the federal government began to build and operate space launch ranges and bases to meet a variety of national needs.

State	Non-federal	Federal	Proposed
Alabama			x
Alaska	x		
California	x	x	
Florida		x	x
Kwajalein		x	
New Mexico	x	x	
Oklahoma	x		
Texas	x		x
Virginia	x	x	
Washington			x
Wisconsin			x
Wyoming			x

Table 2: Spaceport summary by state

While U.S. military and civil government agencies were the original and still are the primary users and operators of these facilities, commercial payload customers have become frequent users of federal launch ranges. Federal facilities are not the only portals to and from space. Indeed, the commercial dimension of U.S. space activity is evident not only in the numbers of commercially procured launches but also in the presence of non-federal launch sites supplementing federally operated sites. Since 1996, the FAA has licensed the operations of seven launch or reentry sites, some of which are co-located with federal facilities. These spaceports serve both commercial and government launch operators.

Table 2 shows which states have non-federal, federal, and proposed spaceports. Figure 1 shows a map of U.S. spaceports and launch sites. Non-federal and federal U.S. spaceports capable of supporting launch and landing activities are described. A subsection detailing state and private proposals for future spaceports is also included.

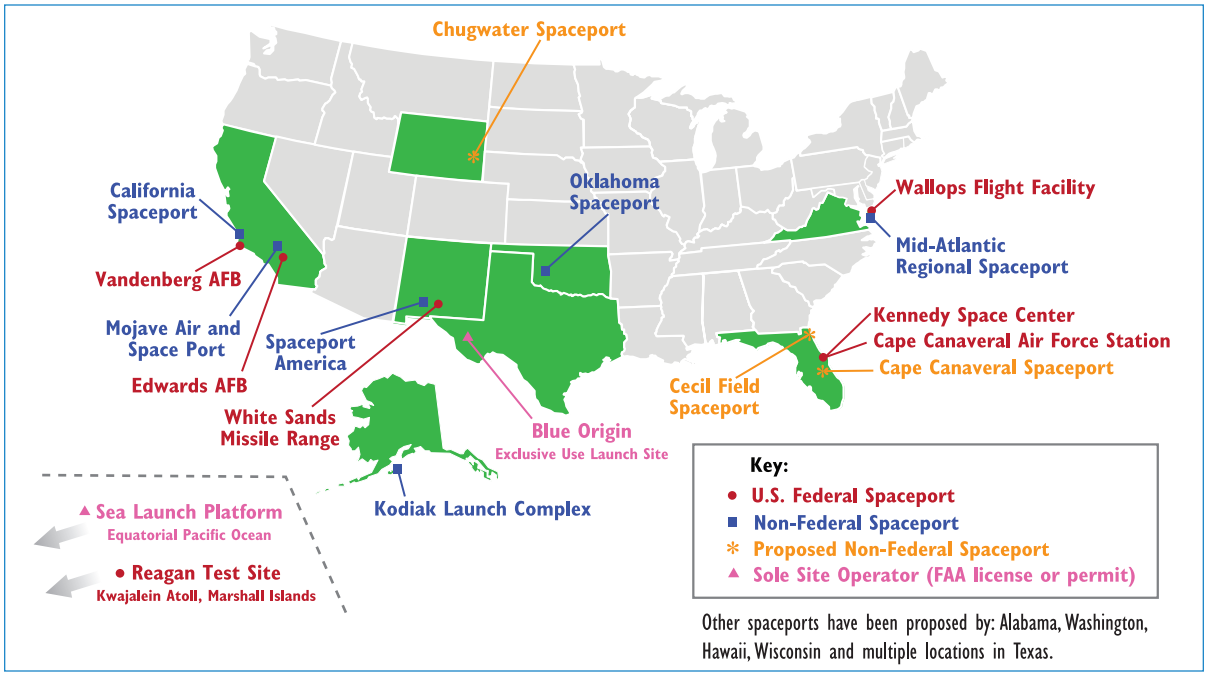


Figure 1: US spaceports and launch sites

Non-Federal Spaceports

While the majority of licensed launch activity still occurs at U.S. federal ranges, significant future launch and landing activity may originate from spaceports operated by private entities or state and local governments. For a non-federal entity to operate a launch or landing site in the United States, it is necessary to obtain a license from the federal government through the FAA. To date, the FAA has licensed seven non-federal launch sites. Three are co-located with federal launch sites, including the California Spaceport at Vandenberg Air Force Base, California, and the Mid-Atlantic Regional Spaceport at Wallops Flight Facility, Virginia. Spaceport America is located near the federally operated White Sands Missile Range. In addition, Blue Origin uses an exclusive use launch site in Texas that is not an FAA licensed spaceport. Similarly, Sea Launch also does not need an FAA launch site operator license. The first orbital launch from an FAA-licensed site occurred on January 6, 1998, when a Lockheed Martin Athena 2, carrying NASA's Lunar Prospector spacecraft, successfully lifted off from Cape Canaveral Spaceport.

Blue Origin Launch Site

Blue Origin Launch Site	
Location	Van Horn in Culberson County, Texas
Owner/Operator	Blue Origin
Description	Private property used by Blue Origin to test vertical launch vehicles
Infrastructure	Van Horn Ranch is a 66,800 hectare (165,000 acre) ranch with basic support infrastructure

Blue Origin West Texas launch site is private property. Blue Origin proposes to launch RLVs on suborbital, ballistic trajectories to altitudes in excess of 99,000 meters (325,000 feet). After reviewing the environmental assessment and finding of no significant impact for the proposed Blue Origin West Texas launch site, FAA issued to Blue Origin the first experimental permit for a reusable suborbital rocket in September 2006. The first flight of Goddard, a subscale prototype of the company's planned New Shepard vehicle, took place in November 2006; subsequent flights of Goddard took place in 2007.

In November 2007, Blue Origin reported that its second suborbital space ship was undergoing construction at its R&D facility in Kent, Washington. Also reported was the planned development of a third vehicle.[1] There was no publicly announced launch site activity in 2008.

California Spaceport

On September 19, 1996, the California Spaceport became the first commercial spaceport licensed by the FAA. The California Spaceport offers commercial launch and payload processing services and is operated and managed by Spaceport Systems International (SSI), a limited partnership of ITT Federal Service Corporation. Co-located at VAFB on the central California coast, SSI signed a 25-year lease in 1995 for 0.44 square kilometers

California Spaceport SLC-8

(0.17 square miles) of land. Located at 34° North latitude, the California Spaceport can support a variety of mission profiles to low-polar-orbit inclinations, with possible launch azimuths ranging from 220° to 165°. California Spaceport supports satellite processing for launches at VAFB's SLC-2, SLC-3, SLC-6, and SLC-8. In April 2008, the modification to the access tower at Level 5 of SLC-8 was completed to provide for 100K clean room operations.[2]

California Spaceport	
Location	Vandenberg AFB, California
Owner/Operator	Space Systems International (SSI)
License Status	Active FAA Launch Site Operator License
Description	Operating through a 25-year lease since 1995, California Spaceport offers commercial launch and payload processing, and supports a variety of mission profiles to low-polar-orbit inclinations.
Infrastructure	Launch pads, runways, payload processing facilities, telemetry, and tracking equipment.

In September 2008, Orbital Sciences Corporation announced that preparations to launch the Minotaur IV launch vehicle at VAFB were complete.[3] The inaugural flight of the Minotaur IV, carrying the SBSS 1 payload, is scheduled to take place in early 2009 at the California Spaceport's launch pad. Two other Minotaur IV launches carrying the Hypersonic Technology Vehicles HTV-2a and HTV-2b will occur in 2009.[4]

Kodiak Launch Complex

Kodiak Launch Complex

Kodiak Launch Complex (KLC) is a modern spaceport that was designed specifically to provide optimal support for space launches to polar orbit, as well as to provide support for long range ballistic missions. In 1991, the Alaska state legislature created the Alaska Aerospace Development Corporation (AADC) as a public company to develop aerospace-related economic, technical, and educational opportunities for the state of Alaska. In 2000, the AADC completed the $40-million, two-year construction of the first phase of KLC at Narrow Cape on Kodiak Island, Alaska. Total investment to date in KLC's infrastructure exceeds $200 million and AADC is finalizing plans for a third launch pad and a Rocket Motor Storage Facility.[5]

The spaceport offers unrestricted launch azimuths from 110° to 220°, and unrestricted down range flight corridors that preclude need for energy consuming dog leg flight segments. Owned by the state of Alaska and operated by the AADC, the KLC received initial funding from the USAF, U.S. Army, NASA, the state of Alaska, and private firms. Today, it is self-sustaining through launch revenues and receives no state funding; the state of Alaska provides tax-free status and has contributed the land on which the spaceport resides.

Kodiak Launch Complex	
Location	Kodiak Island, Alaska
Owner/Operator	Alaska Aerospace Development Corporation (AADC)
License Status	Active FAA Launch Site Operator License
Description	KLC was the first commercial launch site not collocated with a federal facility. Launch site for military, government and commercial telecommunications, remote sensing, and space science payloads.

As part of its business plan, AADC emphasizes maintaining KLC and keeping the spaceport's infrastructure functional and up to date. Infrastructure related developments completed in

the last two years cost more than $5.26 million and included: the Range Safety and Telemetry System office, laboratory, and store room construction; IPF roof repair; IPF foam installation upgrade; cellular tower installation; gantry system at Launch Pad 1 (LSS) electrical modifications; LCC carpet replacement; purchase and installation of two large rigid frame vehicle storage buildings; enhancements to site security; LSS modifications to accommodate Minotaur IV motor stacks; purchase and installation of four large Megadoors; and surface preparation and repainting the LSS from floor to ceiling.

In addition, AADC augmented its fleet of support vehicles at KLC by purchasing several vehicles that included a new crew transport van, an ambulance, an Oshkosh sander/grader, and a fire truck. AADC also initiated contracts for design of a third launch pad complex and for a Rocket Motor Storage facility.[6] Contract driven activities supported by KLC in fiscal year 2008 included: launch of the FTX-03 and FTG-05 missions for MDA, completion of a mechanical C-4 pathfinder for MDA, and completion of data downlink services for the USAF NFIRE mission.

A Minotaur IV mechanical pathfinder for the USAF is scheduled for spring of 2009.[7] Following the pathfinder there will be launches of a Minotaur IV carrying TacSat 4 and a second Minotaur IV carrying various small satellites for the USAF.

Mid-Atlantic Regional Spaceport

MARS facilities at WFF

The Mid-Atlantic Regional Spaceport (MARS) is designed to provide "one-stop-shopping" for space launch facilities and services for commercial, government, scientific, and academic users. Optimal orbital inclinations accessible from the site are between 38° and 60°; other inclinations, including Sun-synchronous orbit (SSO), can be reached through in-flight maneuvers. The FAA issued a launch site operator's license to the Virginia Commercial Space Flight Authority (VCSFA) in December 1997. In July 2003, Virginia and Maryland created a bi-state agreement to operate, conduct future development of, and promote the spaceport. The agreement also renamed the spaceport, previously called the Virginia Space Flight Center, to MARS.

In March 2008, Virginia created the "Zero Gravity, Zero Tax" incentive that eliminated taxes on business earnings related to human spaceflight training or actual space flights launched from the MARS. The measure became effective July 1, 2008 for the tax year beginning January 1, 2009.[8]

In June 2008, Orbital Sciences Corporation (OSC) announced that it will launch its Taurus II launch vehicle, currently under development, from MARS. OSC aims to conduct its first International Space Station-bound transportation demonstration flight by the end of 2010. Pad 0-A will be renovated in order to support the Taurus II. Virginia approved a $16 million bond package to help pay for the launch pad renovation and other improvements including a new vehicle

integration facility and a fixed liquid fueling system.[9] According to OSC, the Taurus II program is expected to create 125 jobs split between the Dulles and Wallops Island locations.

Mid-Atlantic Regional Spaceport	
Location	Wallops Island, Virginia
Owner/Operator	Virginia Commercial Space Flight Authority
License Status	Active FAA Launch Site Operator License
Description	Commercial spaceport co-located with NASA's Wallops Flight Facility that supports vertical and horizontal space launch for commercial, government, and non-profit users.
Infrastructure	Two orbital launch pads, multiple suborbital launching rails, payload processing and integration facilities, vehicle storage and assembly buildings, class 100,000 clean room, mobile liquid fueling capability, on-site and down range telemetry and tracking, and payload recovery capability.

In 2008, the payload processing and integration facility's class-100,000 high bay was completed. Pad 0-B gantry improvements are 60% complete and will continue on a non-interference basis with launches.[10] Long-term development plans include developing a new mid-to-heavy class launch capability that includes an additional launch pad, launch mount, pad water deluge system, large capacity liquid fueling storage and transfer facility at the pad, a 1,100-square-meter (21,000-square-foot) horizontal integration facility, a 230-square-meter (2,500-square-foot) payload propellant fueling facility, and the necessary transportation infrastructure to support the launch vehicle process flow. These facilities are currently in the design phase with construction anticipated to commence in calendar year 2009 and completion in mid calendar year 2010.[11]

In August 2008, MARS supported the launch of the Alliant Tech Systems ALV X-1 rocket carrying HYBOLT, SOAREX, and SCRAMP. A Minotaur I carrying TacSat 3 will launch in 2009.

Mojave Air and Space Port

Mojave Air and Space Port

Mojave Air and Space Port (formerly Mojave Airport) in Mojave, California, became the first inland launch site licensed by the FAA on June 17, 2004, allowing Mojave Air and Space Port to support suborbital launches of RLVs. The Kern County, California, government established the Mojave Airport in 1935. The original facility was equipped with taxiways and basic support infrastructure for general aviation. A short time after its inception, the Mojave Airport became a Marine Auxiliary Air Station. The largest general aviation airport in Kern County, Mojave Air and Space Port is owned and operated by the East Kern Airport District (EKAD), which is a special district with an elected Board of Directors and a General Manager.[12]

One of the original hangars at Mojave Air and Space Port was demolished in May 2008 to build a larger structure for the Mojave's National Test Pilot School. Hangar 161 was built by the Navy for the Mojave Marine Corps Auxiliary Air Station in 1942. Recently, it has housed aircraft used by the school for training test pilots and flight test engineers.[13]

In August 2008, the East Kern Airport District qualified for a $1.7-million grant

Mojave Air and Space Port	
Location	Mojave, California
Owner/Operator	East Kern Airport District (EKAD)
License Status	Active FAA launch site operator license. In late 2007, the FAA instituted safety-related amendments to the license. The FAA approved EKAD's Launch and Recovery Site Boundaries, Mission Preparation Areas and Energetic Liquids Storage Plan, November 2008.[13]
Description	An airport being used for flight testing, space industry development, and aircraft heavy maintenance and storage.
Infrastructure	Air traffic control tower, three runways, rotor test stand, engineering facilities, and high bay building. Easy access to restricted airspace. Space zoned specifically for rocket motor development and testing.

from the FAA to build an engine run-up pad adjacent to the approach to Runway 30 equipped with two tie down points rated to the F-22.[14] Runway 30 was recently extended to 3,800 meters (12,500 feet) using another FAA grant. The pads would allow aircraft engines from F-4 fighters to Boeing 747-400 airliners to run-up engines during tests. Primary users of the pads would include the National Test Pilot School, BAE Flight Systems, and CalSpan's Bicycle Works, which all operate jet aircraft. The district also received three other FAA grants this fiscal year. For 2009, another project is on the way, which includes upgrading the entire airport apron from the main control tower south to the T-hangars.[15]

In July 2008, Scaled Composites and Virgin Galactic unveiled the WhiteKnightTwo, a flying launch pad to support commercial suborbital space travel at the Mojave Air and Space Port.[16]

Oklahoma Spaceport

After seven years of development, in June 2006 the Oklahoma Spaceport became the sixth commercial spaceport licensed by the FAA. In 1999, the Oklahoma state legislature created the Oklahoma Space Industry Development Authority (OSIDA). The FAA license allows OSIDA to provide launch and support services for horizontally-launched suborbital RLVs at the Clinton-Sherman Industrial Airpark (CSIA) launch site, located near Burns Flat in Washita County.

Oklahoma Spaceport

Oklahoma Spaceport	
Location	Washita County, Oklahoma
Owner/Operator	Oklahoma Space Industry Development Authority
License Status	Active FAA Launch Site Operator License
Description	Provides launch and support services for horizontally-launched suborbital RLVs
Infrastructure	A 4,100-meter (13,500-foot) runway; 5,200-square-meter (50,000-square-foot) manufacturing facility; 2,800-square-meter (30,000-square-foot) maintenance and painting hangar; 6 commercial aircraft hangars, including a 2,800-square-meter (30,000-square foot) maintenance and paint facility; 39 hectare (96 acre) of concrete ramp, control tower, crash and rescue facility; and 435 square kilometer (168 square miles) of land available for further construction.

The spaceport supports Armadillo Aerospace flight testing for their Lunar Lander in competition for the Northrop Grumman Lunar Lander Challenge.[17]

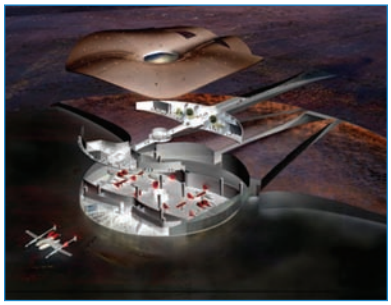
In September 2008, the Rocket Racing League announced the successful results of the first seven test flights of the Bridenstine DKNY Rocket Racer. These test flights took place at the Oklahoma Spaceport.[18]

Spaceport America

Spaceport America is being developed for use by private companies and government organizations conducting space activities and operations. The state owns and operates the spaceport and will lease the facilities to the users. Virgin Galactic is an anchor customer that will locate its world headquarters at Spaceport America.

Spaceport America	
Location	Upham, New Mexico
Owner/Operator	New Mexico Spaceport Authority (NMSA)
License Status	Active FAA Launch Site Operator License issued in December 2008
Description	A commercial spaceport in development that will support vertical and horizontal space launch

Spaceport development is planned to begin 2009 after receiving a launch site operator's license from the FAA in December 2008. However, bids were collected, an award was made, and work on improvements to the road that provides access to the Spaceport America site began in September 2008.[19] The spaceport is estimated to be fully constructed by 2010. To provide economic support for spaceport development, Sierra County approved a tax levy in April.[20] The addition of Sierra County to Doña Ana County's approval in 2007 allows the creation of a regional taxing district that will provide approximately $49 million from Doña Ana and $2.4 million from Sierra for construction of the spaceport.[21]



Cutaway view of Spaceport America facility

UP Aerospace and Lockheed Martin conducted a successful research test flight in August.[22] In April, UP Aerospace, the first company to launch a commercial payload from Spaceport America, signed a 10-year memorandum of understanding with NMSA to use Spaceport America for spaceflight operations.[23] Microgravity Enterprises, a commercial space development company focusing on affordable rocket flight for commercial and educational purposes, signed an MOU with NMSA in April to operate from Spaceport America.[24] Lockheed Martin signed an agreement in April with NMSA to continue to conduct testing at the spaceport.[25] In October, Rocket Racing, Inc. and Armadillo Aerospace announced a partnership to offer commercial space flights from Spaceport America.[26]

Federal Spaceports

Since the first licensed commercial orbital launch in 1989, the federal ranges have continually supported commercial launch activity in addition to handling government launch operations. The importance of commercial launches is evident in the changes taking place at federal launch sites. Launch pads have been developed with commercial, federal, and state government support at the two major federal sites for U.S. orbital launches for the latest generation of the Delta and Atlas launch vehicles. CCAFS and VAFB host pads for the Delta II, Delta IV, and Atlas V. Recognizing that the ranges are aging, the U.S. government is engaged in range modernization. This effort includes the ongoing Range Standardization and Automation program, a key effort to modernize and upgrade the Eastern Launch and Test Range at CCAFS and the Western Range at VAFB.

Cape Canaveral Air Force Station

The 45th Space Wing, headquartered at Patrick AFB, conducts launch operations and provides range support for military, civil, and commercial launches at CCAFS. The 45th Space Wing manages the Eastern Launch and Test Range (ELTR). The ELTR is used to gather and process data on a variety of East Coast launches and deliver it to range users.

Delta IV launch from CCAFS

Users of CCAFS include the USAF, Navy, NASA, and various private industry contractors. The eastern range also supports the Space Shuttle launches and U.S. Navy submarine and ballistic missile testing. With its mission partners, CCAFS processes a variety of satellites and launches them on Atlas V, Delta II, Delta IV, and upcoming Falcon 9.

SpaceX plans to deliver Falcon 9 hardware to the CCAFS in the fourth quarter of 2008.[27] The Falcon 9 will launch from the newly refurbished Space Launch Complex 40. In May, the Titan service tower at Space Launch Complex 40 was demolished to make way for the new Falcon 9 launch infrastructure.

Cape Canaveral Air Force Station	
Location	Cape Canaveral, Florida
Owner/Operator	U.S. Air Force
License Status	N/A
Description	CCAFS conducts launch operations and provides range support for military, civil, and commercial launches. Home of the 45th Space Wing which oversees the Eastern Range.
Infrastructure	Telemetry and tracking facilities, jet and Shuttle capable runways, reentry corridors, operations control center, movable hangar, fuel tanks, water towers, and launch pads.

CCAFS supported a launch in March of a Delta II carrying an Air Force GPS satellite, a launch in April of an Atlas V carrying a commercial communication satellite (ICO G1), and a launch in June of a Delta II carrying a gamma-ray exploration satellite (GLAST) for NASA. CCAFS is scheduled to support the March 2009 launch of a Delta IV Heavy carrying a US government payload. CCAFS also supported four shuttle launches for NASA in 2008.

Edwards Air Force Base

The original landing site for the Space Shuttle, Edwards Air Force Base (EAFB), California, is the home of more than 250 first flights and about 290 world records. The first two Shuttle flights landed on Rogers Dry Lake, a natural, hard-pack riverbed, measuring about 114 square kilometers (44 square miles). Today, NASA prefers to use KSC as the primary landing site for the Space Shuttle and uses EAFB as a backup site. EAFB is the DoD's premier flight test center, leading in unmanned aerial vehicle (UAV), electronic warfare, directed energy test capabilities, and testing of future hypersonic vehicles.

Space Shuttle lands at Edwards

In February 2008, Edwards AFB hosted a forum and site visit for about 75 private land developers and energy groups to introduce Enhanced Use Lease (EUL) opportunities on base, including building a solar plant. The forum's purpose was to provide information about the Air Force's EUL process, requirements for qualifying, the base's mission and an overview of the project, which included a site visit to a proposed solar plant location. Through the EUL program, Edwards can lease underused land, natural infrastructure, and equipment. Consideration for the EUL may be either cash or in-kind consideration such as construction of new facilities, provision of facilities, and operations support. The Air Force identified 3,288 acres of underused land on Edwards for lease.[28]

Edwards Air Force Base	
Location	Edwards AFB, California
Owner/Operator	U.S. Air Force
License Status	N/A
Description	Landing site for Space Shuttle. DoD uses EAFB as a flight test center for unmanned aerial vehicle (UAV), electronic warfare, directed energy test capabilities, and testing of future hypersonic vehicles.
Infrastructure	Telemetry and tracking facilities, jet and Shuttle capable runways, reentry corridors, operations control center, movable hangar, fuel tanks, and water tower

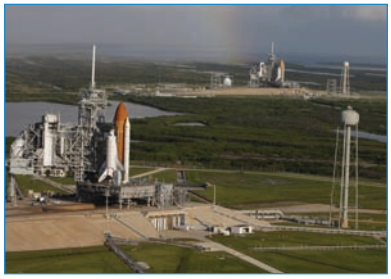
Edwards completed an environmental assessment for reentry corridors to EAFB for lifting entry vehicles like the X-38 configuration.[29] An additional environmental assessment is being developed for corridors that will allow flight tests within the atmosphere for ranges of 741 kilometers (400 nautical miles) and 1,528 kilometers (825 nautical miles).

In October 2008, a major runway construction at the Edwards AFB was finished ahead of its targeted December 2008 completion. The $118 million project was headed by the U.S. Army Corps of Engineers and included work by Joint Venture, CH2M Hill Construction, and the Interstate Highway construction team.[30]

Space Shuttle Endeavour landed at EAFB in November 2008 after being diverted from KSC due to bad weather.[31] The U.S. Air Force's X-51 WaveRider vehicle, the fastest air-breathing, jet-fueled vehicle built in the U.S., is scheduled to fly from EAFB in late 2009.[32]

Kennedy Space Center

Established as NASA's Launch Operations Center in July 1962, Kennedy Space Center today serves as the primary launch site for NASA's human spaceflight space missions. NASA KSC manages NASA's requirements for using expendable launch vehicles flown primarily from CCAFS and VAFB with support from the USAF. NASA KSC and Space Florida are cooperating to establish a technology and commerce park at Kennedy Space Center. Exploration Park is expected to support expanded private sector participation in space exploration, support commercial space transportation, and promote commercial development of technologies for application in space and on Earth.[33]



Atlantis and Endeavour

In 2008, NASA KSC initiated an environmental study of potential sites on KSC

for a Commercial Vertical Launch Complex capable of supporting vehicles in the heavy class (approximately 2 million pound thrust). NASA is working with the USAF to identify potential alternative sites on CCAFS to include in the evaluation.[34]

Kennedy Space Center	
Location	Cape Canaveral, Florida
Owner/Operator	NASA
License Status	N/A
Description	Primary launch and landing site for NASA's human spaceflight missions and also procures and oversees expendable launch vehicle services for NASA missions.
Infrastructure	Launch pads, supporting Space Shuttle operations, Vehicle Assembly Building (VAB), and Shuttle Landing Facility

NASA KSC is actively supporting the Commercial Orbital Transportation Services (COTS) demonstration. NASA KSC also is jointly developing with Space Florida a new space experiment platform called FASTRACK to use the emerging capabilities of the commercial suborbital vehicles and other carriers for science and technology experiments. An engineering unit of FASTRACK was test flown aboard Zero Gravity Corporation's reduced gravity aircraft in September 2008.[35]

Work on transition of KSC's Complex 39 to support the Constellation program has begun.[36] With the upcoming Shuttle retirement in 2010, NASA's Exploration and Systems Mission Directorate has assigned KSC new roles in the Constellation program such as final assembly duties for Orion and building the Altair landers.[37] In June 2008, NASA selected contractors to provide ground support equipment for Constellation and other space programs at KSC. The IDIQ contract has a maximum value of $400 million. The contract covers all required management, labor, facilities, materials, and equipment to fabricate, mark, package, deliver, clean, assemble, precision clean and test equipment, ground systems, and other hardware for KSC.[38]

In June 2008, United Launch Alliance's launched the Gamma-ray Large Area Space Telescope (GLAST) using a Delta II rocket from KSC.[39] A total of four Space Shuttle launches took place in 2008. KSC will support the launch of NASA's Lunar Crater Observation and Sensing Satellite (LCROSS), which will launch in early 2009.

Reagan Test Site

Kwajalein Atoll

Located at Kwajalein Atoll, part of the Republic of the Marshall Islands, the U.S. Army's Reagan Test Site (RTS) is part of the DoD Major Range and Test Facility Base (MRTFB). The first Naval Station was established on Kwajalein after World War II. The facilities have gone through a series of infrastructure upgrades and names resulting in the Ronald Reagan ballistic Missile Defense Test Site (RTS), which has been operational since 2001.[40] The advantages of RTS include its strategic geographical location, allowing launch in virtually all azimuths, unique instrumentation, and ability to support ballistic missile testing and space operations. RTS is completely instrumented to support space launch

customers with radar, telemetry, optics, and range safety systems. As a U.S. Army DoD MRTFB, RTS receives annual federal funding in addition to direct cost reimbursement from customers.

In 2008, development continued on fiber connectivity to CONUS and Redstone Arsenal, (Huntsville Alabama). The Kwajalein Space Operations Control Center (KSPOCC) in Huntsville supports limited space operations using satellites until the fiber installation is complete in early 2010.[41] At that time, customers will have the flexibility to conduct missions from the Huntsville facility or Kwajalein. A launch pad on Omelek Island was constructed in 2006 to support space launch missions including those conducted by SpaceX.

Reagan Test Site	
Location	Kwajalein Atoll, Republic of the Marshall Islands
Owner/Operator	U.S. Army Space and Missile Defense Command
License Status	DoD Spaceport
Description	RTS conducts 24/7 space control operations to provide space situational awareness, and protect key space assets supporting U.S. Central Command, U.S. Pacific Command, and U.S. Northern Command. Launch facilities support space launch as well as scientific, tactical, and strategic missile launches.
Infrastructure	Telemetry, radars, and optical tracking systems, ship-based telemetry/safety system, mission control facility, wideband connectivity with the continental U.S., multiple safety systems and launch facilities, runway, warehouse and industrial use space, user and engineering office space.

In April 2008, the Communication/Navigation Outage Forecasting System (C/NOFS) satellite was successfully launched from Reagan Test Site by Orbital's Pegasus vehicle. SpaceX Flight 3 of Falcon 1 launched in August but failed to deliver its payloads, Trailblazer, PRESat, and NanoSail-D, to orbit. In September, SpaceX Flight 4 of the Falcon 1 launch vehicle was successfully launched and achieved Earth orbit, becoming the first privately-developed liquid-fuel rocket to orbit the Earth.

Vandenberg Air Force Base

VAFB is currently the headquarters of the 30th Space Wing and the Air Force Space Command organization responsible for all DoD space and ballistic activities for the West Coast. All of the U.S. satellites destined for near-polar orbit launch from the Western Range at VAFB. The 30th Space Wing Western Range Operations Control Center provides flight safety, weather, scheduling, instrumentation control, vehicle designation information, and tracking data to and from inter- and intra-range sensors in real or nearly real-time for ballistic and space launch support. Range tracking capabilities extend over the Pacific Ocean as far west as the Marshall Islands. Boundaries to the north stretch as far as Alaska and as far south as Central America. Vandenberg is host to the 14th Air Force Headquarters and the Joint Functional Component Command for Space.

Atlas V on SLC-3

In January 2008, construction began on a new facility for the incoming 21st Space Operations Squadron. This facility will house command and control instruments as well as satellite operators to support the space mission. These operations included missile warning systems, meteorological data, NASA launch and re-entry missions, and intelligence related projects. Completion of the facility is expected in October 2009.[42]

Vandenberg Air Force Base	
Location	Vandenberg AFB, California
Owner/Operator	U.S. Air Force
License Status	N/A
Description	Headquarters of the 30th Space Wing and the Air Force Space Command organizations responsible for all DoD space and ballistic activities for the West Coast.
Infrastructure	Launch pads, vehicle assembly, and processing buildings, payload processing facilities, telemetry and tracking facilities, control center, engineering, user office space, and Shuttle-capable runways.

Preparations for the March 2008 launch of Atlas V required major modifications to Space Launch Complex 3 (SLC-3). The first of these modifications was a 10-meter (30-foot) high extension to the mobile service tower to house the rocket during its construction. In addition, there was a 6-meter (20-foot) depth increase in the exhaust duct to direct the rocket exhaust. The base also built a new 227-metric ton (250-ton) platform to carry the weight of the rocket and made numerous improvements to the SLC-3 ground systems and control centers.[43]

SLC-6 is currently undergoing a series of renovations to enable launching the Delta IV Heavy. Currently the pad is configured to launch the standard Delta IV Common Core Booster. Additional infrastructure is required to launch the Delta IV Heavy. Pad modifications should be complete in 2010.[44]

In March 2008, the first Atlas V rocket to launch from Vandenberg AFB occurred.[45] The launch of the GeoEye-1 satellite aboard Delta II took place from Vandenberg Air Force Base in September 2008.[46] The base was used as a test site for NASA's Interstellar Boundary Explorer (IBEX) satellite.[47] Orbital Sciences Minotaur II+ target vehicle launched from the Air Force Base in September 23, 2008, to support MDA's missile-observing satellite, Near Field Infrared Experiment (NFIRE).[48] In October, VAFB launched a Delta II rocket carrying the Thales Alenia-Space COSMO-SkyMed 3 satellite. The 30th Space Wing team supported the United Launch Alliance in preparing for the launch from SLC-2 only six weeks after the successful launch of the GeoEye-1 satellite in September; normally SLC-2 crews have three to four months to prepare for a launch.[49] In December 2008, VAFB launched an MDA Ground Based Interceptor as part of a missile intercept test.[50]

Boeing Launch Services won a contract to launch the WorldView-2 commercial imaging satellite aboard Delta II for Colorado-based DigitalGlobe from VAFB in mid-2009.[51] In 2009, VAFB will launch Taurus and in January and June.[52] VAFB is scheduled to launch an NOAA-N satellite aboard a Delta II in February 2009.[53]

Wallops Flight Facility

The predecessor of NASA, the National Advisory Committee for Aeronautics (NACA), established an aeronautical and rocket test range at Wallops Island, Virginia, in 1945. Since then, over 16,000 rocket launches have taken place from the Wallops Flight Facility (WFF), which is operated for NASA by the Goddard Space Flight Center, Greenbelt, Maryland.

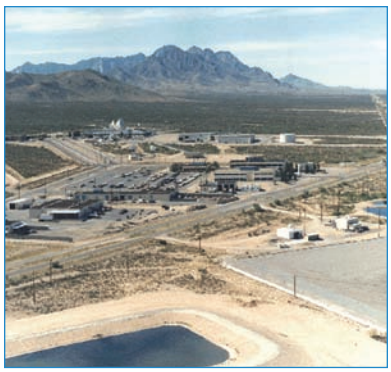
Black Brant launch at WFF

NASA has made capital improvements to several of its key integration facilities during 2008 to enable support of larger spacecraft and launch vehicle elements. The Wallops Research Park is in final planning and approval stages. The park consists of a 97-hectare (240-acre) area adjacent to Wallops that will offer space for the growth of aerospace, research, education, recreation, and commercial activities.[54] A facility housing Northrop Grumman is under construction and a hangar/office facility supporting BaySys Technologies is planned for construction soon.[55] Modifications are underway to an existing suborbital launch site to accommodate a technology demonstration of an alternative launch abort system concept, known as the Max Launch Abort System (MLAS). This system supports NASA's Constellation Program. Improvements to the Wallops Main Base and Wallops Island boat basins have been constructed to reestablish capabilities for transporting flight systems from main base integration facilities to launch sites.[56] As part of Virginia's agreements with Orbital Sciences Corporation supporting Taurus II integration and launch operations, the Virginia General Assembly approved a $16-million bond package for infrastructure upgrades at Wallops.[57] This funding will be used to upgrade infrastructure at WFF and the co-located MARS facilities.

Ten total major launches occurred from WFF in 2008, plus numerous uninhabited aerial systems missions and launches of DoD targets. Types of launches included science, hypersonics, and launch vehicle and payload technology demonstrations. Wallops personnel and facilities are currently integrating the NASA Max Launch Abort System (MLAS) scheduled for launch in Spring 2009. Test flights of a two-stage NASA Terrier-Orion sounding rocket tested new tracking, data processing, payload positioning, power, and communications systems. WFF supported the launch of the Alliant Tech Systems ALV X-1 rocket carrying HYBOLT, SOAREX, and SCRAMP. A Minotaur I carrying TacSat 3 will launch from the co-located MARS in early 2009.

Wallops Flight Facility	
Location	Wallops Island, Virginia
Owner/Operator	NASA
License Status	N/A
Description	A federally funded research, development, and testing facility supporting vertical launch and aircraft based launch.
Infrastructure	Runway, telemetry and tracking facilities, integration & testing facilities, Class-100,000 clean room for spacecraft. Co-located with Mid-Atlantic Regional Spaceport (MARS)

White Sands Missile Range



White Sands Missile Range

Once exclusively military, White Sands Missile Range (WSMR) today attracts other government agencies, foreign nations, and private industry to its world-class test facilities. The largest overland test range in America, WSMR is operated by the U.S. Army and used by the Army, Navy, Air Force, Marine Corps, and MDA. It is also home to the NASA White Sands Test Facility. Situated 26 kilometers (16 miles) northeast of Las Cruces, New Mexico, this range covers 8,100 square kilometers (3,127 square miles).

In June 2008, Lockheed Martin Missile and Fire Control conducted a test to launch a GPS-guided rocket from a wheeled launcher to shoot down targets at the White Sands Missile Range.[58]

White Sands Missile Range	
Location	White Sands, New Mexico
Owner/Operator	U.S. Army
License Status	N/A
Description	WSMR provides missile test range facility not just for the U.S. military but for other government agencies, foreign nations, and private industry. After KSC and EAFB, WSMR is the Space Shuttle's tertiary landing site.
Infrastructure	Full telemetry and tracking facilities, runway engine and propulsion testing facilities, class-100 clean room for spacecraft parts.

In September 2008, NASA and Pratt & Whitney Rocketdyne tested the methane-fueled RS-18 engine at the WSMR. The RS-18 engine was built by Pratt & Whitney Rocketdyne and modified under NASA's Exploration Technology Development Program, which is developing rocket engine and propulsion technologies for future missions to the Moon and Mars.[59]

Several demonstration flights for the Orbital Science's Orion abort launch system will take place at the White Sands Missile Range at the end of 2008.[60] As part of Orbital's indefinite-delivery indefinite-quantity (IDIQ) contract worth $100 million over 10 years from the Department of Defense, it will provide launch vehicle engineering services to all U.S. Army, Navy, and Air Force suborbital programs managed by WSMR.[61]

Proposed Spaceports

Several states plan to develop spaceports offering a variety of launch and landing services. Two common characteristics of many of the proposed spaceports are inland geography – a contrast to the coastal location of most present-day U.S. spaceports – and interest in hosting RLV operations.

Cape Canaveral Spaceport

Space Florida was created on May 30, 2006, when then-Florida Governor Jeb Bush approved Florida House Bill 1489. Space Florida consolidates the state's previous space and aerospace entities and coordinates all space-related issues in Florida. Under an arrangement between the federal government and Space Florida, excess CCAFS facilities were licensed to Space Florida for use by commercial launch service providers on a dual-use, non-interference basis.

In August 2008, the Air Force agreed to transfer Cape Canaveral Air Force Station's LC-36 to Space Florida who will operate it as a commercial space launch complex as part of a larger Commercial Launch Zone. The launch complex is part of a plan to develop a duty-free trade zone to the International Space Station following a $14.5-million appropriation by the State of Florida in April 2008. The new facility is projected to cost $55 million and would

RLV support hangar

be designed to accommodate multiple launch vehicles. In October, Space Florida announced environmental assessments would begin for LC-36, followed by the build out of Pad A, which is scheduled for completion by fall 2010.[62] Space Florida selected an architecture and engineering firm in November 2008 to perform the conceptual site design and environmental baseline studies, and has been working with the Air Force to develop explosive site plans for LC-36. Space Florida must finish its license agreement with the Air Force and work out design requirements and the concept of operations for the Commercial Launch Zone. The first commercial launch to take place from LC-36 is planned for late 2010.[63]

A high-expansion foam fire-fighting system in the RLV support hangar adjacent to the space shuttle landing facility runway was finished and successfully tested in November 2008. The RLV hangar can now accommodate fueled aircraft or space tourism vehicles.[64]

Cape Canaveral Spaceport	
Location	Cape Canaveral, Florida
Owner/Operator	Space Florida
License Status	Will be licensed to use certain excess Cape Canaveral Air Force Station facilities for commercial launch providers on a joint-use basis. A five-year license from the Air Force to use Launch Complex-47 (LC-47) for suborbital launch vehicles carrying academic payloads. Space Florida intends to license Launch Complex-36 (LC-36) for five-years from the USAF to launch light to medium rockets.
Description	Launch site for commercial, civil, and military launch vehicles and suborbital launch vehicles carrying academic payloads. Space Florida received $4 million in direct appropriations to support its operations for fiscal year 2009.[63]
Infrastructure	One orbital launch complex with a remote control center, one suborbital launch complex with two pads and a blockhouse, an off-site solid rocket motor storage facility that includes heavy rail access, a 27-m (90-ft) high bay with overhead cranes, a storage building; and a 5,200-square-meter (50,000-square-foot) RLV support hangar adjacent to the KSC Shuttle Landing Facility runway.

In November 2007, Space Florida teamed with Nevada-based Bigelow Aerospace to establish the Florida Space Transportation Initiative, an investment fund of both public and private financing that would support the development of new orbital space transportation system at the Kennedy Space Center.[65] This initiative would help finance development and domestic production of commercially built orbital transportation systems for moving crew and cargo to and from Low Earth Orbit (LEO) and would potentially compliment NASA's Commercial Orbital Transportation Initiative (COTS). Bigelow Aerospace committed up to $100 million towards this initiative.

In December 2007, Space Florida partnered with Chicago-based PlanetSpace, a consortium of ATK, Lockheed Martin, and Boeing, to respond to NASA's request for proposals for commercial ISS transportation services.[66] PlanetSpace proposed to launch a 48-meter (158-foot) solid-fuel rocket by 2011 from Space Florida's Commercial Launch Zone, which includes such facilities as the launch pad at LC-36. In addition to the State of Florida's $14.5 million appropriation, Space Florida is seeking bonding authority for additional monies as required. Space Florida is working with the other Commercial Resupply Services bidders for a Cape Canaveral launch presence as well.

In September 2008, a Super Loki Rocket with a normal dart and meteorological payload launched from Cape Canaveral spaceport facilities. The launch was part of an educational activity for middle school students.[67]

Cecil Field

Originally developed as a Naval Air Station, Cecil Field was proposed for closure by the Base Realignment and Closure (BRAC) process in 1993. Five years later, based on the recommendation of the Base Reuse Commission, Jacksonville Aviation Authority (JAA) took ownership. The airport was identified as a potential launch site in the feasibility study of a Florida commercial spaceport. Space Florida has been instrumental in providing guidance and direction for developing the Cecil Field Spaceport.[68] The JAA is pursuing a launch site operator's license.

Cecil Field aerial view

The JAA submitted a final application for a launch site operator's license to the FAA in August 2008. The JAA expects to receive approval by February 2009 to allow commercial space travel from the airport. If Cecil Field receives approval, the first space launch flights could begin as early as 2010.[69]

Cecil Field	
Location	Jacksonville, Florida
Owner/Operator	Jacksonville Aviation Authority (JAA)
License Status	Environmental assessment for spaceport operations completed in 2007. Jacksonville Aviation Authority submitted launch site operator license application in 2008. Approval expected in February 2009.
Description	Planned commercial spaceport offering horizontal launch for commercial, government, and non-profit users. Cecil Field is a retired Naval Air Station.
Infrastructure	Four runways, 175 buildings, 8 aircraft hangars, an active air traffic control tower, warehouse, industrial, office, general use, and support facilities.

The JAA has several new facilities under construction or in the planning phase. Hangar 880, a 2,100-square-meter (23,000-square-foot) corporate jet maintenance and repair and overhaul (MRO) hangar began construction in 2008 with completion scheduled in the summer of 2009. Hangar 925, a 5,900-square-meter (64,000-square-foot) MRO hangar with 1,500-square-meter (16,000-square-foot) shop and office space sized for up to 3 767-type aircraft for MRO activities, is scheduled for construction in the summer of 2009 with completion in 2010.

In addition, JAA is constructing a 3,700-square-meter (40,000-square-foot) aircraft coating and MRO facility in conjunction with Florida Community College of Jacksonville scheduled for operation in the spring of 2010. Alenia-North America is also constructing a 30,000-square-meter (327,000-square-foot) aircraft facility and hangar complex for assembly of the C-27J Spartan military cargo plane in 2010.

JAA has land available for construction of another hangar facility on the southwest side of the airport that we have reserved for space operations when we gain a spaceport tenant. JAA can assist with financing for hangar, assembly, and launch facilities.[70]

Chugwater Spaceport

Chugwater aerial view circa 1960

Chugwater Spaceport	
Location	Platte Country, Wyoming
Owner/Operator	Private Owner
License Status	Environmental assessment for site approval is in progress
Description	A private decommissioned Atlas-E launch site used by a number of small companies to develop and test rocket equipment.
Infrastructure	Plans for future infrastructure include a functioning 2,225,000-newton (500,000-pound-force) vertical test stand for engine testing, up to three vertical launch pads, on-site machine shop, and shooting range. An additional horizontal engine test area is in development. The planned configuration of the spaceport launch site includes vertical launch pads with water acoustic suppression system.

The Chugwater Spaceport was originally an Atlas E missile base outside of Chugwater, Wyoming, built in 1960 and decommissioned in 1965. Designed to store and launch a complete Atlas E ICBM, the facilities are designed with many special amenities for rocketry. In March 2006, Frontier Astronautics bought the property and began renovation to use it as a launch site. Since the last change in ownership, maintenance work has been performed to get original military equipment operational.

South Texas Spaceport

Willacy County Development Corporation was created in 2001 to manage the spaceport site evaluation and other technical and administrative elements of the project under a Texas Aerospace Commission grant. The designated spaceport site is a 40.5-hectare (100 acre) undeveloped site in Port Mansfield, adjacent to the Charles R. Johnson Airport. It lies approximately 150 kilometers (93 miles) south of Corpus Christi and 65 kilometers (40 miles) north of Brownsville. The site initially may support the suborbital and small orbital launch systems currently in service or being developed for service in the near future, with a long-term focus on RLVs. All launches will be from spoil islands or barges in the Mansfield ship channel in the Laguna Madre or Gulf of Mexico.

South Texas Spaceport	
Location	Willacy County, Texas
Owner/Operator	Willacy County Development Corporation for Spaceport Facilities
License Status	Have not applied
Description	A private site designated as a spaceport adjacent to the Charles R. Johnson Airport. Launches to be conducted from spoil islands or barges in the Mansfield ship channel.
Infrastructure	Road, fire hydrants, metal building with offices and bathrooms, and a concrete slab.

Spaceport Alabama

There was no publicly announced activity in 2008

Spaceport Alabama	
Location	No land has been acquired but possible location in Baldwin County
Owner/Operator	Spaceport Alabama Program Office at Jacksonville State University
License Status	Have not applied
Description	Proposed as a next-generation spaceport, Spaceport Alabama will be a full-service departure and return facility, supporting orbital and suborbital space access vehicles. Under the current spaceport development plan, a spaceport facility could become operational within 10 years, depending on market demand.
Infrastructure	Plans call for developing an R&D park, a commerce park, supporting community infrastructure, intermodal connectivity, and other services and infrastructure necessary for providing a turnkey capability in support of space commerce, R&D, national security, science, and related services are also included in this plan.

Spaceport Sheboygan

On August 29, 2000, the Wisconsin Department of Transportation officially approved creating the Spaceport Sheboygan, located on Lake Michigan in Sheboygan, Wisconsin. The city of Sheboygan owns the spaceport, which strives to support space research and education through suborbital launches for student projects.

Spaceport Sheboygan	
Location	Sheboygan, Wisconsin
Owner/Operator	Owner: City of Sheboygan; Operator: Rockets for Schools
License Status	Have not applied
Description	Spaceport Sheboygan conducts suborbital sounding rocket launches for the purpose of educating students and the general public.
Infrastructure	Portable launch pads, equipment, and facilities, including mission control. Proposed for renovation adjacent to the launch pads, the proposed Great Lakes Aerospace Science and Education Center will serve as a hands-on space travel-oriented center focusing on math and science-oriented education and tourism. Plans for developing additional launch infrastructure are ongoing and include creation of a development plan that includes support for additional suborbital and future orbital RLV operations.

Suborbital sounding rocket launches to altitudes of up to 55 kilometers (34 miles) have been conducted at the site. Additionally, Rockets for Schools, a student program founded in Wisconsin by Space Explorers, Inc., and developed by the Aerospace States Association, has conducted suborbital launches at Spaceport Sheboygan since its inception in 1995. Each year, hundreds of students from Wisconsin, Illinois, Iowa, and Michigan participate in these launches, which took place most recently in May 2008. Currently, Rockets for Schools is a volunteer run program of the Great Lakes Spaceport Education Foundation.

Over 1,500 schoolchildren toured the Great Lakes Aerospace Science and Education Center

Rocket launch from Spaceport Sheboygan

and 1,000 members of the general public took part in educational sessions, including a teacher education session. Approximately 50 rockets were launched as part of the Rockets for Schools annual event including high power specialty rockets reaching up to 3,048 meters (10,000 feet) altitude. The Wisconsin Aerospace Authority met in late 2008 to discuss updates on the Great Lakes Aerospace Science and Education Center and to identify aerospace industries established throughout Wisconsin.[71]

Spaceport Washington

Spaceport Washington, a public and private partnership, has identified Grant County International Airport in central Washington, 280 kilometers (174 miles) east of Seattle, as the site of a future spaceport. The airport (formerly Larson Air Force Base and now owned and operated by the Port of Moses Lake) is used primarily as a testing and training facility. Spaceport Washington proposes to use Grant County International Airport for horizontal and vertical take-offs and horizontal landings of all classes of RLVs. The spaceport does not have an official development plan yet, but the intended configuration of the spaceport launch site will either be vertical launch and horizontal recovery or horizontal launch and recovery.[72]

Spaceport Washington	
Location	Grant County International Airport, Washington
Owner/Operator	Port of Moses Lake
License Status	Have not applied
Description	Spaceport Washington, a public and private partnership, proposes to use Grant County International Airport for horizontal and vertical take-offs and horizontal landings of all classes of RLVs.
Infrastructure	A 4,100-meter (13,452-foot) main runway and 3,200 meter (10,500-foot) crosswind runway. A 12,100-hectare (30,000-acre) potential vertical launch site has been identified. An Aerospace Overlay Zone has been established in the Grant County Unified Development Code. The site is certified as an emergency-landing site for the Space Shuttle. Additional infrastructure development could occur depending on customer response.

Spaceport Washington aerial view

West Texas Spaceport	
Location	Pecos County, Texas
Owner/Operator	Pecos County/West Texas Spaceport Development Corporation
License Status	Have not applied
Description	The Pecos County/West Texas Spaceport Development Corporation is developing a spaceport at a sparsely populated location with underused national airspace. Currently the West Texas Spaceport is mainly an R&D site for UAVs and suborbital rockets.
Infrastructure	The Greasewood site in Pecos County has an air conditioned control center, an industrial strength concrete pad, and a 30x30 meter (300x300 feet) scraped and level staging area, broadband internet on site, controlled fenced access, a 1,300-square-kilometer (500-square-mile) recovery area, and access to optical tracking and high-speed video capability. The Pecos County Airport has five runways with hangar space. Future infrastructure plans include developing a privately-funded 1,100-meter (3,500-foot) runway, a static engine test facility, and a hangar for balloon and wind sensitive activities.

West Texas Spaceport

The Pecos County/West Texas Spaceport Development Corporation, established in mid-2001, is moving forward with developing a spaceport 29 kilometers (18 miles) southwest of Fort Stockton, Texas. A joint project with the school district has made a state-of-the-art technology center available for Pecos County Aerospace Development Center users. The Technology Center has multiple monitors, high-speed Internet service, and full multiplexing capability. For the past two years, Pecos County/West Texas Spaceport Development Corporation has been involved in educational activities, under the framework of Texas Partnership for Aerospace Education, to promote and support academic programs in aero-science and rocketry.

COMMERCIAL HUMAN SPACEFLIGHT TRAINING

Introduction

An emerging group of organizations within the United States provide training in a variety of areas related to commercial human spaceflight. Some examples of training offered include flights in high performance aircraft or simulation devices that replicate the stresses of space launch and re-entry or zero-g (gravity) parabola flights that simulate microgravity. In February 2008, AST released a report titled *Commercial Human Spaceflight Crew Training Survey* that identified an initial list of organizations that currently offer or could offer human spaceflight training services. That study supplies the foundation content for this chapter; however, this section also focuses on the capabilities and milestones completed in 2008 of only the organizations that are developing or offering services tailored for commercial human spaceflight training.

A number of training services focus on rigorous training programs for launch vehicle flight crews. Other types of training may be designed to help prepare and screen spaceflight participants. Finally, training may be offered as entertainment for those seeking to experience simulated spaceflight or the astronaut training experience. This chapter includes organizations that may focus on one or more types of training.

Aurora Aerospace

L-39 aircraft

Aurora Aerospace is led by Howard Chipman, M.D., a board-certified emergency physician and certified flight instructor rated in L-39 jets and gliders. He has attended cosmonaut training in Russia and is familiar with the training required to enable people to fly into space. Aurora Aerospace offers a two- to three-day course on spaceflight training and medical screening for spaceflight.[1] This course is appropriate for those interested in space travel or who have an interest in experiencing some of the training and educational aspects involved in spaceflight. Participants have the opportunity to fly an L-39 high performance military jet and experience zero gravity in a specially configured aircraft. Ground-based training includes centrifuge training for high-g environments and spatial disorientation training in a multi-axis disorientation machine ("MAD Machine").
In addition, Aurora Aerospace has a spacecraft simulator where students can learn orbital and suborbital flight procedures. High altitude/hypoxia training is offered as a stand-alone training for pilots. Medical screening, treatment, and

Location	Tampa Bay, Florida
Company Description	Aurora Aerospace is an organization based at the St. Petersburg-Clearwater Airport offering commercial spaceflight training and medical screening for spaceflight.
Overview of Services	High performance jet; zero-G (gravity) flights; centrifuge training, high altitude/ hypoxia training; spatial disorientation training; space simulator training; unusual attitude training, high-G (gravity); and high performance glider training.

certification is provided to ensure space flight participants can fly into space safely and comfortably. Aurora Aerospace facilities and equipment include an L-39 Albatross jet, Rockwell 700 Zero Gravity aircraft, centrifuge, "MAD Machine," and a spacecraft simulator with hypoxia/high altitude equipment.

Barrios Technology

Location	Houston, Texas
Company Description	Barrios Technology is an aerospace engineering and technology services firm.
Overview of Services	Requirements definition, curriculum development, training products and training services for: spaceflight crewmembers, mission/flight controllers, ground systems personnel, space vehicle flight simulation and special facilities, and simulation planning and execution. Barrios' instruction products and services follow formal instructional systems design with the five elements of analyze, design, develop, implement, and evaluate. Using an iterative process with evaluations performed throughout the life cycle, training objectives are effectively met.

Founded in 1980, Barrios is headquartered in Houston, Texas, near NASA's Johnson Space Center, where it works with NASA's human spaceflight programs. Also, Barrios has an office in Colorado Springs, Colorado, that focuses on space systems support for the Department of Defense. Currently Barrios primarily uses NASA facilities for training purposes. Future business opportunities may enable Barrios to develop their own facilities or work out agreements with other organizations to acquire access to spaceflight training equipment and facilities.[2]

Civilian Aero and Space Training Academy

The company began operating out of Washington State on October 4, 2006 and has plans for Highly Reusable Launch Vehicle operations at the proposed Washington Spaceport. In 2008 CASTA entered into a joint venture to use an existing centrifuge with multi-RLV platform simulation and spatial disorientation training software. CASTA plans to offer a six-day training program, with home study, that will include contracted zero-gravity flights and supersonic and training jets that provide high-G/high altitude flights, helicopters, gliders, and other light aircraft to follow traditional American and Russian training. Each six-day program will have one or more lectures and classes conducted by former astronauts or cosmonauts with experience in Apollo, Soyuz, Shuttle, and ISS flights and training. Medical screening is conducted with a FAA Flight Surgeon before graduation, and qualification certificates are issued.

Location	Paine Field, Moses Lake, Washington
Company Description	The civilian aero and space training academy (CASTA), under the direction of Joseph Sandlin, is developing the civilian aero and space training academy.
Overview of Services	Physiological training; psychological training, unusual attitude training; High-G (gravity); high altitude flight; high performance jet; flight simulation; space flight operations; neutral buoyancy training; survival training; water and mountain/wilderness; pressure suit training; and parachute training; FAA medical screening.

Executive Aerospace Physiology Training

Chamber operations

Executive Aerospace began offering physiological and high altitude training in 1994. Based at IEEM, Presbyterian Hospital of Dallas, the Executive Aerospace facilities include a classroom and large and advanced hypo/hyperbaric chamber facilities. The chamber can simulate altitudes of 30,048 meters (100,000 feet) above sea level and simulate depths to 50 meters (165 feet) below sea level at controlled rates of descent and ascent.

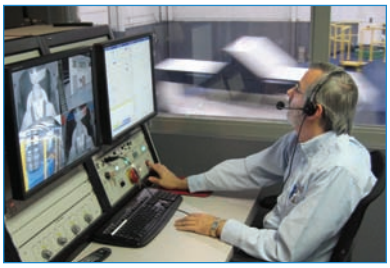
Benjamin D. Levine, M.D., F.A.C.C., Director of IEEM, Presbyterian Hospital of Dallas and Professor of Medicine and Cardiology at the University of Texas Southwestern Medical Center at Dallas, maintains overall responsibility for the Executive Aerospace Physiology Program. Dr. Levine has expertise in hypoxia physiology and also serves as the Team Leader of Cardiovascular Alterations Team for the National Space Biomedical Research Institute. He has served on national and international panels advising NASA as to the appropriate screening strategies to minimize the risk of cardiovascular disease in astronauts during prolonged space flight, as well as the optimal use of a National Lunar Laboratory.[3]

Under Dr. Levine's supervision, IEEM investigators have been actively involved in almost every dedicated life-sciences mission on the Space Shuttle, as well as the largest current medical experiment in the International Space Station.

Location	Dallas, Texas
Company Description	The Institute for Exercise and Environmental Medicine (IEEM) consists of six physicians and eight technical support staff. Physicians of the IEEM, in cooperation with Johnson Space Center, are actively involved with studying the cardiological effects of spaceflight on NASA astronauts. As an integral part of the IEEM, Executive Aerospace Physiology offers services that include high altitude aerospace physiology, high altitude human research, as well as high altitude equipment research and testing. Executive Aerospace's multiplace chambers are certified for both hypobaric and hyperbaric operations.
Overview of Services	Aerospace physiology; hyperbaric oxygenation; flight physicals; decompression sickness; medical evaluation flights; and aerospace medical consults.

Executive Aerospace Physiology under the supervision of Dr. Jeffrey A. Stone has supported the NASA Everest Med Ops project of evaluating the functionality of the G.E. Logiq. e. ultrasound machine and the Distance Doc video recorder in a hypobaric chamber at altitudes of 8,200 meters (27,000 feet) and 4º Celsius (40 º Fahrenheit). These conditions simulate broadcasting from Mt. Everest. The results are relayed to a server in New York and observed over satellite connection. Dr. Stone is assisted by his colleagues, Dr. Laurie Aten and Dr. John Touhey. Dr Aten served as a senior researcher for NASA Johnson Space Center. Dr. John Touhey served as Chief of the USAF Hyperbaric Medicine Program at the USAF School of Aerospace Medicine as well as a consultant to the United States Air Force Surgeon General. All physicians assigned to the Executive Aerospace Physiology Program are board certified in Aerospace Medicine. Dr. Stone is also certified as a Senior FAA Medical Examiner.

National Aerospace Training and Research Center



STS-400 and operator

The NASTAR Center's training curriculum and equipment configurations can accommodate a range of training and research requirements. Academic instruction is provided by experienced industry professionals using simulation technology for "hands on" training. Each research program is supported by the in-house Institutional Review Board and experienced human test subjects. NASTAR Center facilities include: classrooms, configurable centrifuge, spatial disorientation simulator, hypobaric chamber, and night vision training equipment.

The NASTAR Center is the official space training provider for Virgin Galactic. Virgin Galactic's space travelers are currently training for their suborbital space flights at the NASTAR Center.[4] In January, NASTAR announced the creation of its Air and Space Adventure Programs designed to provide realistic flight experiences for astronaut and fighter pilot enthusiasts.[5] In August 2008, NASTAR Center was awarded the Space Frontier Foundation's "Vision to Reality" award for its efforts developing successful space training programs.[6] In February, NASTAR hosted 50 Accredited Space Agents (ASAs) from 14 countries a two-day forum designed to update them on the Virgin Galactic project and to introduce them to the NASTAR Center Air and Space Adventure Programs that are designed to be a "try before you buy" for prospective space travelers onboard Virgin Galactic's suborbital space flights.[7]

Location	Southampton, Pennsylvania
Company Description	The NASTAR Center serves the training and research needs of the aerospace community, including military aviation (fixed and rotary wing), civil aviation (fixed and rotary wing), space travel (government and private) and medical research support and data collection.
Overview of Services	Effects of rapid and sustained G acceleration (multi-axis); combined environments testing (sustained G forces with vibration); suborbital space launch training; altitude exposure; rapid decompression; emergency egress; spatial disorientation; aircraft upset recovery training and research; tactical flight simulation; other physiological training; and night vision goggle training.

Orbital Commerce Project

Flight simulator

Led by George Tyson, OCP has three pilots on staff, one who is in the process of receiving a trainer's certificate, one who is a commercial pilot, and one who is a private pilot. OCP has not determined its final location for operations. It had preliminary discussions with Mojave Air and Space Port and is considering the use of a Federal range. Orbital Commerce Project plans to use a piston aircraft, a rocket-powered aircraft, a suborbital reusable launch vehicle, simulators, a $5-million centrifuge, and a hypobaric chamber for their comprehensive training

program. Training is predicted to start in late 2009 or 2010. The company has developed preliminary prototype simulators and has an airframe use agreement, but no other hardware and minimal funding. In 2008, Orbital Commerce Project developed an agreement with Masten Space Systems to license Masten engine technology.[8]

Location	Oviedo, Florida
Company Description	Orbital Commerce Project (OCP) was created in 2004 specifically as a training provider for commercial suborbital spaceflight.
Overview of Services	Physiological training; hypobaric altitude chamber; unusual attitude training; high G training; high altitude flight; pressure suit training; high performance glider; and high performance jet.

Project Odyssey – Space Florida and Andrews Institute

Andrews Institute

Space Florida and the Andrews Institute for Orthopaedics and Sports Medicine announced a partnership in December 2008 to offer medical diagnostic and training services to private spaceflight passengers and crewmembers.[9] This partnership is an integral component of Project Odyssey, a human spaceflight research and training program that leverages evidence-based medicine, world-class facilities, state-of-the-art technology, and resort-style environs to deliver high-quality results and a strong customer experience. The roadmap for implementing Project Odyssey was detailed in a study prepared by the Haas Center for Business Research and Economic Development at the University of West Florida.[10] The list of organizations that are now cooperating in support of Project Odyssey includes the Florida Governor's Office of Tourism, Trade, and Economic Development; the Andrews Institute; Space Florida; Enterprise Florida; the University of West Florida; the National Flight Academy; the U.S. Navy; and the Gulf Coast Center for Innovation and Entrepreneurship. Various other public and private entities have expressed interest in participating in Project Odyssey.

Project Odyssey aspires to be recognized as a leader in optimizing human performance in both orbital and suborbital spaceflight environments. Its mission is to capture a large share of the international market for educating and training passengers and crewmembers of commercial and civil space flight participants in the orbital and suborbital space flight markets. Project Odyssey training includes biomedical, physiological, and psychological conditioning, as well as exposure to certain environmental factors intrinsic to human spaceflight.

Location	Gulf Breeze, Florida
Company Description	In December 2008, the Andrews Institute and Space Florida announced a partnership to develop a personal spaceflight medical program.
Overview of Services	Biomedical, physiological, and psychological diagnostics and training.

Space Medicine Associates

Location	Belcamp, Maryland
Company Description	An organization of medical professionals offering space medicine and bioastronautics consultation, training and oversight services.
Overview of Services	Comprehensive medical and bioastronautics expertise, operations training and support, risk management and mitigation techniques, medical project management, and assistance for all aspects of commercial and industrial space activities, from space tourism to space-based solar power. Space Medicine Associates plans to use client-based facilities.[11]

Starfighters Aerospace

F-104 and Discovery

Training flights are conducted in supersonic capable aircraft, specifically two-seat TF-104G Starfighters and two-seat T-38C Talons, both highly upgraded and used by NASA for space flight training that totaled more than 80 years of service.[12] The Starfighters F-104 Demonstration Team has operated their high performance aircraft for 14 years performing at air shows and contract flights for the United States Navy and Air Force under the direction of President Rick Svetkoff. Starfighters has become the first commercial operations organization permitted to provide flights from Kennedy Space Center's Shuttle Landing Facility (SLF). The SLF is a perfect venue for training because there is no commercial or general aviation traffic to compete with and the airspace is restricted from the surface to unlimited altitudes, giving and an almost zero chance of injury to persons or property among the uninformed public. State-of-the-art digital classrooms and training facilities house and provide one of the most comprehensive training programs in the world for suborbital space flight crew and participants at the home of America's space program.

Location	NASA John F. Kennedy Space Center, Florida
Company Description	Starfighters Aerospace is moving into the commercial spaceflight arena by applying for a FAA AST Safety Approval for Suborbital Space Flight Training. Starfighters is also partnering with NASA to procure a Space Act Agreement between both organizations. Starfighters has become one of the first commercial operations organization permitted to provide flights from Kennedy Space Center's Shuttle Landing Facility.
Overview of Services	High performance supersonic flight; high altitude flight; high-G flight; unusual attitude/upset recovery training; aerospace medical evaluation; flight physiology training; hypobaric altitude chamber; aircrew life support and egress/ejection systems training; parachute training; pressure suit training.

United Space Alliance LLC and USA Space Operations LLC

Flight crew training

Headquartered in Houston, Texas, USA was established in 1996 as a limited liability company. USA is equally owned by The Boeing Company and Lockheed Martin Corporation and employs 10,000 people at facilities in Texas, Florida, Alabama, and the

Washington, D.C. area. USA is NASA's primary industry partner in human space operations associated with the Space Shuttle, International Space Station (ISS), and Exploration programs.

Astronaut training is divided into two categories: astronaut candidate/generic training and flight assigned training. The astronaut candidate/generic training focuses on generic operations and vehicle systems training and selected specialized non-flight specific training (land and water survival, generic extravehicular activity (EVA), etc.). The flight assigned training focuses on activities associated with the astronaut's flight assignment. The flight assigned training begins 12-24 months before the flight (depending on the complexity of the flight). The phased training begins with task training and advances to fully integrated spacecraft/mission control center simulations. All of this training typically ends three to four weeks before the flight.

Location	HQ in Houston, Texas
Company Description	The United Space Alliance (USA) is the prime NASA contractor for all astronaut, flight controller, and ground support personnel training, except medical training.
Overview of Services	Generic skills/proficiency; documentation (mission rules, etc.); simulator operations (task and vehicle); ground operations; mission operations; microgravity/EVA; pressure suit; land and water survival; parachute training; and flight crew equipment training.

The flight assigned training includes all crew training associated with the following mission phases/activities:

- Pre-launch
- Launch and abort
- Rendezvous, prox ops, docking
- Normal on-orbit activities
- Payload operations
- EVA and IVA
- Undocking and deorbit
- Entry
- Landing and post-landing

USA and its new wholly-owned subsidiary, USA Space Operations, LLC, have the following capabilities:

- Mission, manifest and trajectory planning and analyses
- On-orbit assembly, payload deployment, and servicing
- EVA planning and execution
- Rendezvous, proximity operations, and docking
- Space logistics/supply chain management and operations
- Space operations software engineering
- Ground system design engineering
- Advanced space flight technology
- Launch and recovery operations
- Launch vehicle, spacecraft, and cargo processing
- Mission control operations
- Space operations and systems training
- Sustaining engineering

- Flight crew equipment preparation and maintenance
- Large scale integration

USA has an extensive classroom facility used to train USA personnel and selected NASA personnel including astronauts. The other facilities and equipment currently used to train the astronauts and flight controllers are owned by the government. However, these facilities and equipment could be used to train commercial spaceflight crews and other personnel on a non-interference basis with required NASA training.[13]

USA has developed a software tool-set, Questus™, which is intended to improve productivity and lower overall life cycle costs. Questus™ is an integrated web-based tool-set that implements and facilitates key elements of end-to-end operations, including those associated with training. One tool, INSTRU™, is specifically aimed at training. It is an immersive, multidimensional tool designed to improve training efficiency and effectiveness. In addition, it will allow training to be "owned" by the individuals (including crew) responsible for executing the mission.

Wyle

Wyle's specific commercial spaceflight training courses are offered at their facilities at Brooks City-Base in San Antonio. Wyle is currently under contract to Virgin Galactic, providing Chief Medical Officer and medical operations and training services.[14] Wyle has also supported several of the Space Adventures clients who have flown to the International Space Station.

Centrifuge

Wyle is the prime contractor for NASA's Bioastronautics contract. In this capacity Wyle provides medical operations, ground and flight research, space flight hardware development and fabrication, science and mission integration for flight, and habitability and environmental factors in support of the Space Shuttle, International Space Station, Constellation, and Human Research programs.

Wyle is also part of NASA's Occupational Medicine and Occupational Health contract under which Wyle offers clinical and occupational health care for NASA personnel and the astronaut corps. In San Antonio, Wyle supports the Air Force Research Laboratory to conduct research and develop technologies to enhance the performance and safety of U.S. Air Force combat pilots.

Location	San Antonio, Texas
Company Description	Wyle's life sciences group in Houston, Texas, has 35 years experience in life science research, space medical operations, and engineering for the enhancement of human performance and safety in air and space.
Overview of Services	Human centrifuge training and medical screening; altitude chamber training and medical screening; oxygen systems safety services; decompression sickness assessments.

Wyle is the current provider of all U.S. medical operations and crew health care systems training for NASA's astronauts and flight controllers under the Bioastronautics contract.

Under this contract, Wyle also provides physical training and rehabilitation to prepare the astronauts for the rigors of spaceflight. Acceleration training for all first-time Shuttle crewmembers is performed on the centrifuge operated by Wyle in San Antonio. Wyle also provides training in microgravity operations for medical and life science activities using NASA's C-9 microgravity simulation flights. Wyle facilities include an altitude, thermal, and humidity chamber; 20-man hypobaric altitude chamber; man-rated centrifuge; oxygen systems safety of flight evaluation equipment; instruction and mission simulation facilities; and integrated medical simulation facility.

Zero Gravity Corporation

ZERO-G flies a modified Boeing 727 and has a Space Act Agreement with NASA to operate from any NASA center as well as use of NASA Kennedy Space Center Shuttle Landing Facility and Visitors Center complex.[15]

Location	Las Vegas, Nevada
Company Description	Founded in 1993, Zero Gravity Corporation (ZERO-G) is a privately-held space entertainment and tourism company. ZERO-G has since flown more than 5,000 passengers aboard 200 flights.
Overview of Services	ZERO-G does not currently train commercial human spaceflight crews but has trained human space flight candidates and recently was awarded a contract by NASA to continue that service.[15] ZERO-G has astronauts and former NASA KC-135 employees on staff.

REGULATORY DEVELOPMENTS

In 2008, the FAA published the final rule, Requirements for Amateur Rocket Activities. This rule amends amateur rocket regulations to preserve the level of safety associated with amateur rocketry. At the same time, the new regulations align FAA rules with advances in the amateur rocket industry. This section reviews the new regulation.

Amateur Rockets

In the Notice of Proposed Rulemaking (NPRM) that the FAA published in the Federal Register on June 14, 2007, the FAA redefined amateur rockets to specify an unmanned rocket that:

1. is propelled by a motor or motors having a combined total impulse of 889,600 Newton-seconds (200,000 pound-seconds or less); and

2. cannot reach an altitude greater than 150 kilometers (93.2 statute miles) above the earth's surface.

The NPRM also proposed a number of other changes in the regulations for unmanned rockets aimed at preserving the safety of amateur rocket activities, addressing inconsistencies in the current regulations, and improving the clarity of the regulations. The public was invited to comment on the proposed changes.

During 2008, the FAA reviewed the comments it received, prepared responses to those comments and published the final rule on December 4, 2008. In general, commenters supported the proposed requirements, but they did suggest several changes. The major issues and how the FAA responded are summarized below.

Classification of Amateur Rockets

First of all, commenters looked at the new classes proposed for amateur rockets. The FAA defined Class 1 as an amateur rocket using less than 125 grams (4.4 ounces) of slow-burning propellant and weighing no more than 454 grams (16 ounces) including the propellant. The FAA defined Class 2 as an amateur rocket using less than 125 grams (4.4 ounces) of slow-burning propellant and weighing no more than 1,500 grams (53 ounces) including propellant. The rocketry associations and individual commenters noted that the only difference between Class 1 and Class 2 was weight. The National Association of Rocketry (NAR) wrote that it had conducted computer flight simulations of these two classes of amateur rockets to demonstrate the "heavier models have far less velocity and altitude potential." All commenters on this section recommended combining Class 1 and Class 2 into a single classification.

The FAA analyzed the performance of proposed large model rockets, in light of NAR's suggestion, and found neither model rockets nor large model rockets can affect air traffic if operated in accordance with the regulation. Since local

ordinances generally cover hazards due to the reckless use of model and large model rockets on ground-based property and persons, the FAA agreed to combine the two proposed classes.

Upper Limit for High-Power Rockets

The FAA proposed a new Class 3-High-Power Rocket as an amateur rocket other than a model rocket or large model rocket propelled by a motor or motors having a combined total impulse of 163,840 Newton-seconds (36,818 pound-seconds) or less.

Several commenters recommended the upper limit for Class 3 be reduced from 163,840 Newton-seconds to 40,960 Newton-seconds. They stated this reduction would place the upper limit at the "O" class, as documented in the Tripoli Rocketry Association (TRA) safety code. Some commenters noted that a rocket carrying a motor above the "O" class, or 40,960 Newton-seconds, could reach altitudes greater than 7,620 meters (25,000 feet). These commenters suggested any rocket with the ability to reach greater altitudes belongs in Class 4-Advanced High-Power Rockets.

The FAA agreed. Lowering the dividing line between High-Power and Advanced High-Power Rockets better aligns the final rule with the TRA safety code and the 2008 National Fire Protection Association (NFPA) 1127 Code for High-Power Rockets. This code also addresses rockets having total impulse up to 40,960 Newton-seconds (9,208 pound-seconds) or "O" motor class. Most amateur rocket activities involve rockets with a total impulse of 40,960 Newton-seconds or less. The High Power Rocket class is now defined as having a combined total impulse of 40,960 Newton-seconds (9,208 pound-seconds) or less.

Separation Distances from Amateur Rocket Activities

The FAA proposed that no person may operate a High-Power Rocket or Advanced High-Power Rocket within 457 meters (1,500 ft.) of any person or property not associated with the operation. This is the same separation distance specified in the former regulation.

Several commenters questioned the requirement regarding proposed separation distances. One commenter requested clarification regarding whether uninvolved public includes spectators. The commenters noted the 2008 Edition of NFPA 1127, Code for High Power Rocketry, specifies differing minimum separation distances for spectators and participants that relate to the classifications of rocket motors. Commenters recommended the FAA adopt the NFPA standards that establish minimum separation distances between the launch point, spectators, and other exposed elements of the public. Commenters also noted that both NAR and TRA follow the safety requirements of the rocketry-related codes published by NFPA.

In developing the proposal, the FAA considered amateur rocketry events and participants involved, their families and friends, and a few casual spectators. Various rocketry groups do not include spectators in the 1,500 feet separation distance

for persons or property not associated with the operations. In fact, the 2008 Edition of NFPA 1127 recognizes this disparity by providing separation distances for spectators and participants that are less stringent than the existing FAA requirement.

Most commonly launched amateur rockets are small and their hazards typically are also small. No serious accidents or incidents have been reported by NAR and TRA. While there have been no reported accidents associated with launches of larger amateur rockets, the risk associated with a large amateur rocket launch could be considerably greater. Participants and spectators clearly associated with the activity are not required to comply with the specified separation. Although the FAA did not intend to limit participation at rocketry events, neither did it intend to encourage unusually large crowds. The FAA routinely attaches conditions to certificates of waiver or authorization for larger amateur rocket launches specifying separation distances greater than 1,500 feet applicable to spectators and persons not associated with the operation.

The FAA agrees, in principle, with the commenters' suggestion to adopt the NFPA standard. Generally, those engaged in amateur rocket activities have applied the 457 meters (1,500 ft.) distance requirement to the uninvolved public. As stated in the NPRM, the FAA seeks primarily to codify existing practice. Current amateur rocket activities, especially those under the auspices of various rocketry associations, have not resulted in harm to persons not associated with the operations. The FAA believes the 1,500 feet separation distance has served a useful purpose, and retained this separation minimum in the final rule for High-Power Rockets and Advanced High-Power Rockets.

In consideration of the comments recommending the FAA adopt the NFPA 1127 separation distance requirements in addition to the proposed 1,500 foot minimum separation distance, we will specify a separation distance from any person or property not associated with the operation. This decision is based on the minimum site dimensions provided in NFPA 1127. This separation distance is equal to one quarter of the expected maximum altitude. Under normal conditions, this requirement will be adequate to protect public safety. When greater separation distances are required to protect spectators, the FAA will specify additional operating limitations in any certificate of waiver or authorization it may grant.

Notice Requirements

The FAA proposed that FAA Air Traffic Control (ATC) must receive notice requirement information no less than 24 hours before and no more than 3 days before the amateur rocket activities take place.

Commenters expressed concern that this proposed rule means a temporary flight restriction (TFR) must be in place before an amateur rocket launch can occur and recommended adding clear guidance to prohibit the use of TFRs for amateur rocket activities. Commenters also urged that there be no change in the current Notice to Airmen (NOTAM) procedures.

The FAA stressed that the only change proposed was to the timeline for giving information to ATC. Operators must still notify ATC no less than 24 hours before amateur rocket activities begin. We proposed to change the second half of the timeline from 'no more than 48 hours' to 'no more than 3 days' before amateur rocket activities begin. This change synchronizes FAA regulations with the Notice to Airmen procedures. The FAA did not propose changes to requirements for NOTAMs or TFRs.

Information Required 45 Days Before Rocket Activities, and Estimated Number of Rockets

Rocketry associations and individual commenters questioned the need to apply for a certificate of waiver or authorization at least 45 days advance notice. Due to uncertainties in schedules and weather, among other things, participants in rocket launch events involving High-Power Rockets may not know if the event is really going to occur, if they are going to attend, and what rockets they are going to fly until shortly before the event, the day of the event, or even during the event. Last-minute changes occur for bona-fide reasons involving matters such as wind direction and speed and cloud cover that cannot be predicted with any assurance.

Following current practice rocketry associations complete one annual certificate of waiver or authorization for all their planned amateur rocket events for a calendar year. That certificate describes the types of amateur rockets typically launched at these events. The NAR recommended adoption of requirements that reflect current practice.

The FAA intended to retain the current practice and modified the language in the final rule to do so. The FAA will require each person or organization to provide the information requested at least 45 days before the proposed operation when requesting a certificate of waiver or authorization. An organization can still submit an application for an annual certificate of waiver or authorization, detailing the events for the coming year.

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LIST OF ACRONYMS

AADC	Alaska Aerospace Development Corporation
ACES	Air Collection and Enrichment System
AFB	Air Force Base
AGL	Above Ground Level
AFRL	Air Force Research Laboratory
ALV	ATK Launch Vehicle
ARCTUS	Advanced Research and Conventional Technology Utilization Spacecraft
AST	Office of Commercial Space Transportation (within the FAA)
ATK	Alliant Techsystems
ATV	Automated Transfer Vehicle
AWOS	Automated Weather Observing System
BLS	Boeing Launch Service
BRAC	Base Realignment and Closure
BSC	Benson Space Company
CALVEIN	California Launch Vehicle Initiative
CCAFS	Cape Canaveral Air Force Station
CEV	Crew Exploration Vehicle
CONUS	Continental United States
COTS	Commercial Orbital Transportation Services
CSIA	Clinton-Sherman Industrial Airpark
CSULB	California State University, Long Beach
CSLAA	Commercial Space Launch Amendments Act
DARPA	Defense Advanced Research Projects Agency
DoD	U.S. Department of Defense
EAFB	Edwards Air Force Base
EELV	Evolved Expendable Launch Vehicle
ELTR	Eastern Launch and Test Range
ELV	Expendable Launch Vehicle
ESA	European Space Agency
FAA	Federal Aviation Administration
FALCON	Force Application and Launch from CONUS
FAST	Fully-Reusable Access to Space Technology
FASTT	Freeflight Atmospheric Scramjet Test Technique
GEM	Graphite-Epoxy Motor
GEO	Geosynchronous Earth Orbit
GPS/INS	Global Positioning System/Inertial Navigation System
GSC	Garvey Spacecraft Corporation
GSLV	Geosynchronous Satellite Launch Vehicle
GTO	Geosynchronous Transfer Orbit

HTHL	Horizontal Takeoff, Horizontal Landing
HTP	High-Test Peroxide
HTPB	Hydroxyl Terminated Polybutadiene
HTR	Hybrid Test Rocket
HTS	Horizontal Test Stand
HX	Hydrocarbon X
HYSR	Hybrid Sounding Rocket
ICBM	Intercontinental Ballistic Missile
IPD	Integrated Powerhead Demonstration
IPF	Integrated Processing Facility
ISS	International Space Station
ISRO	Indian Space Research Organization
ITAR	International Traffic in Arms Regulations
JAA	Jacksonville Aviation Authority
LAS	Launch Abort System
KLC	Kodiak Launch Complex
KSC	Kennedy Space Center
LAP	Launch Assist Platform
LAS	Launch Abort System
LASR	Large Array of Small Rockets
LC	Launch Complex
LEO	Low Earth Orbit
LOX	Liquid Oxygen
MARS	Mid-Atlantic Regional Spaceport
MDA	Missile Defense Agency
MEMS	Microelectromechanical Systems
MEO	Medium Earth Orbit
MRTFB	Major Range and Test Facility Base
MSFC	Marshall Space Flight Center
MTA	Mojave Test Area
NASA	National Aeronautics and Space Administration
NG-LLC	Northrop Grumman Lunar Lander Challenge
NLV	Nanosat Launch Vehicle
NPRM	Notice of Proposed Rulemaking
NRO	National Reconnaissance Office
O/M	Oxygen-Methane
ONR	Office of Naval Research
ORS	Operationally Responsive Spacelift
OSIDA	Oklahoma Space Industry Development Authority
OSP	Orbital/Suborbital Program
OTV	Orbital Test Vehicle

OV	Orbital Vehicle
PDR	Preliminary Design Review
PSLV	Polar Satellite Launch Vehicle
PWR	Pratt & Whitney Rocketdyne
R&D	Research and Development
RCS	Reaction Control System
RFP	Request for Proposals
RLV	Reusable Launch Vehicle
RP-1	Rocket Propellant 1
RSRM	Reusable Solid Rocket Motor
RSTS	Range Safety and Telemetry System
RTS	Reagan Test Site
SBIR	Small Business Innovation Research
SLC	Space Launch Complex
SLF	Shuttle Landing Facility
SLV	Small Launch Vehicle
SSI	Spaceport Systems International
SS/L	Space Systems / Loral
SSME	Space Shuttle Main Engine
SSO	Sun-synchronous Orbit
STEREO	Solar Terrestrial Relations Observatories
STS	Space Transportation System
t/LAD	Trapeze-Lanyard Air Drop
TBD	To Be Determined
TCP/IP	Transmission Control Protocol/Internet Protocol
UAV	Unmanned Aerial Vehicle
ULA	United Launch Alliance
USAF	United States Air Force
VAB	Vehicle Assembly Building
VAFB	Vandenberg Air Force Base
VaPaK	Vapor Pressurization
VTS	Vertical Test Stand
VCSFA	Virginia Commercial Space Flight Authority
WAA	Wisconsin Aerospace Authority
WIRED	Workforce Innovation in Regional Economic Development
WFF	Wallops Flight Facility
WSMR	White Sands Missile Range
XA	eXtreme Altitude