Federal Aviation Administration

2010 U.S. Commercial Space Transportation Developments and Concepts: Vehicles, Technologies, and Spaceports

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Table of Contents

Introduction 1
SPACE COMPETITIONS 1
EXPENDABLE LAUNCH VEHICLE INDUSTRY 2
REUSABLE LAUNCH VEHICLE INDUSTRY 2
REENTRY VEHICLES AND IN-SPACE TECHNOLOGY 3
ENABLING TECHNOLOGIES 3
COMMERCIAL HUMAN SPACEFLIGHT TRAINING 4
SPACEPORTS 4
REGULATORY AND LEGISLATIVE DEVELOPMENTS 4

Significant 2009 Events 5

Space Competitions 9
GOOGLE LUNAR X PRIZE 9
AMERICA'S SPACE PRIZE 10
CENTENNIAL CHALLENGES 10

Expendable Launch Vehicles 13
CURRENT EXPENDABLE LAUNCH VEHICLE SYSTEMS 13
Atlas V – United Launch Alliance 13
Delta II – United Launch Alliance 15
Delta IV – United Launch Alliance 15
Falcon 1 – Space Exploration Technologies Corporation 16
Minotaur I – Orbital Sciences Corporation 16
Pegasus XL – Orbital Sciences Corporation 17
Taurus – Orbital Sciences Corporation 17
Zenit-3SL and -3SLB – Sea Launch Company, LLC 18
ELV DEVELOPMENT EFFORTS 19
Athena III – PlanetSpace 19
Eagle S-series – E'Prime Aerospace Corporation 19
Falcon 9 – Space Exploration Technologies Corporation 20
Nanosat Launch Vehicle – Garvey Spacecraft Corporation 22
NEPTUNE – Interorbital Systems 22
Minotaur IV and V – Orbital Sciences Corporation 24
QuickReach – AirLaunch LLC 25
Shadow III – Lunar Rocket and Rover Company 26
Taurus II – Orbital Sciences Corporation 26
NASA EXPLORATION LAUNCH VEHICLES 27
Ares I 27
Ares V 28
Sounding Rockets 29
Black Brant – Bristol Aerospace Limited 29
Orion and Oriole – DTI Associates 30

SpaceLoft XL – UP Aerospace, Inc. 31
Shadow I and II – Lunar Rocket and Rover Company 31
Terrier-Orion – DTI Associates 32

Reusable Launch Vehicles 33
COMMERCIAL RLV DEVELOPMENT EFFORTS. 33
QUAD & MOD-1 – Armadillo Aerospace 33
New Shepard – Blue Origin 34
XA-1.0 – Masten Space Systems. 35
Silver Dart – PlanetSpace 36
Rocketplane XP – Rocketplane Global. 36
SpaceShipTwo – The SpaceShip Company 37
Dream Chaser – Sierra Nevada Corporation 38
Laramie Rose – SpeedUp 39
MICHELLE-B – TGV Rockets, Inc.. 39
Burning Splinter – Unreasonable Rocket 40
Lynx – XCOR Aerospace 40
GOVERNMENT RLV DEVELOPMENT EFFORTS 41
Space Shuttle 41

Reentry Vehicles and In-Space Technologies 43
INTERNATIONAL SPACE STATION CREW AND CARGO TRANSPORT 45
SpaceX Dragon 46
Orbital Sciences Taurus II/Cygnus 47
Other Commercial Crew and Cargo Transport Concepts 48
X-37B ORBITAL TEST VEHICLE. 48
COMMERCIAL ORBITAL HABITAT DEVELOPMENT 49

Enabling Technologies 51
FUTURE RESPONSIVE ACCESS TO SPACE TECHNOLOGY PROGRAM. 51
IMPROVED HEAT SHIELD MATERIAL – SPACEX 52
COMPOSITE TANKS – MICROCOSM, INC.. 52
HIGH PERFORMANCE PRESSURIZATION SYSTEM (HPPS) – MICROCOSM, INC.. 53
VASIMR® ENGINE – AD ASTRA ROCKET COMPANY 53
ROCKET UPPER STAGE – SPEEDUP 54
SOLID ROCKET MOTORS – ALLIANT TECHSYSTEMS, INC.. 54
NOFB MONOPROPELLANT AND ROCKET ENGINES – FIRESTAR TECHNOLOGIES, LLC. 54
LIQUID ROCKET ENGINES AND ASSOCIATED TECHNOLOGIES – GARVEY SPACECRAFT CORPORATION 55
LIQUID ROCKET ENGINES – PRATT & WHITNEY ROCKETDYNE, INC. 56
LIQUID ROCKET ENGINES – SPACE EXPLORATION TECHNOLOGIES CORPORATION 56
LIQUID ROCKET ENGINES – MICROCOSM, INC.. 57
LAUNCH ABORT SYSTEM – ORBITAL SCIENCES CORPORATION 57

SCRAMJET PROPULSION – PRATT & WHITNEY ROCKETDYNE, INC. 58
STAGE RECOVERY SYSTEM – ALLIANT TECHSYSTEMS, INC. & UNITED SPACE ALLIANCE, LLC. 58
SPACECRAFT NAVIGATION LIDAR – SPACEX 59

Spaceports 61
NON-FEDERAL SPACEPORTS 62
Blue Origin Launch Site 62
California Spaceport 63
Cecil Field 63
Mid-Atlantic Regional Spaceport. 65
Mojave Air and Space Port 66
Oklahoma Spaceport. 67
Spaceport America 68
FEDERAL SPACEPORTS 69
Cape Canaveral Air Force Station 69
Edwards Air Force Base. 70
Kennedy Space Center 70
Reagan Test Site 72
Vandenberg Air Force Base 73
Wallops Flight Facility 74
White Sands Missile Range 74
PROPOSED SPACEPORTS 75
Space Florida Spaceport 75
Spaceport Hawaii. 77
Space Port Indiana 78
Spaceport Sheboygan. 78
INACTIVE SPACEPORTS 79

Commercial Human Spaceflight Training 81
INTRODUCTION 81
AURORA AEROSPACE. 81
BARRIOS TECHNOLOGY. 82
CIVILIAN AERO AND SPACE TRAINING ACADEMY 82
EXECUTIVE AEROSPACE PHYSIOLOGY TRAINING 83
FAA CIVIL AEROSPACE MEDICAL INSTITUTE (CAMI) 84
NATIONAL AEROSPACE TRAINING AND RESEARCH (NASTAR™) CENTER . . 86
ORBITAL COMMERCE PROJECT 87
PROJECT ODYSSEY – SPACE FLORIDA AND ANDREWS INSTITUTE 87
SPACE MEDICINE ASSOCIATES 88
STARFIGHTERS AEROSPACE. 88
UNITED SPACE ALLIANCE LLC AND USA SPACE OPERATIONS LLC 89
WYLE 91
ZERO GRAVITY CORPORATION 91

Regulatory and Legislative Developments 93
CENTER OF EXCELLENCE FOR COMMERCIAL SPACE TRANSPORTATION. . . 93
Background 93
Research Areas 93
COMMERCIAL SPACE GRANT PROGRAM. 94
Background 94
A Grant Program. 95

Endnotes. 97

Photo Credits. 113

List of Acronyms 117

INTRODUCTION

Against a backdrop of economic challenge, the year 2009 marked continued progress in the commercial space transportation industry. United States vehicles performed more launches in 2009 than in any year since 2000. Established providers of commercial launch services delivered satellites to orbit, while entrepreneurial ventures continued to develop new expendable and reusable launch vehicles. Firms based around personal spaceflight and other emerging markets continued to sign up customers, with some on track to begin commercial operation within the next two years. Meanwhile, companies pursued innovative technologies to enable new vehicles and enterprises, while spaceports planned infrastructure improvements to support the industry.

In commercial space, as in other fields, technological progress often represents the culmination of steady and deliberate experimentation, refinement, and enhancement. The incremental nature of such advances, however, belies the revolutionary improvements they offer commercial space transportation: increased reliability and safety, lower costs, and new capabilities. Existing and new launch vehicles, the key technologies needed for those vehicles to operate successfully, and the spaceports those vehicles can operate from, are essential to the future of the U.S. commercial space transportation industry. This combination of factors can enable the industry to effectively serve existing customers while fostering new markets, such as personal spaceflight and commercial resupply of the International Space Station (ISS).

This report reviews developments and concepts that defined U.S. commercial space transportation in 2009. It showcases current and planned U.S. commercial space activities. It also examines 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, and new developments in commercial human spaceflight training.

Whether new developments are highly publicized events 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

In 2009, companies continued to pursue prizes in the three currently active space competitions: Google Lunar X PRIZE, America's Space Prize, and NASA's Centennial Challenges. The Google Lunar X PRIZE, an international competition

active since 2007, challenges teams to land on and explore the surface of the Moon, and offers a variety of missions that result in a total prize purse of $30 million. As of November 2009, 21 teams were registered for the Google Lunar X PRIZE. NASA awarded substantial prize money in 2009 with the Power Beam, Astronaut Glove, and Regolith Excavation challenges. The most significant space competition in 2009, however, was the Northrop Grumman Lunar Lander Challenge (NGLLC), whose total prize purse of $2 million was claimed with various teams completing Level 1 and Level 2. Masten Space Systems won $1 million for winning Level 2 and $150,000 for second place in Level 1, while Armadillo Aerospace was awarded $500,000 for second place in Level 2.

Expendable Launch Vehicle Industry

Although several established ELV companies experienced setbacks in 2009, the year also witnessed 18 successful ELV launches. Sea Launch entered bankruptcy in 2009, but was able to continue launch operations and is restructuring internally through new financing from a private venture, Space Launch Services. While the Orbital Sciences Corporation Taurus vehicle experienced a failure in which the NASA Orbiting Carbon Observatory (OCO) was lost, the company conducted other successful launches in 2009, and proceeded with development of its new Minotaur IV and Taurus II vehicles. Space Exploration Technologies Corporation (SpaceX) continued development of its Falcon 9 heavy-lift vehicle, as well as its Falcon 1e enhanced small launcher; the first launch of both vehicles is expected in 2010. Meanwhile, as the White House reviewed the long-term launch options presented by the U.S. Human Spaceflight Plans Committee (the "Augustine Commission"), NASA successfully completed a suborbital Ares-1X test flight. This test flight demonstrated technology and operations concepts and collected data to inform the continued development of the Ares 1 vehicle, the first of two new ELVs to be developed under the Constellation program.

Reusable Launch Vehicle Industry

Development of RLVs in 2009 remained focused largely on addressing the emerging personal spaceflight market. On December 7, Virgin Galactic and Scaled Composites unveiled the first SpaceShipTwo vehicle, christened the *VirginSpaceShip (VSS) Enterprise*. Once a vehicle testing program is completed, commercial suborbital space tourism flights are expected to begin—potentially by 2011. Meanwhile, Masten Space System's Xoie and Xombie vehicles, as well as Armadillo's MOD vehicle, completed successful qualification flights for first and second place finishes in the 2009 NGLLC competition. As these vehicle development activities progressed, the best known RLV—the Space Shuttle—completed five flights in 2009, with five more expected before the Shuttle's scheduled retirement at the end of 2010.

Reentry Vehicles and In-Space Technology

The planned retirement of the Shuttle has prompted the need for new government and commercial vehicles designed to carry cargo and crews to the ISS and other low Earth orbit (LEO) destinations. In 2009, NASA and its industry partners continued developing the Orion Crew Exploration Vehicle (CEV), successfully demonstrating the capsule's parachute deployment as well as a system that maintains stable engine thrust for precise maneuvering and landing. SpaceX, supported by a Space Act Agreement under NASA's Commercial Orbital Transportation Services (COTS) program, worked on its Dragon capsule, testing its heat shield and a laser-based guidance system designed to assist in ISS maneuvering. SpaceX plans to conduct a series of three COTS demo flights of the Falcon 9 and Dragon system in 2010. Meanwhile, Orbital Sciences Corporation, also supported by COTS, continued development of its Taurus II launch vehicle and Cygnus advanced maneuvering spacecraft. The first Taurus II demonstration flight is planned in 2011.

Beyond the ISS, Bigelow Aerospace continued developing a scaled-up version of the Genesis inflatable habitat modules the company launched in 2006 and 2007. Sundancer, slated for launch in 2010 or 2011, will be capable of supporting crews, and will serve as the basis for a larger orbital habitat with added modules in the future. In May 2009, Bigelow successfully obtained government approval to conduct passenger-related activities without having to file Technical Assistance Agreements, Technology Transfer Control Plans, or certain other export control-related paperwork—paving the way for faster development of the company's marketing plans.

Enabling Technologies

Successful RLV and ELV development efforts depend on new technologies that offer improved operability, reliability, and performance while lowering costs. The year 2009 saw several advances in these key enabling technologies, most notably enhanced propulsion, navigation, and reentry components. Liquid fuel engines such as Garvey Aerospace's new P-13 system continued development, while ATK's enhanced five-segment solid rocket booster successfully conducted its first full-scale test. Ad Astra's VASAMIR plasma engine continued development, successfully conducting its first full-power test in September. In preparation for future international Space Station resupply missions, SpaceX successfully tested its DragonEye laser range-finding equipment in July. SpaceX also demonstrated its Phenolic Impregnated Carbon Ablator (PICA) heat shield material, which will be used aboard its Dragon capsule as well as a proposed re-usable second stage of SpaceX's Dragon 9 rocket. Other companies continued work on a diverse portfolio of technologies from composite propellant tanks to stage recovery systems

Commercial Human Spaceflight Training

As a new generation of suborbital RLVs and spacecraft become operational, they will require specialized training for pilots and in some cases passengers. 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 two years since that initial report's publication, a number of companies have enhanced their offerings. New companies have also 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

In 2009, U.S. federal and non-federal spaceports continued to support ELV launches while seeking to address the emerging personal spaceflight market. These spaceports continued to carry out ELV launches at similar tempos as in recent years while implementing infrastructure improvements for future commercial ELV and RLV missions. In June, ground was officially broken on construction of Spaceport America. In December, Mojave Air and Spaceport hosted the official unveiling of the first SpaceShipTwo and WhiteKnightTwo vehicles. Meanwhile, two new proposed spaceports, in Hawaii and Indiana, have been allocated money by their respective state legislatures to pursue the goal of building a spaceport.

Additionally, in October 2009, seven non-federal and proposed U.S. spaceports and three non-U.S. spaceports formed the "Spaceports Council" under the aegis of the Commercial Spaceflight Federation—an organization to work together on issues of common interest including airspace access, legal and regulatory frameworks, infrastructure, international policy migration, liability, and voluntary common operating standards. This represents a further step toward developing a network of non-federal spaceports within the United States, featuring relationships with spaceports abroad.

Regulatory and Legislative Developments

Finally, the FAA Office of Commercial Space Transportation initiated two new programs in 2009, designed to further encourage and facilitate the commercial space transportation industry. These two programs are the Center of Excellence for Commercial Space Transportation and the Commercial Space Grant Program.

SIGNIFICANT 2009 EVENTS

January 1: Virgin Galactic formally announces agreement to a 20-year lease as an anchor tenant of Spaceport America, New Mexico's commercial spaceport. Under the agreement, Virgin Galactic will pay $1 million a year for the first five years of the lease, and after that a fee based on the amortization of the remaining cost of the spaceport's facilities. One of the provisions of the lease also requires Virgin Galactic to establish its world headquarters in the state.

January 8: To reduce costs and align products, Northrop Grumman announces a corporate reorganization merging its space and aircraft manufacturing division aircraft. The Space Technology division combines with the Integrated Systems division, which is responsible for a number of manned and unmanned aircraft programs, to create a new Aerospace Systems division.

February 10: An Iridium commercial communications satellite and the defunct Russian military satellite Kosmos 2251 collide in low Earth orbit (LEO). The collision, which occurs 790 kilometers (490 miles) above Siberia, creates a large debris cloud with the potential to damage the International Space Station (ISS) and other spacecraft.

February 24: An Orbital Sciences Corporation Taurus XL vehicle carrying the Orbiting Carbon Observatory (OCO) fails during launch when the rocket's payload fairing stage does not separate properly. The OCO spacecraft, designed to monitor carbon dioxide and other greenhouse gases in the atmosphere, is lost.

March 16: NASA awards the United Launch Alliance (ULA) contracts to launch four scientific missions between 2011 and 2014: the Radiation Belt Storm Probes, the Magnetospheric Multiscale missions, and the TDRS-K and TDRS-L satellites.

March 26: A Soyuz rocket launches the Soyuz ISS 19 mission, carrying two Russian crew members bound for the ISS along with commercial space tourist Charles Simonyi. The flight makes Simonyi the first orbital space tourist to return to the ISS: his first trip was in April 2007. Simonyi lands back on Earth on April 7, along with two departing ISS crew members.

April 16: Space Exploration Technologies Corporation (SpaceX) and Argentina's National Commission on Space Activity (CONAE) sign an agreement to launch SAOCOM 1A and 1B, a pair of earth-monitoring satellites equipped with L-band synthetic aperture radar (SAR) instruments. The satellites are scheduled to launch aboard SpaceX's Falcon 9 vehicle in 2012.

April 20: A Sea Launch Zenit-3SL lifts off from the Odyssey Launch Platform on the Equator in the Pacific Ocean, placing SICRAL 1B, a communications satellite operated by the Italian Ministry of Defense, into GEO.

May 15: The U.S. subsidiary of ICO Global Communications files for pre-arranged bankruptcy protection under Chapter 11 of the U.S. Bankruptcy Code. The company had struggled to recover investment costs on its ICO-G1 satellite, launched in April 2008 to serve the North American market, and retained substantial debt to its hardware suppliers. Under bankruptcy protection, the subsidiary is restructuring its financing while continuing business operations.

May 19: An Orbital Sciences Corporation Minotaur 1 rocket successfully launches the U.S. Air Force Research Laboratory's TacSat-3 satellite to LEO. TacSat-3, built by Alliant Techsystems (ATK), demonstrates a hyperspectral sensor whose operations can be controlled directly by troops in the field.

June 19: Formal Spaceport America groundbreaking takes place in New Mexico, marking the formal beginning of construction on the new facility.

June 22: With more than $2 billion in unpaid debt, Sea Launch files for bankruptcy protection. The company had been experiencing ongoing financial shortfalls stemming from its January 30, 2007, failed launch of the NSS 8 commercial communications satellite. Following the launch failure, Sea Launch did not resume launch operations until January 2008, and several of its launch contracts were canceled. Sea Launch officials announce the goal of emerging from bankruptcy by the end of the first quarter of 2010.

June 27: A ULA Delta IV Medium-Plus vehicle lifts off from Cape Canaveral Air Force Station (CCAFS), placing the GOES O environmental monitoring satellite, operated by the National Oceanic and Atmospheric Administration (NOAA), into GEO.

July 13: A SpaceX Falcon 1 lifts off from Kwajalein Atoll in the Marshall Islands, placing RazakSAT, a remote sensing satellite operated by the Malaysian National Space Agency, into LEO.

July 21: The satellite communications company Globalstar receives a $276 million loan guaranteed by France's export credit agency, Coface, as the first installment in a $586-million loan package. This financing allows Globalstar to pursue plans for its second-generation satellite system. The system, manufactured by Thales Alenia Space, is expected to provide Globalstar customers with voice and data services through 2025. The satellites are slated to launch in sets of six aboard the Soyuz 2 vehicle, operated by Arianespace, beginning in 2010.

August 17: A United Launch Alliance (ULA) Delta II rocket successfully deploys the last of the U.S. Air Force's GPS 2R-series positioning and navigation satellites from CCAFS. The satellite, Navstar GPS 2RM-8, is the final of eight Lockheed Martin-built GPS 2R satellites enhanced to include additional civilian and military bandwidth capacity, higher signal power, and superior jamming resistance. The newly launched satellite joins 18 other functioning GPS2R satellites in the Air Force's 30-satellite GPS constellation.

September 30: Guy Laliberté, Canadian entrepreneur and founder of Cirque de Soleil, becomes the world's seventh space tourist, flying to the ISS aboard a Soyuz through the space tourism company Space Adventures. He returns safely to the Earth 12 days later.

October 8: A Boeing Launch Services Delta II lifts off from Vandenberg Air Force Base (VAFB), placing Worldview 2, a remote sensing satellite operated by DigitalGlobe, into LEO.

October 23: NASA releases the full text of its Review of Human Spaceflight Plans Committee (also known as the Augustine Commission) findings. The committee highlighted that any plan to fly humans beyond LEO would require additional funding of at least $3 billion a year. It also found that the Ares 1 rocket and Orion spacecraft were fundamentally solid from a technical standpoint, but a lack of funding would likely delay their development by several years. The White House planned to consider the options in the report to determine paths forward.

November 5: NASA Centennial Challenges program awards $1.65 million in prize money to Masten Space Systems and Armadillo Aerospace. Masten Space Systems won $1 million for winning Level 2 of the Northrop Grumman Lunar Lander Challenge as well as $150,000 for second place in Level 1. Armadillo Aerospace was awarded $500,000 for second place in Level 2.

November 23: A Lockheed Martin Atlas V lifts off from CCAFS, placing Intelsat 14, a communications satellite operated by Intelsat, into GEO.

December 7: Virgin Galactic formally unveiled its suborbital piloted spacecraft, SpaceShipTwo, and its carrier aircraft, WhiteKnightTwo, at a ceremony at Mojave Air and Space Port north of Los Angeles. This first SpaceShipTwo is named the Virgin SpaceShip (VSS) Enterprise.

December 11: Blue Origin announces its selection of three scientific projects—from Louisiana University, Purdue University, and the University of Central Florida—for future test flights.

December 15: Dynetics announces its purchase of Orion Propulsion, Inc. in order to expand its space hardware capabilities.

December 17: South Korea's Yeongcheon Astro Space Center announces it has selected XCOR Aerospace as its preferred supplier of suborbital launch services via XCOR's Lynx vehicle.

SPACE COMPETITIONS

Space prize competitions have become an established means of promoting innovation and developments in commercial spaceflight technology. The goal of these competitions is to encourage innovative contribution to commercial space launch services and other space capabilities while employing the highest-quality, but still economical and efficient methods. The three main space prize competitions currently active 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, announced in 2007, is an international space prize competition to reward the privately funded teams able to land a robot on the surface of the Moon, travel 500 meters about the surface, and send data back to the Earth in the form of images and videos (called "Mooncasts"). A collaboration of the X PRIZE Foundation and Google, the Google Lunar X PRIZE promotes private enterprise and the exploration of the Moon. The first team to successfully complete the mission objectives will win the grand prize amount of $20 million, if completed by December 31, 2012. The prize money drops to $15 million if the competition is not won until 2013 or 2014. A second place prize valued at $5 million will be awarded to the second team to complete the mission before the end of 2014. Finally, a total of $5 million is available to win for successfully completing additional tasks while exploring the lunar surface, bringing the total Google Lunar X PRIZE purse to $30 million. Space Florida offers an extra $2 million to the first place team if they successfully launch from the State of Florida. Teams are required to have at least 90% of their funding as well as completed registration by December 2010.[1]

Google Lunar X PRIZE LEGO MINDSTORMS challenge poster

As of November 2009, more than 20 teams are registered. These teams range from space tourism organizations to groups of physicians and scientists, hailing from a variety of nations worldwide. The newest teams to join the competition are Synergy Moon, made up of 48 members from 15 countries; Team Selenokhod, the first team from Russia; and Team C-Base Open Moon, a group of five Germans.[2] In addition, a new miniature challenge called "MoonBots: A Google Lunar X PRIZE LEGO MINDSTORMS CHALLENGE" was announced at the National Instruments NIWeek event. The contest, similar to the Google Lunar X PRIZE, challenges teams made up of children and adults to design, program, and build robots capable of conducting simulated lunar missions. Announced in August 2009, registration and participation is free and open to teams across the world.[3]

America's Space Prize

Bigelow Aerospace initiated a commercial spaceflight competition, America's Space Prize, to develop commercial human spacecraft. This prize challenges interested competitors to design a reusable vehicle capable of carrying passengers into orbit, with the eventual goal of transporting humans to Bigelow Aerospace's orbital space complex. The requirements for the competition are to build a spacecraft capable of taking a crew of at least five people to an altitude of 400 kilometers (240 miles), complete two orbits of the Earth, and subsequently 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 also have to demonstrate the ability to dock with a Bigelow Aerospace orbital habitat. Additionally, no more than 20% of the vehicle can be composed of expendable hardware.[4]

The competition deadline is January 10, 2010, with a cash prize of $50 million, funded fully by Bigelow Aerospace. Although the prize remains active, Bigelow Aerospace has stated publicly that apparently the cost of developing such a system is too high for this kind of prize incentive to be effective. The company has therefore decided to take more direct action. Specifically, Bigelow Aerospace partnered with Boeing and submitted a proposal to NASA under the auspices of the Commercial Crew Development initiative to construct a commercial capsule to service its own as well as NASA's needs, thereby lowering the costs to both.[5] Although about 40 teams have shown interest in the prize, financial obstacles have kept any from participating.

Centennial Challenges

Masten Team's qualifying Level 2 completion

There are currently six Centennial Challenges: Regolith Excavation, Green Flight, Lunar Lander, Power Beaming, Tether, and Astronaut Glove. The Green Flight challenge, referred to as the General Aviation Technology Challenge in 2008, does not directly relate to commercial space, nonetheless, the challenge develops technologies that could be applied to future commercial spaceflight, such as bio-fueled and hybrid-powered aircraft. Green Flight, announced at AirVenture 2009, will differ from the General Aviation Technology Challenge in that it will focus more on aircraft efficiency.[6]

The Centennial Challenge that correlates most directly with commercial space transportation is the Northrop Grumman Lunar Lander Challenge (NGLLC), held yearly since 2006. This competition is managed for NASA by the X PRIZE Foundation, which received funding to cover administrative costs from Northrop Grumman. The NGLLC is divided into two levels with separate prizes based on increasingly difficult requirements. In order to win Level 1, teams must construct a vehicle that is able to take off vertically, reach an altitude of at least 50 meters (164 feet) and travel horizontally to land precisely at a target landing area, having remained airborne for at least 90 seconds. Teams must then complete a similar return trip and transport the vehicle horizontally back to the starting point within 150 minutes.

The more difficult Level 2 is completed if a team's constructed vehicle remains airborne for twice as long as Level 1 and lands on a simulated lunar surface. First and second place are awarded for both levels.[7]

Winning teams at NGLLC awards ceremony

The NGLLC rules were altered in 2009 to allow teams to compete at a date and location of their choice between specified dates, rather than compete only at organized challenge events. The 2009 competition window was from early August to the end of October.[8] There were four teams registered for the 2009 NGLLC: Armadillo Aerospace, Masten Space Systems, Unreasonable Rocket, and Bon Nova. As of mid-October, two teams had already qualified for prizes, namely Armadillo Aerospace for Level 2 on September 12, 2009 and Masten Space Systems for Level 1 on October 8, 2009. Bon Nova was registered for attempts on October 26 and 27, but did not complete their demonstration flights in time. Masten Space Systems registered for attempts on October 28 and 29, but ended up forfeiting all but one attempt at the Level 2 purse on October 28 and 29 and a judging decision allowed Masten to take their second official attempt at Level 2 on the morning of October 30. Unreasonable Rocket attempted to qualify for both Level 1 and Level 2 on October 30 – November 1, but did not successfully complete either level. In an official ceremony in the Rayburn House Office Building in Washington, NASA presented Masten Space Systems with checks for $1 million for first place in Level 2 and $150,000 for second place in Level 1. NASA presented Armadillo Aerospace with a check for $500,000 for second place in Level 2, in addition to the $350,000 they won in 2008 for successfully winning first place in Level 1. The total prize purse for the NGLLC of $2 million has now officially been fully claimed.[9]


A view of the excavators awaiting their opportunity to perform

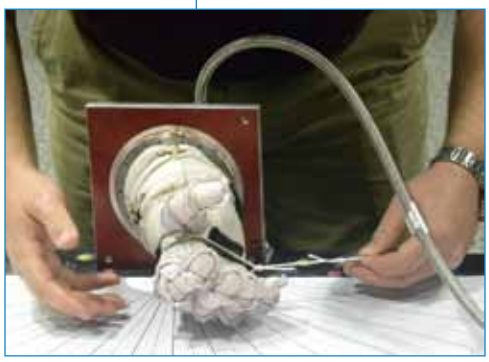
The remaining five Centennial Challenges are space-related and promote further space mission technologies. The Regolith Excavation Challenge concluded on October 18, 2009, with awards for the challenge winner, as well as second and third place, for the first time since its establishment in 2007. Paul's Robotics won the first place prize purse of $500,000 at the event held at the NASA Ames Research Park in Mountain View, California.[10]

The Tether and Beam Challenges are organized by the Spaceward Foundation in order to promote the development of high strength-to-weight materials and wireless power distribution technologies. This year, the competitions are held separately for the first time. The 2009 Tether Challenge, held during the Space Elevator Conference in Seattle, Washington on August 14, 2009, concluded without a winner.[11] The Power Beam Challenge was held November 4-6, 2009,

at NASA Dryden Flight Research Center. The LaserMotive team won level one of the competition and the $900,000 prize purse for successfully driving their vehicle using power beaming. Level two remains to be won and the remaining prize money is available for the 2010 competition.[12]

KC Space Pirates prepare to launch their climber

The Astronaut Glove Challenge, conducted by Volanz Aerospace Inc., tests participants on the dexterity, flexibility, and overall development of a spacesuit glove. Competitors must present a complete glove, consisting of the thermal micrometeoroid garment (TMG), unpowered bladder and bladder-restraint portions. The first Astronaut Glove Challenge was held in Connecticut at the New England Air Museum in May 2007 where Peter Homer, an aerospace engineer from Maine, took home the first place prize of $200,000. The 2009 Challenge was held November 18-19 at the Astronaut Hall of Fame at Kennedy Space Center, and offered a prize purse of $400,000.[13] Peter Homer was back with a new astronaut glove competing against Ted Southern, of Brooklyn, New York. Peter Homer again took home the top prize of $250,000 and second prize of $100,000 was awarded to Ted Southern.[14]



Torque test being performed on the glove designed by Ted Southern

In 2009, $3.65M in NASA centennial challenge prizes have been awarded. The Northrop Grumman Lunar Lander Challenge awarded $1.65 million, level one of the Power Beam challenge was completed awarding LaserMotive $900,000, the Astronaut Glove Challenge awarded a combined total $350,000 to two teams, and lastly, three teams won a combined total of $750,000 during the Regolith Excavation Challenge. Supporters of space competitions and prizes are hoping that these recent successes within the Centennial Challenges will lead to additional money appropriated by Congress for prize competitions. The President's Fiscal Year (FY) 2010 Budget Request asks for $4 million per year for the Centennial Challenges for FY 2010 through FY 2014 as a part of the Innovative Partnership Program.[15] If new funding becomes available, 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 is available to both US government and commercial customers although currently is most active in the government market. The Atlas V, Delta II, Falcon 1, Pegasus, and Taurus vehicles are available for commercial and U.S. government launches. The Zenit-3SL and Zenit-3SLB are 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. 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 4,750 and 7,700 kilograms (10,470 and 16,970 pounds) into geosynchronous transfer orbit (GTO). The Atlas 500 series can place payloads between 3,775 and 8,900 kilograms (8,320 and 19,620 pounds) into GTO. ULA has also proposed a heavy lift variant of the Atlas, the Atlas V HLV, which would have a payload capacity of up to 13,000 kg (28,660 lb) to GTO.[3] No launches of the Atlas V HLV have occurred and none is currently scheduled. The Atlas V launches from Cape Canaveral Air Force Station (CCAFS) in Florida and Vandenberg Air Force Base (VAFB) in California.[2]

Since its introduction in 2002, the Atlas V has performed 19 launches. In 2009, five Atlas V launches took place, including the commercial launch of the Intelsat-14 satellite and the dual-payload launch of NASA's lunar exploration spacecraft Lunar Reconnaissance Orbiter (LRO) and Lunar Crater Observation and Sensing

	SMALL				MEDIUM	INTERMEDIATE		HEAVY	
									
Vehicle	Falcon 1	Minotaur	Pegasus XL	Taurus XL	Delta II	Delta IV	Atlas V	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 (924 lb)	580 kg (1,279 lb)	440 kg (970 lb)	1,458 kg (3,214 lb)	6,097 kg (13,443 lb)	9,390 kg (20,702 lb) (Delta IV M) 13,360 kg (29,440 lb) (Delta IV M+ (5,4))	12,500 kg (27,558 lb) (Atlas V 402) 20,520 kg (45,238 lb) (Atlas V 552)	22,977 kg (50,646 lb)	N/A
Payload Performance (LEO polor)	420 kg (924 lb)	580 kg (1,279 lb)	190 kg (420 lb) (SSO)	1054 kg (2,324 lb) (SSO)	3,123 kg (6,886 lb)	7,510 kg (16,550 lb) (Delta IV M) 11,300 kg (24,920 lb) (Delta IV M+ (5,4))	7,095 kg (15,642 lb) (Atlas V 402) 14,096 kg (31,076 lb) (Atlas V 552)	22,560 kg (49,740 lb)	N/A
Payload Performance (GTO)	N/A	N/A	N/A	430 kg (950 lb)	2,171 kg (4,787 lb)	4,541 kg (10,012 lb) (Delta IV M) 7,020 kg (15,470 lb) (Delta IV M+ (5,4))	4,750 kg (10,450 lb) (Atlas V 401) 8,900 kg (19,580 lb) (Atlas V 551)	13,399 kg (29,540 lb)	6,180 kg (13,624 lb)
Launch Sites	RTS, CCAFS	VAFB, Wallops, KLC	Multi (air launched)	VAFB	CCAFS, VAFB	CCAFS, VAFB	CCAFS, VAFB	CCAFS, VAFB	Pacific Ocean

Table 1: Currently Available Expendable Launch Vehicles

* LEO: inclination of 28.5°, 185 km circular for all vehicles except Falcon 1 (9.1° inclination) and Pegasus

Satellite (LCROSS). The launch of the Air Force's Defense Meteorological Satellites Program (DMSP)-18 mission onboard an Atlas V 401 on October 18, 2009 was the 600th Atlas family launch (including variants which are now decommissioned).[3] Up to five Atlas V launches are planned for 2010.[4]

Delta II – United Launch Alliance

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. The vehicle is marketed commercially by Boeing Launch Services (BLS). The Delta II has the capability to launch payloads of 898 to 2,171 kilograms (1,979 to 4,787 pounds) to GTO, and 2,063 to 6,097 kilograms (4,548 to 13,440 pounds) to low Earth orbit (LEO). The vehicle can launch from either CCAFS or VAFB.[5]

Delta II

Eight Delta II launches occurred in 2009, including the commercial launch of WorldView-2. One Delta II launch is currently planned for 2010.[6]

Both NASA and the U.S. Air Force are phasing out their use of the Delta II, with the final launch of the vehicle currently planned for 2011, carrying NASA's GRAIL spacecraft. The vehicle is no longer in active production, although ULA continues to market the line and has five Delta II vehicles available for sale to government or commercial customers.[7]

Delta IV – United Launch Alliance

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 9,390 kilograms (20,702 pounds) for the Delta IV Medium to 22,977 kilograms (50,646 pounds) for the Delta IV Heavy. Capacity to GTO ranges from 4,541 to 13,399 kilograms (10,012 to 29,540 pounds). The Delta IV operates from CCAFS and VAFB.[8]

Delta IV

The Delta IV has flown eleven times since its introduction in late 2002. Three Delta IV launches, including the Delta IV Heavy launch of the National Reconnaissance Office (NRO) satellite NROL-26, occurred in 2009. Up to four Delta IV launches, including the first Delta IV Heavy launch from VAFB and the FAA-licensed launch of the Geostationary Operational Environmental Satellite (GOES)-P scheduled for March, are planned for 2010.

Falcon 1

Falcon 1 – Space Exploration Technologies Corporation

Space Exploration Technologies Corporation (SpaceX) of Hawthorne, California, has developed the Falcon 1 launch vehicle, which can place up to 420 kilograms (925 pounds) into LEO for about $8.9 million. SpaceX privately developed the entire two-stage vehicle, including the engines, cryogenic tank structure, and guidance system. The first stage engine, known as Merlin 1C (an updated version of SpaceX's Merlin engine), uses pump-driven LOX and kerosene. The second stage engine, called Kestrel, uses a pressure-fed LOX and kerosene system. The Falcon 1 launches from SpaceX's launch facility on the Kwajalein Atoll.[9]

The Falcon 1 performed three launches before reaching orbit. The first, in March 2006, suffered an engine failure 29 seconds into flight due to a fuel leak. The second, in March 2007, reached space but 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 success, placing a payload mass simulator into orbit. Falcon 1 is now fully operational and performed its first commercial launch in 2009, delivering Malaysia's RazakSAT earth observation satellite into orbit on July 13.

No further flights of the basic version of the Falcon 1 are currently planned.[10] The Falcon 1e, an enhanced version of the Falcon 1 with a stretched first stage and larger payload fairing, is slated to enter service in 2010; it will be able to place up to 1,010 kilograms (2,227 pounds) into LEO for $10.5 million.[11] In September 2009, SpaceX and ORBCOMM announced an agreement for SpaceX to be the launch provider for ORBCOMM's 18 satellite next generation constellation. Launches using SpaceX's Falcon 1e, could begin as early as the 4th Quarter of 2010 and continue through 2014.[12]

The Falcon-1 is designed with re-usable elements. The first stage of this vehicle is designed to parachute into the ocean. It can then be recovered, refurbished, and reused. Although the Falcon 1 is technically designed as a partially reusable launch vehicle, it is currently operated as an ELV.

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 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. The Minotaur I has a payload capacity of up to 580 kilograms (1,280 pounds) to LEO.[13]

Minotaur I

The Minotaur I entered service in 2000 and has performed eight launches to date. One Minotaur I flight took place in 2009, the launch of the TacSat-3 satellite from the Mid-Atlantic Regional Spaceport (MARS) in Virginia.[14] The Minotaur I has previously performed launches from VAFB, and can operate from CCAFS and Kodiak Launch Complex (KLC), Alaska.

Pegasus XL – Orbital Sciences Corporation

Pegasus XL rocket and Stargazer carrier aircraft

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." The Pegasus is capable of delivering small satellites of up to 440 kilograms (970 pounds) to LEO. 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.[15]

The Pegasus family has conducted 37 successful launches since 1994; however, no Pegasus launches took place in 2009.[16] At least one Pegasus XL mission is scheduled for 2010.

Taurus – Orbital Sciences Corporation

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 is available in two versions, the Standard Taurus and the Taurus XL, and can deliver payloads of up to 1,458 kilograms (3,214 pounds) to LEO.[17]

Taurus

The Taurus has successfully completed six of eight launch attempts since entering service in 1994.[18] The only Taurus launch attempted in 2009 resulted in a failure, when the fairing of the Taurus XL vehicle carrying NASA's Orbiting Carbon Observatory (OCO) spacecraft failed to separate after launch on February 24, 2009.[19] At least one Taurus launch is planned for 2010.

Zenit-3SL and -3SLB – Sea Launch Company, LLC

The Zenit-3SL is a Ukrainian-Russian launch vehicle marketed and 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 flight design. The Zenit-3SL provides a payload capacity of up to 6,180 kilograms (13,624 pounds) to GTO.[20]

Zenit-3SL lifts off from Odyssey Launch Platform

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 January 2007 launch failure, the Zenit-3SL returned to flight in January of 2008. Following the successful launches of five satellites from sea in 2008, Sea Launch completed one mission in April 2009, the launch of SICRAL-1B, for Telespazio.

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.[21]

Payloads and vehicles for the Land Launch Zenit-3SLB are processed and launched from existing Zenit facilities at the Baikonur Space Center in Kazakhstan. Following its first launch in 2008, the Zenit-3SLB successfully completed three missions in 2009.[22]

On June 22, 2009 Sea Launch Company, LLC filed for Chapter 11 bankruptcy protection in the United States.[23] The company continues to operate normally as it works through a reorganization process in preparation for emergence from bankruptcy.[24] In December 2009, Sea Launch received court approval for $12.5M in debtor- in-possession (DIP) financing from Space Launch Services, LLC. Space Launch Services is joint venture of Excalibur Almaz and PlanetSpace, and is expected to make an equity investment in a reorganized Sea Launch. The DIP financing will provide working capital for Sea Launch as it works through reorganization. The company plans to submit its Plan of Reorganization in the first quarter of 2010.[25] As Sea Launch proceeds through reorganization, it is anticipated that Boeing will divest all or most of its ownership stake in the company; while remaining a supplier to Sea Launch.[26] In 2009, Sea Launch commemorated 10 years of operations, which included 30 launches from its ocean-based platform.[27]

ELV Development Efforts

A number of efforts by both established corporations and startups are currently in progress to develop new ELVs. A number of these launch vehicle providers have succeeded in securing customers for the vehicles being developed – demonstrating that a market exists to support a number of launch options. Many of these providers focus on small to medium payload capacity. Some providers, however, have responded to the demonstrated market for large payloads to meet NASA's ISS resupply requirements. ELV's under development generally share the common goal of reducing launch costs in order to support and further develop the demonstrated market potential.

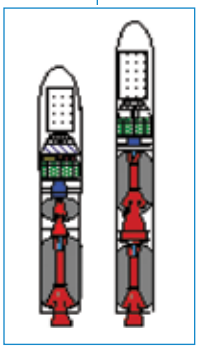
Athena III – PlanetSpace

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 PlanetSpace-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 combined with 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.[28] PlanetSpace filed a protest of this award with the Government Accountability Office (GAO) in January of 2009; in April of 2009 the GAO announced that it had denied the PlanetSpace protest.[29] Nevertheless, PlanetSpace announced earlier in 2008 it planned to proceed with the Athena III design regardless of the outcome of the CRS bid process.[30]



Cutaway view of Eaglet and Eagle

Eagle S-series – E'Prime Aerospace Corporation

The Eagle S-series family of launch vehicles is being developed by E'Prime Aerospace of Colorado, based on the design and technology used in the LGM-118A Peacekeeper Intercontinental Ballistic Missile (ICBM). The concept for this family of vehicles dates back to 1987 when E'Prime signed an agreement with the U.S. Air Force allowing the company to use Peacekeeper technology as the basis for developing 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 would ignite. The smallest vehicle, the Eaglet, would launch 580 kilograms (1,280 pounds) into LEO. A somewhat larger version, the Eagle, would put 1,360 kilograms (3,000 pounds) 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 developing larger pad-launched vehicles, designated S-3 through S-7. These vehicles would have the ability to place larger payloads into LEO and would also have geosynchronous Earth orbit (GEO) lift capability.[31]

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

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.[32]

Falcon 9 – Space Exploration Technologies Corporation

SpaceX's Falcon-9 launch vehicle, and the associated Dragon spacecraft, originated as internally funded Space X projects. Since August 2006, SpaceX has held a cooperative agreement with NASA under the Commercial Orbital Transportation Services (COTS) initiative. Development of the Falcon-9 has proceeded under the auspices of this agreement. Under the COTS agreement NASA provides payments totaling up to $278 million to Space X, and SpaceX contributes internal funds that must match or exceed the NASA funding, towards developing and demonstrating a capability to transport cargo to the International Space Station (ISS). NASA's payments to SpaceX are contingent upon the company achieving specific milestones in developing its capabilities.

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 Vacuum engine. Both stages are designed to be recovered and reused. Launching from CCAFS, the Falcon 9 will be capable of placing up to 10,450 kilograms (23,050 pounds) into LEO and 4,540 kilograms (10,000 pounds) into GTO. In addition to the primary launch site at Space Launch Complex 40, a former Titan IV launch pad at CCAFS, development of launch facilities at VAFB and Kwajalein Atoll is under consideration.[33] Launch price

Falcon 9

estimates for the Falcon 9 range from $44 million to $49.5 million, for satellite launches.[34]

Vehicle	Falcon 9
Developer	Space Exploration Technologies Corporation
First Launch	2010 (Falcon 9); 2012 (Falcon 9-Heavy)
Number of Stages	2
Payload Performance	Up to 10,450 kilograms (23,050 pounds) to LEO and 4,540 kilograms (10,000 pounds) into GTO; for Heavy version, up to 29,610 kg (65,280 lb) to LEO, and 15,010 kg (33,090 lb) to GTO
Launch Site	CCAFS (Falcon 9, Falcon 9-Heavy), Kwajalein (Falcon-9)
Markets Served	Launch of medium and large satellites, ISS crew and cargo resupply

A total of five Falcon 9 flights are planned for 2010.[35] The first Falcon 9 launch is scheduled for February 2010. Although this flight will carry a prototype of SpaceX's reusable Dragon spacecraft, it is not intended to count as one of the demonstration flights SpaceX must complete under its COTS agreement with NASA.[36] Following the initial flight, three Falcon 9/Dragon demonstration flights are planned for 2010. In addition to the demonstration flights, one other Falcon 9 launch is planned for 2010, a commercial launch for MacDonald, Dettwiler and Associates Ltd. of Canada.

In December of 2008, NASA awarded SpaceX a contract, under the Commercial Resupply Services program, to fly a series of cargo flights to the ISS. The contract authorizes SpaceX to conduct missions between 2011 and 2015 to carry approximately 20,000 kilograms (44,000 pounds) of cargo to the ISS and has an estimated value of $1.6 billion. SpaceX will conduct these flights using the Falcon 9 rocket to launch the Dragon spacecraft (discussed in the Reentry Vehicles and In-Space Technologies section of this report), also being developed at SpaceX using COTS funding.[37] In October 2009, SpaceX successfully completed the first two test firings of the nine engine flight first stage that will power the Falcon 9. With the successful completion of these tests the first stage has passed all acceptance testing requirements and has been shipped to Cape Canaveral in preparation for the vehicle's first flight.[38]

In July of 2009, Avanti Communications—which signed a contract for the Falcon 9 launch of the HYLAS commercial communications satellite in September 2007—announced that it was switching the launch of HYLAS from SpaceX to Arianespace. The change was attributed to delays in the development and qualification of the Falcon 9.[39]

In April of 2009, SpaceX signed Argentina's National Commission on Space Activity (CONAE) for two Falcon 9 launches for its pair of SAOCOM L-band Synthetic Aperture Radar satellites.[40] This brings the Falcon 9 mission manifest to a total of 22 launches.

In 2008, SpaceX announced plans to develop the Falcon 9 Heavy. With a capacity of 29,610 kg (65,280 lb) to LEO, and 15,010 kg (33,090 lb) 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 strap-on boosters.[41]

Although the Falcon 9 is technically designed as a partially reusable launch vehicle, it will, at least initially, be operated as an ELV.

Nanosat Launch Vehicle – Garvey Spacecraft Corporation

Prospector-13A test flight

Garvey Spacecraft Corporation (GSC), based in Long Beach, California, is a small research and development (R&D) company focusing on developing 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 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; the first flight of a rocket featuring LOX and methane as propellants; and the launch and 100 percent recovery of several prototype reusable test vehicles.

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

Milestones achieved during 2009 centered around the latest two test vehicles, the Prospector 13 (P-13) and Prospector 10 (P-10). In February 2009, the GSC and CSULB team jointly conducted a test flight of the P-13 to demonstrate the feasibility of the LOX and propylene propellant combination that has been baselined for the NLV. This was the second successful flight of this airframe, which first flew as the K-V in early 2001. Several months later came an attempted launch of the P-10 with its 10-chamber aerospike engine developed by CSULB. Ignition problems marred the liftoff and cut short the mission before achieving any test objectives. Late in the year, GSC received a contract to develop two more test vehicles, with first flight expected in late 2010, under a contract to ORBITEC for a vortex rocket engine development program sponsored by the Air Force Research Laboratory.[42]

NEPTUNE – Interorbital Systems

The NEPTUNE Series is a proposed family of launch vehicles based on the Orbital Transport and Rockets, Inc. (ORTAG) rocket design developed by Lutz Keyser, Wernher von Braun, and colleagues in the 1970s. In February 2008, Interorbital Systems publicly unveiled the design of the NEPTUNE series of modular rockets.[43] The vehicle features a modular design; each NEPTUNE would be assembled from multiple, common propulsion modules (CPMs) coupled with a booster module and a sustainer module The CPMs are made of two propellant tanks and a single throttle-able, ablatively-cooled bipropellant liquid rocket engine.[44]

Interorbital Systems currently proposes three versions of the NEPTUNE rocket. The basic NEPTUNE 30 would be capable of placing a 30-kilogram (66-pound) payload into polar low-earth orbit. It would be composed of five CPMs and a satellite kick stage. The NEPTUNE 1000 would place a 1,000-kilogram (2,200-pound) payload into polar low-earth orbit or accelerate a 190-kilogram (418-pound) payload to Earth-escape velocity. This vehicle is also proposed to serve as the launcher for a two-person LEO crew module for 8-orbit, 12-hour orbital tourism and human-tended payload services. The NEPTUNE 4000 vehicle would place a 4,000-kilogram (8,800-pound) payload into polar low-earth orbit or accelerate a 760-kilogram (1,672-pound) payload to Earth-escape velocity. This vehicle would be the primary launch vehicle for Interorbital Systems' space tourism operations as well as orbital hotel shuttle services.[45]

NEPTUNE design concept

Interorbital Systems plans an orbital space tourism venture using the NEPTUNE 4000 rocket. Under these plans, a NEPTUNE 4000 would be used to launch a crew module. This module, conical in shape, would be capable of carrying a pilot and five tourists into LEO during the launch phase of a commercial orbital tourism flight. Once in orbit, it is planned that the crew would transfer through a hatch in the crew module's heat shield to the orbital station module (OSM). The planned OSM is a unique aspect of the NEPTUNE that would consist 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. The combined OSM and crew module would support a commercial flight of up to seven days in duration. At the end of the flight, the crew module would serve as the crew's return vehicle.[46]

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.[47] On February 27, 2009, Interorbital Systems announced it had joined the SYNERGY MOON team to compete in the Google Lunar X PRIZE.[48] The team plans to use the NEPTUNE 1000 rocket to launch a lander of up to 50 kilograms to the lunar surface in late 2012.[49]

Vehicle	NEPTUNE
Developer	Interorbital Systems
First Launch	Estimated for 2010
Number of Stages	3 or 4
Payload Performance	30 kg (66 lb) to 4,000 kg (8800 lb) to LEO
Launch Site	Island of 'Eua, Kingdom of Tonga for equatorial and polar launches; Pacific Ocean west of Long Beach, California
Markets Served	Google Lunar X Prize; orbital space tourism; satellite and cargo launch; orbital hotel/laboratory/ surveillance/storage services; academic and university payloads

Interorbital is currently selling payload space on both sub-orbital and orbital NEPTUNE 30 flights. The company's TubeSat product offers 0.75 kilograms (1.7 pounds) of payload capacity to orbit for $8,000.[50] Interorbital currently has seven TubeSats and one cubesat on its launch manifest for the its initial planned orbital flight in December 2010, with 20 additional sales pending. Customers include the University of California, Irvine; the InterAmerican University of Puerto Rico, Morehead State University, and the Naval Postgraduate School (NPS). Interorbital will be involved with NPS and the Lawrence Livermore National Laboratory in

global maritime interdiction operation experiments in the first and second quarters of 2010. Non-orbital launches of Interorbital CPMs with NPS payloads will play an important role in data distribution during these exercises. These test launches are precursors to the orbital delivery of several NPS TubeSats (and additional spacecraft of the organizations mentioned above) by the NEPTUNE 30 in late 2010. Various Morehead State University and SYNERGY MOON payloads will also be flown on the pre-orbital test flights of the CPMs.[51]

Interorbital plans a series of four pre-orbital test flights of the NEPTUNE 30 in February, May, July, and September of 2010, leading up to the first orbital launch in December, 2010, from its private spaceport on the island of 'Eua, in the South Pacific Kingdom of Tonga.[52]

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 Minotaur IV will be capable of delivering 1,735 kilograms (3,825 pounds) to LEO.[53]

Minotaur IV

Vehicle	Minotaur IV and V
Developer	Orbital Sciences Corporation
First Launch	2010 (Minotaur IV), 2012 (Minotaur V)
Number of Stages	4 (Minotaur IV), 5 (Minotaur V)
Payload Performance	1,735 kg (3,825 lb) to LEO (Minotaur IV), 640 kg (1,411 lb) to GTO (Minotaur V)
Launch Site	MARS, VAFB, CCAFS, Kodiak Launch Complex
Markets Served	Small satellite launch and responsive space operations for U.S. government-sponsored payloads

The first Minotaur IV launch, carrying the Space-Based Surveillance System (SBSS) satellite for the USAF, previously scheduled for 2009 has been delayed indefinitely due to concerns over the vehicle's third stage. The concerns stem from the fairing separation failure encountered on the February 2009 OCO launch onboard a Taurus rocket. Officials do not expect this issue to affect previously planned 2010 Minotaur flights.[54] In addition to the SBSS launch, up to three Minotaur IV flights are planned for 2010. These include two launches of DARPA's Hypersonic Technology Vehicle (HTV) test vehicle and the launch of the U.S Air Force STPSat-2 from Kodiak Launch Complex in Alaska.[55] Including these planned 2010 launches, Orbital has announced eight finalized Minotaur IV launch contracts with the U.S Air Force.[56]

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 648 kilograms (1,411 pounds) into GTO and 447 kilograms (983 pounds) on a translunar injection trajectory. The Minotaur V shares many of the same subsystems as the Minotaur IV.[57] In 2009, Orbital announced

its first contract for a Minotaur V launch, the 2012 launch of NASA's Lunar Atmosphere and Dust Environment Explorer (LADEE). The launch was ordered under the company's Orbital/Suborbital Program-2 (OSP-2) contract with the U.S. Air Force.[58]

QuickReach – AirLaunch LLC

AirLaunch LLC, based in Kirkland, Washington, had been developing the QuickReach™ vehicle, a small, low-cost, air-launched rocket for defense and other applications, with assistance from the DARPA/Air Force FALCON SLV program. However, with the conclusion of the FALCON program on November 3, 2008, AirLaunch LLC has been put into hiatus. While the company structure still exists, no operations or development activities are being conducted.[59]

Horizontal Test Stand (HTS-2)

The QuickReach would have been carried aloft inside a cargo aircraft, such as a C-17A or other large cargo aircraft. The rocket would then be released from the aircraft at an altitude of 7,600 to 10,700 meters (25,000 to 35,000 feet) and fire its liquid-propellant engines to ascend to orbit. The vehicle was targeted to to place a 450-kilogram (1,000-pound) payload into LEO for less than $5 million.

During the QuickReach development activities to date, AirLaunch achieved significant technological milestones. 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.[60] AirLaunch was also awarded a patent, on December 20, 2008, for a method, known as trapeze lanyard (t/LAD) airdrop, developed to release the QuickReach vehicle from its carrier aircraft.

Vehicle	QuickReach
Developer	AirLaunch LLC
First Launch	TBD
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

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.[61]

Shadow III – Lunar Rocket and Rover Company

Lunar Rocket and Rover Company, Inc., based in Los Alamitos, CA, is developing the Shadow III launch vehicle family. The Shadow IIIA has a planned capability to deliver a payload of up to 32 kilograms (70 pounds) into LEO.[62] The Shadow IIIA is a three-stage, rail-launched vehicle. Each stage would be powered by solid fueled rocket motor. Tests have been conducted for both the first and second stage engines. The third stage would be powered by the flight-proven Altair III (Star 20) motor, manufactured by ATK. The Shadow IIIA could be assembled within 24 hours at its launch site of either CCAFS or VAFB.[63] The primary market for the Shadow IIIA is intended to be the university based micro satellite research community.[64] Lunar Rocket and Rover Company also plans a more advanced Shadow IIIC, with a larger payload capacity. However, development of this vehicle has not progressed beyond the design phase.

Vehicle	QuickReach
Developer	Lunar Rocket and Rover Company
First Launch	TBD
Number of Stages	3
Payload Performance	32 kg (70 lb) to LEO
Launch Site	CCAFS, VAFB
Markets Served	Micro satellite launch for university customers

Taurus II – Orbital Sciences Corporation

In 2007, Orbital Sciences Corporation announced that it had begun studying 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, $320 million cooperative agreement under the Commercial Orbital Transportation Services (COTS) initiative. Under the agreement, NASA will invest $170 million in Orbital Sciences Corporation and Orbital will contribute an additional $150 million towards developing and demonstrating a capability to transport cargo to the International Space Station (ISS). 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.[65] This initial demonstration flight is planned for 2011.[66]

Taurus II

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 December of 2008, NASA awarded Orbital a contract, under the Commercial Resupply Services (CRS) program, to fly a series of cargo flights to the ISS. The contract authorizes Orbital to conduct eight missions between 2011 and 2015 to carry approximately 20,000 kg of cargo to the ISS and has an estimated value of $1.9 billion.[67] Orbital will conduct these flights using the Taurus II rocket to launch the Cygnus spacecraft (discussed in the Reentry Vehicles and In-Space Technologies section of this report), also being developed at Orbital using COTS funding.[68] NASA has also awarded a similar CRS contract to SpaceX.

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.[69]

The basic two-stage Taurus II would be able to place 5,400 kilograms (11,900 pounds) into LEO; a configuration with an enhanced second stage would have a payload capacity of up to 7,600 kilograms (16,720 pounds). 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, CCAFS, and Kodiak Launch Complex.[70]

Development of the Taurus II moved from the design phase to the testing phase in December 2009 with the completion of successful tests of the Castor 30 motor, which will power the second stage of the Taurus II. In June 2009, Orbital broke ground to construct the Taurus II launch infrastructure at NASA's Wallops Flight Facility.[71]

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 Ares I (previously referred to as the Crew Launch Vehicle) and the Ares V (previously referred to as the Cargo Launch Vehicle). 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 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.[72]

Ares I-X launch, October 2009

Development of the Ares I is currently in progress. In December 2005, NASA selected ATK as the prime contractor for the Ares-1 first stage.[73] In July 2007, NASA selected Pratt & Whitney Rocketdyne (PWR)

Vehicle	Ares I
Developer	NASA
First Launch	2015
Number of Stages	2
Payload Performance	23,587 kg (52,000 lb) to LEO (ISS)
Launch Site	KSC
Markets Served	Crew launches for exploration and ISS missions

as the contractor for the J-2X engine, which will serve as the upper stage engine for the vehicle.[74] In August 2007, NASA selected Boeing as the prime contractor for Ares 1 upper stage manufacturing.[75] 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.[76]

On October 28, 2009, a suborbital test launch of the vehicle with an inert second stage, the Ares I-X flight, was successfully completed at Kennedy Space Center.[77] The Ares-1X was a four segment solid rocket booster first stage, with inert dummy upper stages to simulate the mass of the second stage, Orion spacecraft and Launch Abort System. Objectives of this test flight included; characterization of flight properties and stage separation, testing ground and launch operations procedures, and testing launch pad infrastructure and systems of an Ares 1-similar vehicle, testing first stage parachute performance and stage recovery operations. The test was largely successful in terms of collecting the desired data on in-flight parameters, staging events, parachute performance, and in demonstrating launch operations.[78] However, some anomalies were observed, these include a potential first stage parachute malfunction, and observed damage to the recovered first stage.[79] The first in a series of test flights for the crew escape enabling Launch Abort System on the Ares I is scheduled to occur at NASA's White Sands Test Facility in early 2010. In November 2008, the J-2X engine successfully completed its critical design review.[80] In 2009, PWR began testing of the gas generator to be used on the J-2X engine; the first full-engine system test is planned for mid-2011. The operational orbital version of the Ares I vehicle is scheduled to enter service no earlier than 2015, pending any revisions in national space exploration policy.

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.

Artist conception of Ares V

Detailed development of the Ares V is not expected to begin until the end of this decade, pending any revisions in national space exploration policy. The first test flight of the vehicle is scheduled to take place around 2018.[81]

Vehicle	Ares V
Developer	NASA
First Launch	2018
Number of Stages	2
Payload Performance	187,787kg (414,000 lb) to LEO
Launch Site	KSC
Markets Served	Cargo launches for exploration missions

In 2009, a Presidentially chartered committee, the Review of U.S. Human Space Flight Plans Committee, conducted a examination of U.S. human spaceflight plans for the purpose of presenting the executive branch with a set of options concerning the future structure and direction of the nation's human space exploration plans. Among other vehicles and options, the Committee's final report included a description of a new version of the Ares V, known as the Ares V-Lite. The Ares V-Lite would be a somewhat lower performance variant of the Ares V. The first stage would use two of the five-segment solid rocket boosters currently being developed for the Ares I, in conjunction with a five engine core stage powered by derivatives of the RS-68 (the engine used on the Delta IV Heavy). The upper stage would be powered by the J-2X engine planned for the Ares I and V. The Ares V-Lite would be human-rated and capable of launching the Orion spacecraft. If adapted as an element of national space exploration policy, it is likely that the Ares V-Lite would replace both the Ares I and V. It would be used to launch both crew and cargo missions.[82]

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 carry out missions on behalf of specific commercial, government, or non-profit clients (including scientific researchers, academia, and educational organizations). Sounding rockets support a variety of applications, including astronomical observations, atmospheric research, and microgravity experiments. Three of the sounding rockets types discussed in the *2010 Development and Concepts Report* (Black Brant, Oriole/Orion, and Terrier) are made available to the U.S. scientific community through the NASA Sounding Rockets Operations Contract (NSROC) managed by the NASA Sounding Rockets Program Office at Wallops Flight Facility (WFF).[83]

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).[84]

In 2009, eight Black Brant vehicles were launched under NASA's Sounding Rockets Program. In Fiscal Year 2010 up to 15 launches of rockets in the Black Brant family are planned through the Sounding Rockets Program.[85]

Orion and Oriole – DTI Associates

Both the Orion and Oriole are single stage sounding rockets that are often combined with other motors (often of the Terrier family) to create two-stage sounding rockets, with the Oriole or Orion serving as the upper stage. 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.

Oriole sounding rocket

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 flight.

The Orion uses a surplus U.S. Army missile motor, and is capable of launching a 39-kilogram (85-pound) payload to an altitude of 88 kilometers (55 miles), and a 68-kilogram (150-pound) payload to an altitude of 71 kilometers (44 miles). The Orion made its first flight in 1974.[86] 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.

In 2009, one single-stage Orion vehicle was launched under NASA's Sounding Rockets Program. The program does not list any single stage Orion or Oriole launches on its Fiscal Year 2010 manifest, although there are planned launches that include one of these vehicles as an upper stage.

SpaceLoft XL – UP Aerospace, Inc.

Spaceloft XL

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). UP Aerospace markets the SpaceLoft vehicle to serve educational and research markets, such as microgravity and atmospheric sciences experiments, as well as commercial applications, including product marketing and novelty promotion. Spaceport America in New Mexico is the primary launch site for the SpaceLoft XL.

The first successful SpaceLoft XL launch took place on April 28, 2007, from Spaceport America in New Mexico.[87] Three SpaceLoft XL launches took place in 2009. The first, the SpaceLoft SL-3 mission on May 2, 2009, carrying student research experiments suffered a partial failure that resulted in the payload not reaching space.[88] The second on August 4, 2009, lofted a ground-launched UAV prototype for the aerospace company Moog-FTS.[89] The third flight, on October 10, 2009, was a successful launch of an experimental test flight vehicle for Lockheed Martin.[90]

Shadow I and II – Lunar Rocket and Rover Company

Lunar Rocket and Rover Company, Inc., based in Los Alamitos, CA has developed the Shadow I suborbital ELV. The Shadow I vehicle can carry payloads of up to 2.3 kilograms (5 pounds) to altitudes of up to 112 kilometers (70 miles). The Shadow is based on the Loki missile developed by the U.S Army. Including its first flight in 2003, the Shadow I has launched 10 times. Launches have occurred from CCAFS, White Sands Missile Range, and a French Navy ship. Two Shadow I launches are planned for 2010.[91]

A Shadow I sounding rocket launches from a French naval vessel

Lunar Rocket and Rover Company also has plans to develop a more advanced version of the Shadow I, known as the Shadow II. Two versions of the Shadow II are in development. The single stage Shadow IIA would have the capacity to loft payloads of up to 23 kilograms (50 pounds) to an altitude of 129 kilometers (80 miles). The two-stage Shadow IIC would have the capacity to loft payloads of up to 200 kilograms (441 pounds) to an altitude of 185 kilometers (115 miles). The company has built a mobile launch system for the Shadow II and has developed and tested, in association with the U.S. Air Force, hardware related to the Shadow II.[92]

The primary market for the Shadow family of vehicles is the education sector. Payloads flown on the Shadow I have also been used for upper atmospheric research and to examine wind shear information for NOAA.[93]

Terrier-Orion – DTI Associates

The Terrier is a first stage motor used in conjunction with various upper stage engines to form multi-stage, spin-stabilized sounding rockets. The basic version uses a Terrier Mk 12 Mod 1 engine (a surplus U.S. Navy missile motor), while more powerful versions use the Terrier Mk 70 motor. The Terrier stage is 46 centimeters (18 inches) in diameter. Versions of the Terrier, with various upper stages, in use in 2010 include: the Terrier-Improved Orion, which can loft payloads weighing from 91 to 363 kilograms (200 to 800 pounds) to altitudes ranging from 75 to 225 kilometers (47 to 140 miles); the Terrier-Malemute, which can loft payloads weighing from 91 to 227 kilograms (200 to 500 pounds) to altitudes ranging from 400 to 700 kilometers (248 to 435 miles); the Terrier-Lynx, which can loft payloads weighing from 113 to 227 kilograms (250 to 500 pounds) to altitudes ranging from 254 to 378 kilometers (235 to 435 miles); and the Terrier-Oriole, which can loft payloads weighing from 363 to 680 kilograms (800 to 1500 pounds) to altitudes ranging from 184 to 340 kilometers (114 to 211 miles).[94]

Terrier Orion sounding rocket

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 in July 2001. In 2009, six vehicles in the Terrier family were launched under NASA's Sounding Rockets Program. In Fiscal Year 2010, up to eight launches of rockets in the Terrier family are planned through the Sounding Rockets Program.[95]

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 direct government financial assistance—many of which are developing space hardware for the first time. The second discusses the only operational government RLV program, 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

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.

Scorpius Super Mod

QUAD is a four-tank vertical takeoff and landing vehicle. In 2007, Armadillo developed a variant of the QUAD vehicle, the MOD-1 vehicle, for competition in Level One of the Northrop Grumman Lunar Lander Challenge (NGLLC). 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.

After narrowly falling short of the NGLLC prize in 2007, in 2008 the MOD-1 successfully performed two 90-second flights between pads 100 meters apart, capturing the $350,000 first prize for NGLLC Level One. Armadillo then entered an updated version of the MOD vehicle, called the Scorpius Super Mod, in the 2009 NGLLC. The Scorpius uses lightweight, composite, high pressure helium tanks developed by Microcosm, Inc., and is considerably less massive than earlier versions of the vehicle.[1] Under new Challenge rules teams were allowed to compete from a site of their choosing within a window of flight opportunities running from July through October of 2009. On September 12, 2009, Armadillo conducted its 2009 NGLLC Level Two qualifying attempts from the company's home airport in Caddo Mills, Texas.[2] The Scorpius successfully completed both legs of the Level Two competition, completing the second flight leg with 30 minutes remaining in the flight window, while achieving a landing accuracy of 87 centimeters (34.3 inches).[3] This success qualified Armadillo for the $1,000,000

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

Level Two Prize; however the company would ultimately receive the $500,000 second place as a result of Masten Space Systems completing a higher scoring Level Two attempt in October 2009. The 2009 flights were performed under the newly revised amateur rocket exemption to FAA launch license regulations.

Armadillo expects the MOD vehicle 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 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 reach higher suborbital altitudes, is also being considered.[4] Armadillo plans to double the flight ceiling achieved from its Caddo Mills home base from 900 to 1,800 meters before attempting high-altitude flights from Spaceport America in New Mexico. The company then plans to increase the in-flight reduced-gravity time and begin to fly scientific payloads.[5]

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 on launch pad in 2006

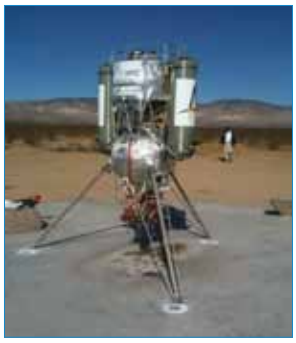
As part of the New Shepard development process, Blue Origin has several prototype vehicles for flight testing at the company's Texas facility. The first such vehicle, named Goddard, is powered by an HTP monopropellant engine and is intended to perform flights to altitudes of about 600 meters (2,000 feet) and lasting no longer than one 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.[6]

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

Development activities continued during 2008 and 2009. The company is in the process of building a second prototype vehicle and continues to purchase land around their Texas launch site in order to create a safety buffer zone.[7] In November 2009, Blue Origin announced that it selected three research payloads to fly on uncrewed suborbital flights of the New Shepard vehicle. These payloads were selected as Phase 1 of the New Shepard Research Flight Demonstration Program and are intended both

to provide scientific and educational value and to demonstrate the feasibility of scientific experiments using the New Shepard vehicle. Blue Origin expects flight opportunities for uncrewed scientific payloads to be available in 2011; and for crewed flight opportunities to be available in 2012.[8]

XA-1.0 – Masten Space Systems



The XA-0.1E Xoie vehicle after completing one leg of the Level Two NGLLC

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 $75,000.[9] The company plans to sell payload space on the vehicle for as little as $99 for a 350-gram (12-ounce) "Soda Sat"; a 5-kilogram (11-pound) payload would have a cost of $1,250.[10]

As part of the development of the XA-1.0, Masten is building several prototype vehicles.

Masten Space Systems Company competed in the 2009 Challenge at both Level One and Level Two. Following an unsuccessful attempt on September 16, 2009, (completing only one flight leg), Masten flew its XA-0.1B Xombie vehicle at the Mojave Air and Space Port in California in a second Level One attempt on October 8, 2009. On this attempt, the Xombie vehicle completed both legs within the time window, and achieved a landing accuracy of approximately 16 centimeters (6.3 inches).[11] As a result the company qualified for the NGLLC Level One second prize (the first prize had been secured by Armadillo Aerospace during the 2008 NGLLC); when no other teams completed Level One in 2009 Masten won the $150,000 prize.

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 entered its XA-0.1E Xoie vehicle in Level Two of the Challenge. After some technical problems were overcome Xoie completed the first leg of Level Two near the end of the team's two-day launch window. However, upon landing the vehicle developed a small fire due to a fuel leak. Damage to the vehicle was minor, but significant enough to prevent the return leg from being flown within the window. However, the NGLLC judges decided to allow Masten an additional flight attempt the following morning. After working to repair Xoie, Masten made a final attempt to qualify for the Level Two prize on October 30, 2009. The vehicle successfully flew both legs, qualifying for Level Two with less than six minutes remaining in the allotted time.[12] When the final team to compete in the Challenge, Unreasonable Rocket, failed to qualify, Masten won the $1,000,000 Level Two first prize, as the landing accuracy it had achieved—within 19 centimeters (7.5 inches)—was better than that of the only other team to qualify, Armadillo Aerospace.[13]

In 2010, the company plans to focus on further testing of the XA-0.1B & E as a stepping stone toward developing the XA-1.0. Masten aims to begin low altitude commercial flights in early 2010. Masten also holds a Small Business Innovation and Research (SBIR) contract with the Department of Defense to use its vehicles as a testbed for network communications.[14]

Silver Dart – PlanetSpace

SilverDart quarter-scale prototype

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. The 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 has proposed to launch the Silver Dart using a rocket under development at one time in Canada, the Canadian Arrow, from a proposed spaceport in Cape Breton, Nova Scotia.[15]

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

In February 2009, PlanetSpace unveiled two quarter-scale Silver Dart Unmanned Aerial Vehicles (UAVs).[16] PlanetSpace plans to begin flight tests of these vehicles in 2010 in order to study the flight characteristics of the lifting body design. One of the quarter scale UAVs accommodates rocket propulsion and is designed to test aerodynamic properties of the vehicle under rocket powered flight.[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.

Artist's conception of RocketplaneXP

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.

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 2009, Rocketplane shut down its Oklahoma operations, and suspended active development of the Rocketplane XP. The company continues fund-raising efforts and has stated that the vehicle could fly in 2011, contingent on financing.[18]

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 space flights for private individuals, and scientific research payloads. The venture also developed 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. Virgin Galactic has exclusive use of both the SS2 and WK2 vehicles for the first 18 months of commercial passenger spaceflight operations.[19]

SpaceShipTwo and WhiteKnightTwo

In January 2008, Virgin Galactic and Scaled Composites unveiled the designs for WK2 and SS2. Production of the two craft continued throughout 2008 and 2009. In March 2008, senior officials from Virgin Galactic and the Kiruna Spaceport in Sweden announced plans to use Spaceport Sweden as a secondary launch site for SS2. In July 2008, the WK2 was publicly rolled-out.[20] In July 2009, Virgin Galactic announced that Aabar Investments of Abu Dhabi made a $280-million investment in Virgin Galactic, taking a 32% ownership stake in the company. As part of the agreement Aabar gains exclusive regional rights to host Virgin Galactic flights at a spaceport being considered for development in Abu Dhabi. Aabar has also committed to an additional $100-million investment towards developing a small satellite launch capability, in conjunction with Virgin Galactic.[21] WK2 made its maiden test flight on December 21, 2008, reaching the altitude of 4,880 meters (16,000 feet) as planned. As of November 13, 2009, WK2 has completed 22 test flights.[22]

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 May 2009, Scaled Composites, and subcontractor Sierra Nevada Corporation, successfully completed the first phase of test firings of the rocket motor that will propel SS2. The motor uses a hybrid nitrous

oxide system, and is the largest of its kind in the world.[23] SS2 was publicly rolled-out for the first time on December 7, 2009.[24]

As of July 2009, Virgin Galactic had signed up approximately 300 customers for its suborbital space tourism flights. Commercial tourism flights will begin after the 18- to 24-month-long test flight program for SS2 is completed.[25]

Dream Chaser – Sierra Nevada Corporation

Dream Chaser is an RLV under development by the Space Systems Business Area of Sierra Nevada Corporation (SNC), created in 2009 after the company acquired SpaceDev and MicroSat Systems, 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% 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. The Dream Chaser will launch vertically and land horizontally on conventional runways.

DreamChaser and Atlas V, design concept

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.[26]

Vehicle	Dream Chaser
Developer	Sierra Nevada Corporation (SNC)
First Launch	2011
Number of Stages	3
Payload Performance	6-9 people
Launch Site	CCAFS
Markets Served	Suborbital space tourism, ISS crew and cargo resupply, orbital space tourism, military missions

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 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.[27] As of the end of 2009, SNC has completed over 1,200 hours of wind tunnel tests on Dream Chaser, test articles and over 300 firings of the hybrid rocket engine technology intended for use in the vehicle.[28]

SNC submitted a proposal to NASA's Commercial Crew Development program, a $50-million pool of funds from which NASA will award funded SAAs in early 2010 to further the development of concepts related to commercial provision of crew transport to orbit. If this proposal

is successful SNC intends to use the funds to support an air drop test of a Dream Chaser prototype test article. This test would test subsonic flight aerodynamics and control surface effectiveness. Sierra Nevada has speculated that this drop test could occur using Virgin Galactic's WhiteKnightTwo as the carrier aircraft.[29]

Laramie Rose – SpeedUp

Laramie Rose

SpeedUp of Laramie, Wyoming, developed the Laramie Rose vehicle, originally to compete in the NGLLC. 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 or 2009 NGLLC; however, the Laramie Rose vehicle did perform its first tethered hover test in April 2008, and development continues.[30] With the end of the Northrop Grumman Lunar Lander Challenge in 2009 SpeedUp plans to use Laramie Rose as a development test bed only.[31]

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

MICHELLE-B – TGV Rockets, Inc.

TGV Rockets, Inc. (TGV) is developing the Modular Incremental Compact High Energy Lowcost Launch Example (MICHELLE)-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. MICHELLE-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 MICHELLE-B and, in the second quarter of 2007, performed three tests of its "workhorse" engine for the vehicle. Research and development work continues while the company seeks additional capital needed for full-scale vehicle development.[32]

MICHELLE-B concept

Vehicle	MICHELLE-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	Field operable; requires 15 x 15-meter (50 x 50-foot) reinforced pad
Markets Served	Remote sensing; science, including microgravity research; national security applications

Burning Splinter – Unreasonable Rocket

Unreasonable Rocket's Silver Ball prototype

Unreasonable Rocket of Solana Beach, California, is a father-son team that developed two versions of the Burning Splinter vehicle to compete in the NGLLC. The "Burning Splinter 90" vehicle (also called "the blue ball") was designed to compete in Level One of the NGLLC, and "Burning Splinter 180" vehicle (also called "the silver ball") was designed to compete in Level Two of the Challenge. Both vehicles are vertical takeoff, vertical landing crafts powered by a single engine using hydrogen peroxide propellant.[33] During development of these vehicles 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 NGLLC.[34] In October 2009, Unreasonable Rocket was the last team to compete in the NGLCC. The team competed in both levels, but failed to qualify in either, although the "blue ball" vehicle came within five seconds of completing a Level One leg before running out of propellant.[35] With the conclusion of the NGLLC, Unreasonable Rocket is considering its options for future projects.[36]

Vehicle	Burning Splinter
Developer	Unreasonable Rocket
First Launch	2009
Number of Stages	1
Payload Performance	25 kg (55 lb) to 50 m (165 ft)
Launch Site	Cantil, CA
Markets Served	Lunar Lander Challenge competition

Lynx – XCOR Aerospace

Lynx wind tunnel model with U.S. quarter (for scale)

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. However, the company made significant technical and aerodynamic changes during the launcher design process. The changes resulted in a new vehicle designation: the Lynx.[37]

Vehicle	Lynx
Developer	XCOR Aerospace
First Launch	2010
Number of Stages	1
Payload Performance	Two people (one pilot, one participant) to suborbital altitude
Launch Site	Mojave Air and Space Port (initial planned site) and others (in future)
Markets Served	Suborbital space tourism; suborbital government and science missions

Since 2006, XCOR has performed fundraising and technical development for its suborbital launch vehicle.[38] In December 2008, the firm announced a partnership with RocketShip Tours to begin selling suborbital space tourism tickets for $95,000 a flight. In the same month, XCOR successfully performed its first hot fire of the 5K18 kerosene-LOX engine that will be used on the Lynx. Development activities continued during 2009. In July 2009, the company completed a series of subsonic wind

tunnel tests at the Air Force Research Laboratory, testing the Lynx's aerodynamic design. Supersonic wind tunnel tests are planned.[39] XCOR continued development of the 5K18 engine and reached several technical milestones, including demonstration of reliable stop and re-start capabilities and the ability to run continuously at thermal equilibrium.[40] XCOR anticipates filing a new FAA launch license application, and expects to perform the first Lynx flight by mid-2010.[411] Meanwhile, on December 17, 2009, South Korea's Yeongcheon Astro Space Center announced its selection of the Lynx vehicle as its preferred supplier of suborbital launch services.

Government RLV Development Efforts

Throughout the 1980s and 1990s, the Department of Defense (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 129 launches since its introduction in 1981.

Space Shuttle on the launch pad

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. Five Space Shuttle flights occurred in 2009, including the final mission to service the Hubble Space Telescope, flown by *Atlantis* in May. As of January 1, 2010, five Space Shuttle flights are planned before the fleet is retired by the end of the year. The Space Shuttle's day-to-day operations are managed by United Space Alliance, a Boeing-Lockheed Martin joint venture in operation since 1996.

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

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, and provided for additional funding to industry by way of the American Recovery and Reinvestment Act of 2009. 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 habitats.

Orion Crew Exploration Vehicle

The U.S. space exploration strategy 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 Orion design was amended in April 2009 to reduce the maximum number of crew from six to four members for initial missions to the ISS or to the Moon.[1] Orion's first crew transport to the ISS is planned for 2015, while the first lunar flight is currently targeted for 2020.[2]

Artist rendition of the Ares V departure stage in orbit with the Orion capsule docked with the Altair lander

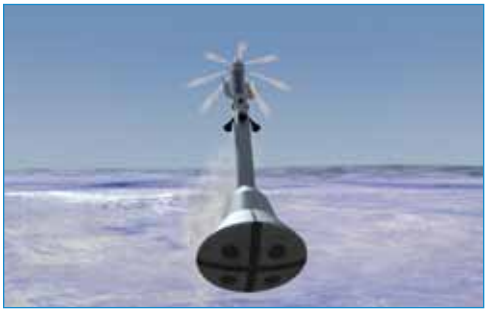
The spacecraft will consist of a combined pressurized crew module and service module launched into orbit by the Ares I crew launch vehicle. For missions to the Moon and Mars, NASA will precede the Ares I launch with an Ares V cargo launch vehicle. Ares V will deliver the Altair lunar lander and the Earth Departure Stage to LEO. Orion will then dock with these vehicles, and the Earth Departure Stage will propel Orion and Altair 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. It 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 of Apollo-era modules.

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.



Concept of the abort flight tests of the Orion crew exploration vehicle's launch abort system at the White Sands Missile Range in New Mexico

Contracts for the Altair lunar lander and Earth Departure Stage have not yet been awarded. NASA is developing conceptual designs for Altair and has been seeking input from industry experts to support that effort. In 2009, NASA issued the Altair Conceptual Design Contract, which was to evaluate conceptual designs and develop necessary products for design review. This particular procurement is on hold pending assessment of the conclusions of the final report by the Review of U.S. Human Space Flight Plans Committee.[3] However, industry continues to demonstrate to NASA various technologies that can be incorporated into the Altair lander. In June 2009, Northrop Grumman successfully demonstrated the use of their heritage pintle injector technology in order to maintain stable combustion over a broad throttling range. This is a vital requirement to providing a soft and precise landing on the Moon's surface.[4]

In October of 2009, NASA successfully completed a demonstration test of Orion's main parachute test equipment. This was part of a series of tests supporting the design of the Orion parachute recovery system, derived from the system NASA used to recover the Apollo spacecraft. The 2009 test was made necessary by a failed 2008 parachute test of an Orion mock-up vehicle, where a set-up parachute did not inflate properly and led to the failure of the entire parachute system. NASA's 2009 tests were an attempt to improve the testing technique and prevent such an anomaly from occurring again. By introducing "smart" avionic systems that automatically sense the attitude and pitch rate of the test vehicle, which can lead to a more precise release of the vehicle from the test platform for the parachute test can be achieved. A 9,400-kilogram (20,700-pound) test vehicle was dropped 6,248 meters (20,500 feet) by a C-130 aircraft above the U.S. Army's Yuma Proving Grounds.[5] At least one more test is scheduled in 2010.

Additional 2010 milestones include the first full-scale test of the new launch abort system scheduled for spring 2010 at the U.S. Army's White Sands Missile Range. This test will involve both the Orion spacecraft and the launch abort system in

order to simulate an emergency abort scenario from the launch pad. In preparation for that test, Alliant Techsystems (ATK) and Lockheed Martin completed a successful ground test of the abort system's attitude control motor (ACM) in December of 2009.[6]

The overall Constellation Program is managed at 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 at Moffett Field, California, leads the development of Orion's thermal protection systems. Langley Research Center in Hampton, Virginia, is the lead for integrating the launch abort system while the Marshall Space Flight Center in Huntsville, Alabama, is responsible for developing the propulsion elements for the abort system.

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 is scheduled to 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, propellants, and oxygen to the ISS and remained docked with the ISS for six months and performed orbital reboosts. The ATV eventually offloaded 2½ tonnes of waste from the ISS before returning to Earth in a controlled destructive re-entry.[7] The ESA has contracted industry to produce four more ATVs to be flown through 2015, starting with the Johannes Kepler, which is due to launch in mid-2010.[8] Additionally, the Japan Aerospace Exploration Administration (JAXA) conducted the maiden voyage of the H-2 Transfer Vehicle (HTV) in September 2009, delivering supplies to the ISS and returning to earth, also burning upon re-entry after a seven-week mission.[9]

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.[10]

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

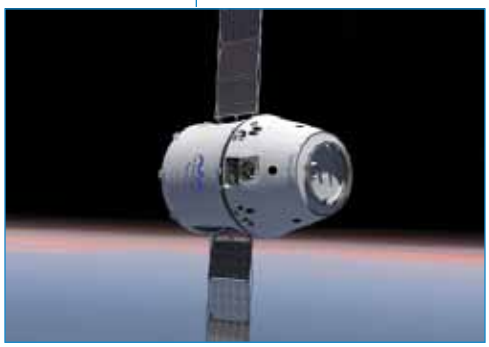
- external, unpressurized cargo delivery and disposal;
- internal, pressurized cargo delivery and disposal;
- internal, pressurized cargo delivery and return;
- an option for crew transportation.

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

Phase Two of the program culminated in the December 2008 awards of two ISS Cargo Resupply Services (ISS-CRS) contracts, which also went to SpaceX and Orbital Sciences. The contracts call for delivering 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.[11]

SpaceX Dragon

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 will be carried by SpaceX's Falcon 9 launch vehicle, and comprises three elements: the nose cone, 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).



The SpaceX Dragon Lab vehicle in orbit

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.[12]

In February 2009, SpaceX's conducted high temperature tests on the Dragon's heat shield material. The tests, successfully conducted at NASA's Ames Research Center, subjected the material to temperatures as high as 1,850 degrees Celsius (3,360 degrees Fahrenheit), simulating the conditions that the Dragon capsule crew can expect upon re-entry.[13] In addition, SpaceX successfully demonstrated a proximity sensor, called DragonEye, on NASA's STS-127 shuttle mission in July 2009. DragonEye, a Laser Imaging Detection and Ranging (LIDAR) sensor, provides laser-based range and bearing information between the Dragon spacecraft to the ISS. DragonEye will make its operational debut on the final flight of the Dragon spacecraft under NASA's COTS program.

SpaceX plans to conduct a series of three COTS demo flights of the Falcon 9 and Dragon system in 2010 culminating with an actual berthing of an empty Dragon vehicle with the ISS, returning to Earth via parachuted water landing. Then, starting in 2011, the first of the 12 (non-demo) CRS missions ordered by NASA are scheduled to begin. All flights are scheduled for launch from SpaceX's Space Launch Complex 40 at Cape Canaveral, Florida.[14] 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.[15]

SpaceX is also pursuing the commercial market with the DragonLab spacecraft. Introduced in November 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 being able to provide 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.[16] 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.[17]

Orbital Sciences Taurus II/Cygnus

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.

Artist rendition of Orbital's Cygnus spacecraft approaching the ISS

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 early 2011 from Wallops Flight Facility. Orbital is preparing to begin operational CRS missions in 2011 and as many as eight operational ISS cargo flights between 2011 and 2015.[18]

The pressurized cargo module is based the on the Multi-Purpose Logistics Module (MPLM), developed by Thales Alenia Space for NASA. The solar arrays will be developed by Dutch Space, who will be responsible for the design, manufacture, assembly, integration, and testing of the arrays for nine pressurized cargo missions to the ISS.[19]

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 (OTVs) that can serve as the cargo carriers to the ISS.[20] In 2008, the PlanetSpace team proposed this vehicle to NASA as part of the COTS Phase-2 funding for the ISS-CRS project.

- Sierra Nevada Corporation's (formerly SpaceDev's) Dream Chaser Space Transportation System is a lifting body RLV based on the NASA HL-20 lifting body spaceplane. The vehicle is designed to launch on a human-rated Atlas V rocket.

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 that 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.

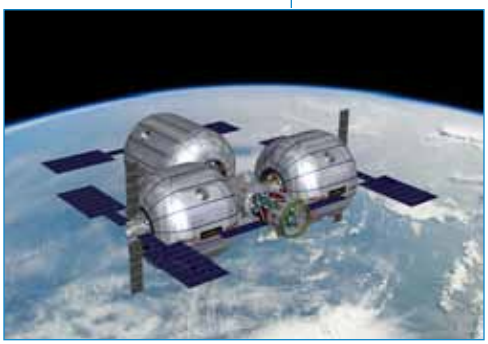
Artist's concept of an X-37 vehicle, similar to the X-37B in development

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 April of 2010, using an Atlas V rocket to be launched from Cape Canaveral.[21] 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. The entire test flight will be unmanned. Other flights for the X-37B will be for testing advanced thermal protection materials, autonomous approach and landing schemes, and orbital and ground operations.[22]

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.



Artist rendition of Bigelow's planned space complex in orbit

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.

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 2009, Bigelow announced that it had successfully obtained approval from the U.S. Directorate of Defense Trade Controls to conduct activities related to passengers without having to file Technical Assistance Agreements, Technology

Transfer Control Plans, or other ITAR-related paperwork. This is considered a major development as it eases the commercial space industry's path regarding complex and expensive export-approval processes.

In October of 2009, Bigelow Aerospace teamed with Boeing in a proposal to NASA in response to the Agency's new Commercial Crew Development program (CCDev). Developed as a result of the American Recovery and Reinvestment Act of 2009, CCDev directs up to $50 million in stimulus funds towards private sector development and demonstration of human spaceflight concepts and associated enabling technologies.[23] Boeing and Bigelow's proposal centered on accelerating the development of a new crew capsule that could potentially launch atop multiple rockets, and could also dock with either the ISS or the Bigelow orbiting habitats.[24] Awarding of CCDev funding is expected in early 2010.

ENABLING TECHNOLOGIES

Organizations from industry and various government agencies 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 composite cryogenic propellant tanks, propulsion systems, thermal protection systems, navigation and docking sensor systems, and vehicle recovery systems. This chapter reviews some of the accomplishments made in 2009 with emphasis given to those organizations and technologies that have achieved significant testing milestones.

Future Responsive Access to Space Technology Program

The Future-Responsive 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. The ultimate goal is to fly a ground-launched suborbital vehicle capable of reaching speeds of Mach 4-7, 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.[1]

Display model of a proposed FAST booster

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.[2] 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.[3] 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.[4]

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.[5] In July of 2009, Andrews Space delivered a composite liquid oxygen tank it had jointly developed with the University of Dayton Research Institute under the FAST program to the U.S Air Force Research Laboratory.[6] In May 2009, AFRL issued a Request for Information (RFI) to identify resuable booster systems concepts. This RFI is intended to kick-off a process, as a follow-on to the FAST program, that will lead to a subscale responsive launch vehicle with a resuable first stage and expendable second stage. It is envisioned that in 2017-2018, this vehicle will be ready to fly as a demonstrator and will have achieved a technology readiness level preparing it to begin full-scale development.[7]

Improved Heat Shield Material – SpaceX

SpaceX developed an improved high performance heat shield material called PICA-X, based on PICA (Phenolic Impregnated Carbon Ablator), a material first created by NASA. PICA holds the record for the fastest reentry speed of a spacecraft into Earth's atmosphere: NASA's Stardust sample return capsule, which reentered at 12.9 kilometers per second (28,900 miles per hour) in January 2006.

Testing of SpaceX's PICA heat shield material

Developed with the assistance of NASA, the SpaceX variants of the rigid, lightweight material have several improved properties and greater ease of manufacture than older types of ablative heat shields. Tests at the Arc Jet Complex at NASA Ames Research Center subjected samples of PICA-X to temperatures as high as 1850 °C (3360 °F), simulating the reentry heating conditions that will be experienced by SpaceX's Dragon capsule.

In all cases, the SpaceX versions of PICA demonstrated equal or improved performance in comparison to the heritage material. All of SpaceX's initial production will be used for internal applications, including the heat shields of Dragon spacecraft, as well as the Falcon 9 second stage, which is designed to return from orbit for recovery and reuse.[8]

Composite Tanks – Microcosm, Inc.

In 2009, Microcosm, Inc. (MI) and Scorpius Space Launch Company (SSLC), both of Hawthorne, California, continued developing cryogenic composite LOX tanks for a variety of applications and customers. MI's tank design and SSLC's manufacturing method prevent gas permeation and leakage. In addition, they manage 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, Microcosm's proposed launch vehicle, and potentially increases the mass to orbit by over 30 percent. MI/SSLC offer 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 to others in the aerospace community, as well as customers with other applications.[9]

Microcosm's composite propellant tank

At the AIAA Space 2009 conference, Microcosm presented a low-cost launch infrastructure that can be created on the basis of Scorpius technology. A high-pressure helium tank without a metallic liner was developed and flown on an Armadillo Aerospace vehicle that took second prize in Level Two of the NGLLC. These high pressure tanks have been further developed using the composite bosses that had been applied to the all-composite propellant tanks, resulting in an all-composite configuration. The use of this technology for storing high-pressure helium is an expansion of the all-composite tank technology into all of the tanks in the Scorpius pressure-fed

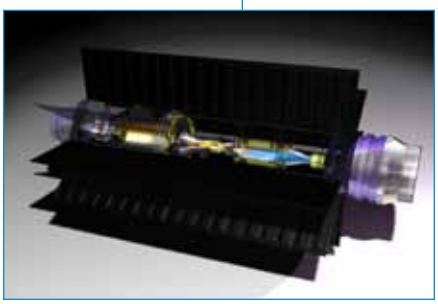
architecture. It also has wide applicability in aerospace, transportation, energy, and other fields.[10]

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

Microcosm continued development in 2009 of the HPPS for the company's family of launch vehicles and upper stages, and for other customer applications. The HPPS uses high pressure cold gas. Typically, as cold gas is expanded, the resulting loss of pressure causes the remaining cold gas to cool down. However, by using a specialized catalytic converter, the HPPS provides pressurized heated gas to compensate for this temperature reduction. Thus the system is very scalable and the HPPS reduces in half the comparable gas required for the typical pressure-fed system, thus potentially lowering cost and mass of launch vehicles using the system.[11] A monolithic tank using the all-composite design described above has been sized for the 63.5 centimeter (25-inch) pod of the Mini-Sprite, a proposed micro-satellite launch vehicle designed to deliver 102 kilograms (225 pounds) to orbit. This configuration replaces the dual tank arrangement at this small scale, simplifying the structure of the pod with a conveniently available tank size.

VASIMR® Engine – Ad Astra Rocket Company

The Variable Specific Impulse Magnetoplasma Rocket (VASIMR®) is an electromagnetic thruster for spacecraft propulsion. The VASIMR® engine is not intended to launch a vehicle into space from ground-level. Rather, it would be an efficient method of propulsion for high payload commercial robotic operations in cislunar space and high speed 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 fill the high power electric propulsion niche, affording substantially higher thrust at high specific impulse than existing electric thrusters. Scientist and former astronaut Franklin Chang-Diaz created the VASIMR® concept and has been working on its development since 1979.



The VASIMR engine

On October 28, 2008, Ad Astra announced that the VASIMR® Helicon first stage, which generates the plasma that is later accelerated by the drive, achieved its full rated power of 30 kilowatts. Demonstrating the engine, in its two-stage configuration, at its full rated power of 200 kW, occurred on September 30, 2009, at Ad Astra's Houston research laboratory. This paves the way for further testing, leading to the critical design of the VF-200 flight engine to be completed in early 2012.[12] On December 8, 2008, an agreement was signed between Ad Astra and NASA to test the VASIMR® engine aboard the International Space Station. This test is being planned for late 2013[13].

Rocket Upper Stage – SpeedUp

SpeedUp's Laramie Rose prototype vehicle

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 began to perform static firings of sub-scale engines in 2009; and plans to begin captive carry tests on other launch providers' rockets in 2010.[14]

Solid Rocket Motors – Alliant Techsystems, Inc.

ATK was named the prime contractor by NASA to develop 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. Improvements include the use of lighter materials throughout the rocket, more advanced avionics, and an additional, fifth segment. The core tooling used to achieve the new propellant shape is being manufactured.[15] 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 September 10 test of the 5-segement solid rocket booster

In 2009, test series continued with the solid rocket booster. On October 28, 2009, the Ares 1-X suborbital test vehicle launched, using a four-segment version of the solid rocket motor as its first stage. The test was a success, according to ATK and NASA.[16] Five ground tests of a new five-segment Ares I rocket motor are scheduled in 2009-2011. On September 10, 2009, ATK conducted the first burn test of the new, five-segment booster, which performed as expected.[17]

NOFB Monopropellant and Rocket Engines – Firestar Technologies, LLC

NASA has awarded Firestar Engineering, LLC a $600,000 Phase I/II SBIR contract in February 2008 to develop and test a continuous operating 100 lbf NOFB monopropellant thruster overseen by NASA Johnson Space Center, NASA Marshall Space Flight Center, and NASA Glenn Research Center. NOFB monopropellants are non-toxic, high performance, self-pressurizing monopropellants that can generate over 300s of I_{sp} performance. These monopropellants were previously invented, characterized, and operated from

Test runs of the Firestar monoprop engine

2004–2007 under NASA's Mars Advanced Technology program managed by the Jet Propulsion Laboratory/Caltech (JPL). The 100 lbf NOFB monopropellant thrusters are candidates for a variety of NASA programs as well as low cost, non-toxic thrusters for the commercial spacecraft market . Since October of 2009, Firestar Technologies and its partners have successfully demonstrated continuous operation of a scaled down 25lbf vacuum equivalent version of the NOFB monopropellant thruster. Ongoing development work is focused on scaling this NOFB monopropellant thruster up to the 100 lbf level and conducting vacuum chamber testing of this engine. Overlapping this work, NASA has also just recently awarded a Phase I SBIR to Firestar Engineering (Technologies) for investigating an NOFB clustered truncated aerospike engine option for future NASA ascent vehicles. In parallel with NASA's ongoing rocket engine development efforts, as of February 2008, Firestar Technologies has also been funded under DARPA (Defense Advanced Research Projects Agency) Phase I/II SBIR contracts for developing an extreme altitude unmanned aerial vehicle (UAV) engine that burns NOFB monopropellants. This program would support DARPA's Rapid Eye program. All of these programs overlap and have been supporting the ongoing development and military standard (MIL-STD) testing of NOFB monopropellants and their associated fluid-handling hardware.[18]

Liquid Rocket Engines and Associated Technologies – Garvey Spacecraft Corporation

Garvey Spacecraft Corporation (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 21 flight tests. The partnership developed two aerospike rocket engines as well as 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.

Garvey Aerospace's P-13 rocket

In February 2009, GSC and CSULB successfully flew the P-13, consisting of a refurbished airframe that first flew in 2001 and a LOX/propylene engine developed by CSULB students. This propellant combination has the potential to provide higher specific impulse while retaining the density of RP-1. Two months later, in April, the team attempted to fly CSULB's P-10 vehicle with a next-generation aerospike engine that featured ten Ceramic Matrix Composite (CMC) thruster chambers. The engine was successfully ignited during a static fire test the previous year. This time, however,

an ignition problem in one of the chambers resulted in an early termination of the mission and total loss of the vehicle.

Development is still continuing with Hyper Therm High Temperature Composite (HTC) on CMC chamber applications, with static fire testing starting near the end of 2009. This material could see use in upper stages and attitude control thrusters as a replacement for chambers made from heavy refractory metals.[19]

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 dem¬onstrated 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.[20] 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.[21] By November of 2008, the J-2X had passed its critical design review and was on track to commence full-scale testing in 2010.[22]

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.[23]

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 it with the liquid oxygen to create thrust. This cooling allows for higher performance without significantly increasing engine mass.[24]

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.[25]

The Merlin 1C Vaccum engine on the test stand

In July 2009, the Merlin 1C engine propelled the fifth Falcon 1 into orbit. SpaceX's far larger Falcon 9 rocket, due to make its maiden launch in February of 2010, will employ nine Merlin 1C engines on its first stage.

A vacuum version of the Merlin 1C, with a larger bell nozzle and a much larger, radiatively cooled expansion nozzle that maximizes performance in the vacuum of space , will be used on the Falcon 9's upper stage.[26] Throughout 2009, SpaceX conducted numerous tests of the Merlin 1C vacuum engine, including a full six-minute mission duration firing. With a thrust of approximately 42,000 kilograms (92,500 pounds) of force in vacuum conditions, and a vacuum specific impulse of 342 seconds, the new engine demonstrated the highest efficiency ever for an American hydrocarbon rocket engine.[27]

In October 2009, SpaceX successfully conducted two static firings of the flight-ready first stage of its new Falcon 9 rocket. Using nine of its Merlin 1C engines, the 10- and 30-second long firings generated nearly a million pounds (454,000 Kg) of thrust using RP-1 and LOX. The Merlin 1C engine is one of very few liquid rocket engines designed in the United States in the last three decades. The October tests cleared the way for the stage to travel to Cape Canaveral in preparation for the inaugural launch of the Falcon 9 in early 2010.[28]

Liquid Rocket Engines – Microcosm, Inc.

Microcosm has continued with developing 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. As of the end of 2009, the conceptual sizing of the large, Stage 3 engine has been completed. It is of a standard Scorpius design, namely ablative, pressure-fed, burning LOX and kerosene, and is, essentially, scaled down from the Stage 3 engine of the proposed Sprite.[29]

Microcosm's ablatively-cooled engine

Launch Abort System – Orbital Sciences Corporation

Orbital Sciences 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.[30] The LAS will be composed primarily of solid rocket motors, separation mechanisms, canards, and an adapter structure. The LAS will provide escape

ATK's November 20, 2008 test of the launch abort system

capability for the Orion crew from pad operations through ascent. According to Orbital, the new design, using Orbital's small launch vehicle technology, will improve flight crew safety as compared to current human space flight systems.[31]

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.[32] As of the end of 2009, the hardware underwent final testing and shipped to White Sands, NM for the Pad Abort 1 test, currently scheduled to take place in early 2010.[33]

Scramjet Propulsion – Pratt & Whitney Rocketdyne, Inc.

Artist concept of the X-51A in flight

By the end of 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. The X-1 demonstrator engine, 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 2010. According to PWR, the program will set the foundation for several hypersonic applications including access to space.[34] By the end of October 2008, the X-2 scramjet engine, a developed version of the X-1, had completed ground testing.[35] With ground-testing complete, the vehicle has been cleared for its inaugural test flights, which are expected to start in early 2010.

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

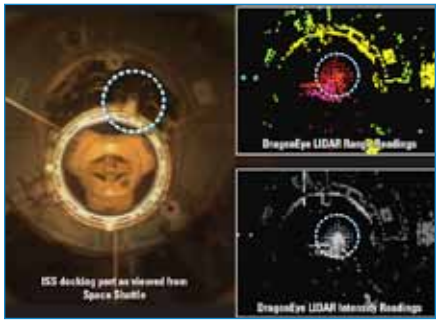
ATK and United Space Alliance successfully tested the world's largest rocket stage recovery parachute system. In September and November 2007, the 46-meter (150-foot) in diameter, 900-kilogram (2,000-pound) parachute carried a 19,000-kilogram (42,000 pound) weighted test unit safely to the Earth.[36] 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 of 2008, the drogue parachute system was successfully tested, being attached to a 10,800-kilogram (24,000-pound) test article.[37] The first flight of the Ares 1-X took place on October 28, 2009. This was the first full-scale test of the new triple

parachutes. During splashdown, two of the three parachutes failed, causing the depleted first stage to hit the water harder than expected and denting it. This was not seen as a catastrophic failure though, and work is underway to determine the cause of the mishap.[38]

Damage to the first stage of the Ares I-X following the parachute malfunction

Spacecraft Navigation LIDAR – SpaceX

SpaceX demonstrated DragonEye, a new navigation sensor system, in proximity to the International Space Station (ISS). Carried in the payload bay of Space Shuttle Endeavour, the sensor was launched aboard NASA's STS-127 mission on July 15, 2009.



DragonEye's test aboard STS-127

Developed in just ten months from concept to final hardware, the DragonEye LIght Detection And Ranging (LIDAR) system provides three-dimensional images based on the amount of time it takes for a single laser pulse from the sensor to reach a target and bounce back. It further provides range and bearing information from the Dragon spacecraft to the ISS.

DragonEye will make its operational debut on the final flight of the Dragon spacecraft under SpaceX's NASA Commercial Orbital Transportation Services (COTS) program, where the sensor will guide the Dragon spacecraft's approaches to the ISS for berthing. According to SpaceX's launch manifest, this should take place in 2010. It will subsequently fly aboard all 12 Dragon missions to re-supply the ISS under NASA's ISS Commercial Resupply Services (CRS) program.[39]

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. Spaceports usually have access to airspace that is restricted to allow spaceflight operations that minimize danger to other aircraft and people on the ground. 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
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.

Table 2 shows the states that have active non-federal, federal, and proposed spaceports. Figure 1 shows a map of active 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.

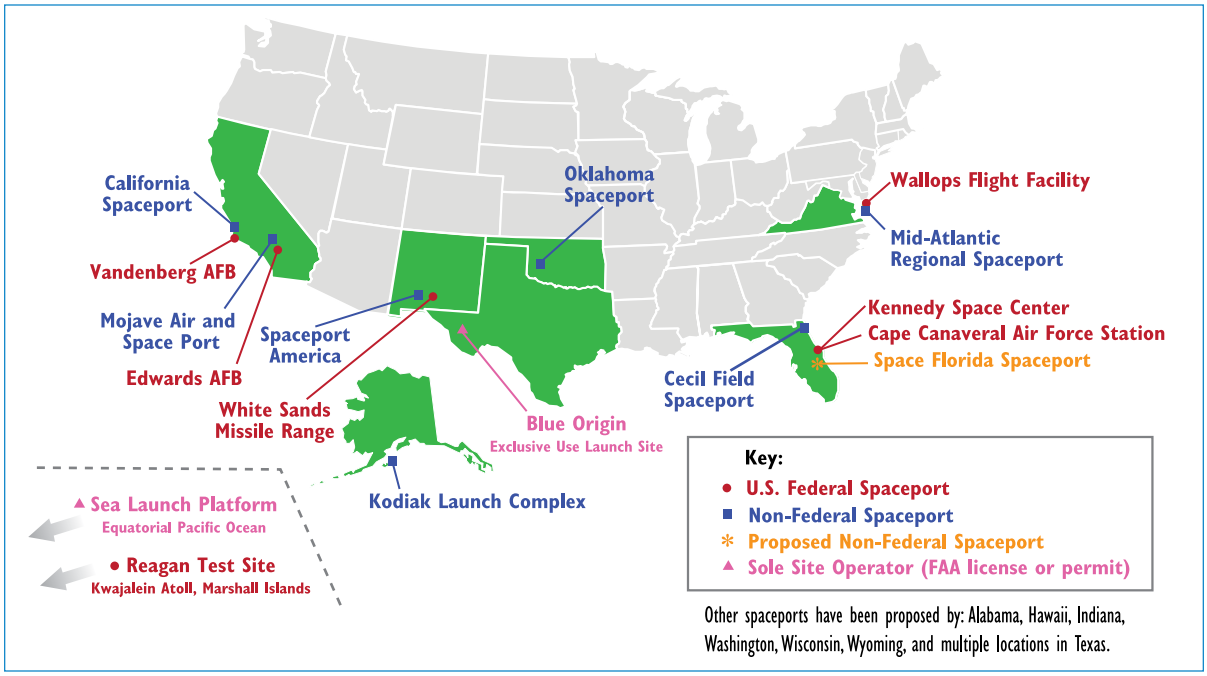


Figure 1: US spaceports and launch sites

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. At present seven spaceports hold active FAA Launch Site Operator licenses. The newest licensed spaceport is Cecil Field in Florida which received its license on January 11, 2010.

Representatives from nine non-federal and proposed spaceports met in Florida in July 2009 to hold the Spaceports Executive Summit. The event was hosted by Space Florida and was focused on discussing the best practices and challenges the leaders face in further developing their spaceports.[1] The summit was followed by the formation of the Spaceports Council, under the guidance of the Commercial Spaceflight Federation, in October 2009. The Spaceports Council includes seven non-federal and proposed non-federal U.S. spaceports and three foreign spaceports that will work together on issues of common interest including airspace access, legal and regulatory frameworks, infrastructure, international policy migration, liability, and voluntary common operating standards.[2] The Spaceports Executive Summit and the creation of the Spaceports Council represent strong steps towards the stable development of a network of non-federal spaceports within the United States.

However, competition among spaceports also exists. State governments in Virginia, Florida, and Texas have passed or are considering legislation that would limit the liability of "space flight entities." These state incentives are part of a growing competition among states and the spaceports they represent to attract spaceflight vehicle manufacturers and operators. To attract more business, some spaceports are also marketing their facilities and access to restricted airspace to entice developers of unmanned aerial vehicles.

Blue Origin Launch Site

Blue Origin's West Texas launch site is private property where the company proposes to launch RLVs on suborbital, ballistic trajectories to altitudes in excess of 99,000 meters (325,000 feet). The FAA issued 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.

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

As part of Phase 1 of the New Shepard Research Flight Demonstration Program, Blue Origin has selected three unmanned research payloads to fly on the New Shepard with the earliest possible unmanned flight opportunity in 2011 and crewed opportunities in 2012.[3]

California Spaceport

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.

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 (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 many of VAFB's launch sites via the Integrated Processing Facility (IPF). The IPF can maintain a clean room environment as high as class-1,000. In April 2008, the modification to the access tower at Level 5 of SLC-8 was completed to provide for class-100,000 clean room operations.[4]

SLC-8

In September 2008, Orbital Sciences Corporation announced that the preparations to launch the Minotaur IV launch vehicle at VAFB/California Spaceport were complete.[5] The inaugural flight of a Minotaur IV, carrying the SBSS 1 payload, is scheduled to take place in 2010 at the California Spaceport's launch pad.[6] Two other Minotaur IV launches carrying the Hypersonic Technology Vehicles HTV-2a and HTV-2b will occur in early 2010.[7]

Cecil Field

Cecil Field	
Location	Jacksonville, Florida
Owner/Operator	Jacksonville Aviation Authority (JAA)
License Status	Active FAA Launch Site Operator License
Description	Commercial spaceport supporting 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.

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 provided guidance and direction for developing the Cecil Field Spaceport.[8] On January 11, 2010, Cecil Field was awarded an FAA launch license.

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 and was completed in November 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 three 767-type aircraft for MRO activities, is scheduled for construction in the summer of 2010 with completion in 2011.

JAA has land available for construction of another hangar facility on the southwest side of the airport that has been reserved for space operations when Cecil Field gains a spaceport tenant. JAA can assist with financing for hangar, assembly, and launch facilities.[9]

Kodiak Launch Complex

The Alaska Aerospace Corporation (AAC) is state owned and independently operated. The corporation has a conventional top-down business organization including a board of directors, CEO, President & COO, vice presidents, and directors who oversee focus areas. AAC's corporate offices are in Anchorage, Alaska.

RPT lift-off from LP 1 at Kodiak

AAC's core business area is space launch, and it developed, owns, and operates the Kodiak Launch Complex (KLC), a state-of-the-industry spaceport on Kodiak Island, Alaska, that provides access to space for commercial and government interests. The corporation's charter includes more than space launch, and it therefore participates in other aerospace fields as well, such as Unmanned Aircraft Systems, Range and Spaceport consultation, and Range and Spaceport/ Launch Complex engineering/support services.

KLC is the nation's high-latitude space launch facility, and it was designed specifically to support space launches to polar and high inclination orbits. Ballistic missions are launched from KLC as well. 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. KLC facilities feature all-weather indoor processing; a certified range consisting of two internally redundant, GPS and telemetry tracking Range Safety and Telemetry Systems that mitigate single point failures, and fiber optic connectivity to the world.

The Launch Operations Control Center includes an open architecture office bay with 60 offices. The Tech Control Center is the communications hub for the facility and is Defense Security Service certified for red communications. The Weather Forecast Office is staffed by certified meteorologists during launch missions and can simultaneously track up to six balloon-borne sondes. The Payload Processing Facility is a large structure that is designed to accommodate spacecraft preparation for flight including tanking of spacecraft reaction systems. Depending on the mission it can be operated as a class-100,000 clean room or as an ultra-clean class-10,000 clean room.

The Integrated Processing Facility is KLC's rocket assembly building. It is environmentally controlled and rockets are received and processed year-round in shirtsleeve comfort. Processed rockets are moved to Launch Pad (LP) 1 or 2 inside of the environmentally-controlled rail-mounted Spacecraft Assemblies Transfer

Facility. This facility has doors on both ends that abut matching doors on the Integration Processing Facility and the Launch Service Structure at LP 1. For launches from LP 2, the Spacecraft Assemblies and Transfer Facility is parked over LP 2 until final launch operations commence. The Launch Service Structure at LP 1 is an environmentally controlled facility featuring 48 meters (157 feet) of hook height, four work platforms adjustable in 0.3 meter (one-foot) increments, and custom designed work platform inserts that accommodate various rocket classes up to 16 feet in diameter. LP 1 includes a flame trench rated to 4,900,000 Newtons (1.1 million pounds-force).

Kodiak Launch Complex	
Location	Kodiak Island, Alaska
Owner/Operator	Alaska Aerospace Corporation (AAC)
License Status	Active FAA Launch Site Operator License
Description	Kodiak Launch Complex was the first commercial launch site located outside of a federal facility. Launch site for military, government, and commercial telecommunications, remote sensing, and space science payloads
Infrastructure	Launch Control Center with integral Launch Operations Control Center, Weather Forecast Office, and Tech Control Center; Maintenance and Support Facility; Instrumentation Field, Payload Processing Facility; Integration Processing (rocket assembly) Facility; mobile Spacecraft Assemblies Transfer Facility; two launch pads with two more in design; and a Rocket Motor Storage Facility

As part of its business plan, AAC emphasizes maintaining KLC and keeping its infrastructure up to date. In 2009, major infrastructure related developments cost more than $8.25 million and included: replacement of KLC's radar surveillance systems with a new single system that fulfills both surface and aerial surveillance requirements; installation of a second cell phone tower to broaden coverage; refurbishment of the road to the Narrow Cape Lodge (a commercial lodge located about three miles from the Range that is operated solely in support of KLC); floor repairs in the Integration Processing Facility; beginning construction of the Rocket Motor Storage Facility that will reduce motor shipping costs and support Operationally Responsive Space missions; and initiating design of the LP 3 and LP 4 complex.

Two space launch missions, both for the USAF using Minotaur IV vehicles, are scheduled for 2010.[10]

Mid-Atlantic Regional Spaceport

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 degrees and 60 degrees; other inclinations, including Sun-synchronous orbit (SSO), can be reached through in-flight maneuvers. The FAA issued a launch site operator 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, initially called the Virginia Space Flight Center. The agreement renamed the spaceport to MARS.

Pad 0-B

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.

Launch site infrastructure to support integration and launch of Orbital Sciences Corporation's (OSC) Taurus II launch vehicle and other mid-class launch vehicles is currently under development at MARS. OSC aims to conduct its first International Space Station-bound transportation demonstration flight from MARS in early 2011.[11] Approximately $75M in new processing and launch infrastructure are underway and will be completed by the end of 2010. In March 2009, the Virginia General Assembly approved $10-million in capital outlay to develop fueling support equipment, improvements to support buildings and services, and the development of a vehicle integration facility. The state legislature has committed $26-million in the past two years to the spaceport expansion.[12] Pad 0-A will be renovated in order to support the Taurus II class of vehicles. According to OSC, the Taurus II program is expected to create 125 jobs split between the Dulles and Wallops Island locations.[13]

OSC won a $1.9-billion contract from NASA for cargo re-supply services to the International Space Station (ISS). Under this contract, OSC will launch eight ISS cargo re-supply missions from MARS between 2011 and 2015 using the Taurus II launch vehicle.[14]

Developing the new mid-to-heavy class launch capability at MARS 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. This work started in 2009 with completion expected in mid- to late-2010.

On May 19, 2009, the Air Force Research Laboratory successfully launched TacSat-3 from MARS.[15]

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

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. In late 2007, the FAA instituted safety-related amendments to the Mojave Air and Space Port launch site operator license. The FAA approved EKAD's Launch and Recovery Site Boundaries, Mission Preparation Areas, and Energetic Liquids Storage Plan, November 2008.[16]

Mojave Air and Space Port	
Location	Mojave, California
Owner/Operator	East Kern Airport District (EKAD)
License Status	Active FAA launch site operator license.
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.

Hangar 161, one of the original hangars at Mojave Air and Space Port, was built by the Navy for the Mojave Marine Corps Auxiliary Air Station in 1942. The hangar was demolished in May 2008 in order to build a larger structure for the Mojave's National Test Pilot School.[17]

In August 2008, the East Kern Airport District qualified for a $1.7-million grant from the FAA to build an engine run-up pad adjacent to the approach to Runway 30 equipped with two tie-down points.[18] 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. Runway 30 was recently extended to 3,800 meters (12,500 feet) using another FAA grant. The district also received three other FAA grants this fiscal year. In 2009, upgrades were approved to rebuild paving at the airport general aviation T-hangars at the west end of the airport, upgrade utilities, and install a new and larger water line to provide for future expansion. These upgrades are scheduled to be completed by March 2010.[19]

Mojave was the site of Masten Space Systems qualification for first place of the Level Two of the Northrop Grumman Lunar Lander Challenge on October 30, 2009.[20]

Oklahoma Spaceport

In 1999, the Oklahoma state legislature created the Oklahoma Space Industry Development Authority (OSIDA). The mission of OSIDA was to establish a spaceport in Oklahoma and on June 12, 2006, the Oklahoma Spaceport received its Launch Site Operators license from the FAA. 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

OSIDA has struggled to generate business at the Oklahoma Spaceport in recent years mainly due to the setbacks with space tourism company, Rocketplane Global, but has managed to continue operations through more concentrated efforts within the aerospace field. OSIDA is working with the University of Oklahoma and Oklahoma State University to help establish Oklahoma as a center for unmanned aerial systems development. The Oklahoma Spaceport's infrastructure and access

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.

to special airspace are attractive for both spaceflight vehicle developers and unmanned systems.[21]

The Oklahoma Spaceport is the only spaceport with its own sub-orbital flight corridor strictly assigned to it. In July 2009, OSIDA executive director Bill Khourie stated that OSIDA has discussed the possibility of creating a point-to-point flight plan between the Oklahoma Spaceport and Spaceport America.[22] During the year Armadillo Aerospace conducted flight testing for its vertical takeoff and landing vehicles in competition for the Northrop Grumman Lunar Lander Challenge.[23]

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 development continues to progress after NMSA received a launch site operator license from the FAA in December 2008. On December 31, 2008, Governor Bill Richardson announced a 20-year lease agreement between Virgin Galactic and the State of New Mexico, with Spaceport America as the new world headquarters for Virgin Galactic.[24] Ground breaking for the spaceport occurred on June 19, 2009. A new 3,000-meter-long (10,000-foot) by 60-meter-wide (200-feet) runway is being built by David Montoya Construction, Inc., of Alameda, New Mexico. The runway is designed for day-to-day space tourism and payload launch operations and will be able to accommodate returning launch vehicles, fly-back rocket boosters, and other space launch and training vehicles. The runway is expected to be complete by late summer 2010.[25]

Runway construction

On October 10, 2009, Lockheed Martin Space Systems of Denver launched a proprietary rocket prototype from the spaceport, with UP Aerospace providing the launch services. The launch was reportedly successful and was the third time Lockheed has teamed with UP Aerospace.[26]

In November 2009, the New Mexico Spaceport Authority awarded a $32.5-million contract to Albuquerque-based Summit West to build Spaceport America's new terminal-hangar facility. The three-floor, 10,200-square-meter (110,000-square-foot) facility will serve as the headquarters of operations for Virgin Galactic,

considered the anchor-tenant company for the spaceport, as well as for the Spaceport Authority. Work began in mid-December 2009 and will finish within 12 months.[27]

On July 8, 2009, FNF New Mexico, LLC, of Albuquerque, NM, was awarded with the Site Enabling contract. FNF has experience in large-scale construction projects including airports and highway construction and will design and execute a plan to facilitate the spaceport construction. The activities include preparing the site for construction and coordination with all contractors for site security, dust control, and other crucial functions.[28]

Spaceport America	
Location	Upham, New Mexico
Owner/Operator	New Mexico Spaceport Authority (NMSA)
License Status	Active FAA launch site operator license
Description	A commercial spaceport in development that will support vertical and horizontal space launch.
Infrastructure	Current infrastructure includes a launch pad, weather station, rocket motor storage facilities, and trailers. Planned infrastructure includes a central control facility, runway, maintenance and integration facility, launch and recovery complex, and a cryogenic plant.

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 CCAFS and VAFB, the two major federal sites. These federal ranges also 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, located near Kennedy Space Center and the Space Florida Spaceport. 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.

Staff throughout the 45th Space Wing provide vital support, including weather forecasts, launch and range operations, safety, and public affairs. The wing also provides its vast network of radar, telemetry, optical, and communications instrumentation to facilitate a safe launch on the Eastern Range.[29]

Delta IV Heavy on SLC 37B

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

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.

mission partners, CCAFS processes a variety of satellites and launches them on Atlas V, Delta II, Delta IV, and the upcoming Falcon 9 vehicles.

2009 includes many highlights at CCAFS. Three Delta II launch vehicles deployed two GPS satellites and the STSS Demo satellites on-board. The Delta IV and Atlas V vehicles deployed two Wideband Global SATCOM satellites, the NRO L-26, the classified PAN satellite, and Intelsat-14.

Edwards Air Force Base

Atlantis takes off from EAFB

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 lakebed, 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.

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

Space Shuttles Atlantis and Discovery landed at Edwards during 2009. The U.S. Air Force's X-51A WaveRider vehicle, the fastest air-breathing, jet-fueled vehicle built in the U.S., is scheduled to fly from EAFB in 2010.[30] On December 18, 2009, the Stratospheric Observatory for Infrared Astronomy, a modified 747SP jet known as SOFIA, flew the first test flight from Edwards where the jet flew with a large door open on its side to allow its telescope to view the sky. More test flights from Edwards are planned for the airborne observatory in spring of 2010.[31]

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

Ares I-X rocket on pad 39B

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.[32]

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.[33]

Work on transition of KSC's Complex 39 to support the Constellation program has begun.[34] 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.[35]

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

In 2009, KSC finished upgrades to pad 39B to support launch of the Ares I-X test rocket. The upgrades included three 180-meter (600-feet) high lightning towers The Fixed Service Structure on pad 39A now features a V-shaped pair of arms to help stabilize the tall and skinny Ares I rocket. The Space Shuttle White Room, access arm for crew, and External Tank "beanie cap" vent were removed. Following the successful test of the Ares I-X the entire pad 39B is slated to be demolished and rebuilt.[36]

The KSC and Space Florida have partnered to enable developing a mixed-use technology and commerce park known as Exploration Park at Kennedy Space Center. Exploration Park will become home to diverse private sector technology and innovation enterprises, offering opportunities that support NASA's mission, grow and deploy U.S. commercial space capabilities, and respond to national priorities in science and technology. KSC has established a flexible, long-term area development plan for Exploration Park. The initial phase is soon to be under design/construction by Space Florida and its selected master developer, Pizzuti. Up to 29,300 square meters (315,000 square feet) of planned floor space will be available for research/lab facilities, processing and light manufacturing, and offices. In addition, NASA and Space Florida plan to incorporate the existing 9,300-square-meter (100,000-square-foot) Space Life Sciences Laboratory into the park, broadening the lab's accessibility and use beyond NASA.

Exploration Park is ideally located on KSC grounds in close proximity to launch, payload processing, and technical labs operated by NASA and by the U.S. Air

Force on neighboring Cape Canaveral Air Force Station. It offers easy and reliable 24/7 access for clients, workers, and visitors because it is located just outside the restricted access portion of KSC. The park is serviced with all necessary utilities and emergency services, and will offer sites ready for development and leases within dedicated or multi-tenant facilities.

NASA launched a Delta II carrying Kepler and an Atlas V carrying the Lunar Reconaissance Orbiter & Lunar Crater Observation and Sensing Satellite (LCROSS) in 2009. NASA successfully launched Space Shuttle missions STS-119, STS-125, STS-127, STS-128, and STS-129 during 2009. NASA also performed the successful launch of the Ares I-X suborbital test in October 2009.

Reagan Test Site

Falcon 1 launch from Omelek

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 and management of the facility was turned over to the Army in 1964. 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 operating under that name since 2001. 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.

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	The Reagan Test Site (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 2009, development continued on fiber connectivity to the continental U.S., specifically Redstone Arsenal in Huntsville, Alabama. The Kwajalein Space Operations Control Center (KSPOCC) in Huntsville supports space operations using satellites until the fiber installation is complete in mid-2010. At that time, customers will have the flexibility to conduct missions from either 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.

In July 2009, the RazakSAT satellite was successfully launched from Reagan Test Site by Flight 5 of the Falcon 1 launch vehicle.

Preparations are underway to support the larger Falcon 1e and Falcon 9 SpaceX vehicles in the near future.[37]

Vandenberg Air Force Base

Tower roll back at SLC-2

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, as far north 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.

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

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.

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.[38]

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.[39]

Vandenberg's launch range assisted in launching a Taurus XL carrying NASA's Orbiting Carbon Observatory in February 2009. VAFB's SLC-2 launched four Delta II vehicles in 2009 carrying the NOAA-N Prime weather satellite, the Missile

Defense Agency's Space Tracking and Surveillance System Advanced Technology Risk Reduction spacecraft, DigitalGlobe's WorldView-2 Earth imaging satellite, and NASA's WISE scientific satellite. An Atlas V launched from SLC-3 carrying a military weather satellite in October 2009.

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 NASA, DoD, and commercial rocket launches have taken place from the Wallops Flight Facility (WFF), which is operated for NASA by the Goddard Space Flight Center, Greenbelt, Maryland.

Wallops Flight Facility

The successful launch of TacSat-3 on May 19, 2009, marked Wallops' and the co-located Mid-Atlantic Regional Spaceport's third successful Minotaur I launch. On July 8, 2009, Wallops conducted a successful demonstration of NASA's Max Launch Abort System (MLAS), a technology test of an alternative concept for safely conducting an abort of the Orion Crew Module, in the event of a failure of the Ares I booster. In addition to several other major suborbital science missions, Wallops also launched NASA's Inflatable Reentry Vehicle Experiment (IRVE-2), a sounding rocket flight that carried the first successful demonstration of an inflatable ballute, a potential concept for either Earth or planetary reentry.

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

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).

Orion launch abort test pad

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.[40]

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. This program is developing rocket engine and propulsion technologies for future missions to the Moon and Mars.[41]

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.

Several demonstration flights for the Orbital Science's Orion launch abort system will take place at the White Sands Missile Range. In March 2009, NASA completed work on a launch complex that will serve as the test site for the Orion launch abort system. The first launch abort system test is scheduled for early 2010.[42]

Proposed Spaceports

Eight 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. While some proposed spaceports are focused on offering facilities for launch into space as soon as possible, other spaceports are focusing on facilities to provide public spaceflight education with plans for hosting spaceflights in the long-term. This year new profiles have been added for proposed spaceports in Hawaii and Indiana. Spaceport supporters in North Carolina have discussed the possibility of creating a spaceport within the state but their efforts are in the early stages.[43]

Space Florida 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.

RLV hangar, Space Florida Spaceport

The U.S. Air Force's Space and Missile Systems Center / Space Development and Test Wing (SMC/SDTW) at Kirtland AFB, NM released a Request for Proposal in late May 2009. They had identified Florida as one of four states pre-qualified to respond to the two task orders identified to provide launch facilities, launch site, operations support, range and range integration support, logistics support, facility engineering, and program support for Minotaur V launches. Space Florida provided a proposal response at the end of June to provide LC-46 and Area 57

Solid Motor Processing Area for launch and processing. This proposal is currently being evaluated.[44]

In June 2009, Space Florida and United Launch Alliance (ULA) completed a refinancing of the outstanding conduit debt on Launch Complex 41 (LC-41) at Cape Canaveral Air Force Station. This transaction was concurrent with the transfer of the ground lease with the U.S. Air Force from Lockheed Martin to ULA. Approximately $92-million in outstanding debt was refinanced, with liability for repayment transferred from Lockheed Martin to ULA.[45]

Space Florida Spaceport	
Location	Cape Canaveral, Florida
Owner/Operator	Space Florida
License Status	Space Florida's license application is in process for Launch Complex-46 and the application for Launch Complex-36 is drafted
Description	Launch sites for vertical take-off commercial launch vehicles. Space Florida received $4 million in direct state appropriations to support its operations for fiscal year 2009.
Infrastructure	Three commercial orbital launch complexes 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 5,200-square-meter (50,000-square-foot) RLV support hangar adjacent to the KSC Shuttle Landing Facility runway, and a 9,290-square-meter (100,000-square-foot) Space Life Sciences Lab at KSC.

Space Florida provided SpaceX with several surplus NASA pressure vessels in 2009. Space Florida paid to relocate the pressure vessels from Santa Susanna, California, to LC-40. SpaceX was awarded a contract under NASA's Commercial Resupply Service (CRS) valued at $1.6 billion for 12 cargo flights to the International Space Station over six years. Space Florida has under active consideration several requests from SpaceX for additional financial assistance to prepare LC-40 for these flights, and will work with the Florida Legislature and the U.S. Congress in 2010 to identify additional ways and means for supporting these requests.[46]

NASA's Kennedy Space Center and Space Florida have partnered to enable the development of a mixed-use technology and commerce park known as Exploration Park at Kennedy Space Center. Exploration Park will become home to diverse private sector technology and innovation enterprises, offering opportunities that support NASA's mission, grow and deploy U.S. commercial space capabilities, and respond to national priorities in science and technology.[47]

KSC has established a flexible, long-term area development plan for Exploration Park. The initial phase is soon to be under design and construction by Space Florida and its selected Master Developer, Pizzuti. Up to 29,300 square meters (315,000 square feet) of planned floor space will be available for research/lab facilities, processing and light manufacturing, and offices. In addition, NASA and Space Florida plan to incorporate the existing 9,300-square-meter (100,000-square-foot) Space Life Sciences Laboratory into the park, broadening the lab's accessibility and use beyond NASA. Exploration Park is ideally located on KSC grounds in close proximity to launch, payload processing, and technical labs operated by NASA and by the U.S. Air Force on neighboring Cape Canaveral Air Force Station. It offers easy and reliable 24/7 access for clients, workers, and visitors because it is located just outside the restricted access portion of KSC. The park is serviced with all necessary utilities and emergency services, and will offer sites ready for development or leases within dedicated or multi-tenant facilities.[48]

Space Florida entered into a joint venture agreement in March 2009 with Astrotech, a provider of payload integration services for the military, NASA, and commercial markets. This agreement provides the framework for Space Florida and Astrotech to engage in collaborative ventures that will result in more space-related business for Florida. Possibilities include:

- A "turn-key" type service for commercial satellite operators, allowing the operator to procure payload integration and launch services in one bundled package;
- Outsourcing operation of commercial satellites on orbit; and
- A mechanism to use Space Florida's status as an Independent Special District of the state to procure/provide some type of secondary reinsurance for commercial payloads launched from Florida.

Spaceport Hawaii

Spaceport Hawaii	
Location	Kona International Airport, Keahole, Hawaii
Owner/Operator	Hawaiian Office of Aerospace Development
License Status	State legislature has allocated $250,000 to fund license application
Description	Spaceport Hawaii is exploring two options: a commercial suborbital space tourism launch site; and/or a suborbital point-to-point transportation service connecting two Hawaiian islands
Infrastructure	A main runway at Kona International Airport; possibly a secondary takeoff and landing runway at Kalaeloa Airport on the island of Oahu featuring a visitor's center, space camp, and flight simulators

In July 2009, Hawaiian lawmakers approved $250,000 in funding to develop a launch site.[49] This marked the first step in what is expected to be a multi-year process of environmental impact analyses and community impact surveys that spaceport proponents hope will result in establishing Spaceport Hawaii.[50] Spaceport planners are currently considering two main options. The first would be a commercial suborbital space tourism site, where space vehicles would lift off and land on the same runway, most likely a converted airstrip at Kona International Airport in Keahole, Hawaii (on the "Big Island"). The second option would be the world's first infrastructure for suborbital point-to-point travel. Vehicles would depart from Kona International Airport, ascend to a suborbital altitude of 105 kilometers (65 miles), and land approximately 550 kilometers (340 miles) to the west at Kalaeloa Airport on the island of O'ahu 45 minutes later.[51] This second option is seen as a possible prelude to regular trans-Pacific suborbital point-to-point travel—for instance, flights from Hawaii to Tokyo with greatly reduced travel times.

Rocketplane Global has expressed early interest in serving the suborbital point-to-point route using its proposed Rocketplane XP vehicle. Rocketplane's plan calls for a Spaceport Hawaii Visitor's Center at Kalaeloa Airport, featuring a space camp, flight simulators, and other space exhibits.[52]

Space Port Indiana

In May 2008, Space Port Indiana™, Inc. (SPI) began conducting rocket launches from its facilities, and offering opportunities for various types of tests including microgravity, radiation hardened testing, power systems, and rocket engines. It also conducts regularly scheduled high altitude balloon launches and heavy lifting balloon launches are also available. Space Port Indiana™, Inc. also conducts high altitude tests of equipment and suits to be worn by commercial space travelers. In a partnership with the Purdue College of Technology-Columbus, the National Centre for Future Space Exploration was formed and is located in Columbus, Indiana.[53]

Space Port Indiana	
Location	Columbus, Indiana
Owner/Operator	Space Port Indiana, Inc.
License Status	State legislature has allocated $250,000 to fund license application
Description	Space Port Indiana is designed to offer military, industry, and educational organization low cost access to a safe, secure, and equipped location to test ground, air and near space activities.
Infrastructure	Located at the Columbus Municipal Airport with access to controlled airspace and adjacent special use Airspace, a rocket test cell that can accommodate up to 13,000 newtons (3,000 pounds of thrust), and telemetry, tracking, GPS, communications, guidance, and air space management tools.

The National Centre for Future Space Exploration was created to serve as a pipeline for the people of Indiana to gain skills and employment in an industry that will require ground operations, tracking, telemetry, payload integration, environmental services, and a host of other skills. The curriculum offered by the Centre will support the needs of industry including OEMs, airports, DHS, FEMA, and military agencies.[54] On November 23, the Commercial Spaceflight Federation announced the formation of the Spaceports Council, of which Space Port Indiana™, Inc. is a member.

Spaceport Sheboygan

On August 29, 2000, the Wisconsin Department of Transportation officially approved creating 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. The centerpiece of Spaceport Sheboygan will be the proposed Great Lakes Aerospace Science & Education Center (GLASEC). This facility is proposed to use the Sheboygan armory and provide 4,600 square meters (50,000 square feet) of space to provide space travel, math, and science oriented education center. The center will include hands-on multi-sensory exhibits, a theatre and planetarium, and a mission control facility that will provide simulated space missions from launch to landing. By December 2009, five million dollars has been raised of the $11 million to open GLASEC.[55]

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. Currently,

Rockets for Schools is a volunteer run program of the Great Lakes Spaceport Education Foundation. Over 1,500 kids participated in activities at the Spaceport Sheboygan site.

The Wisconsin Aerospace Authority (WAA) was created in 2006 and is tasked with promoting the aerospace industry and education for the aerospace sector in Wisconsin, as well as the creation of and promotion of a spaceport in Sheboygan. Although Spaceport Sheboygan is currently focused on education, in the long-term supporters hope the facility could be used to launch vehicles into space. The WAA held a press conference as part of the Rockets for Schools event, in May 2009, announcing the release of their Strategic Plan and a student logo design contest. The WAA Board met last in October 2009.[56]

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 education and tourism. Plans for developing additional launch infrastructure are ongoing and include creating a development plan that includes support for additional suborbital and future orbital RLV operations. Sheboygan is located near an airport and has access to "restricted airspace over Lake Michigan.

Inactive Spaceports

The following proposed spaceports have shown interest in developing spaceflight infrastructure but have not announced significant progress in recent years.

Inactive Spaceports	
Chugwater Spaceport	
Location	Platte Country, Wyoming
Owner/Operator	Private Owner
License Status	Have not applied
Description	A private decommissioned Atlas-E launch site used by a number of small companies to develop and test rocket equipment.
Infrastructure	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. No updates reported in 2009.
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. 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
Infrastructure	Road, fire hydrants, metal building with offices and bathrooms, and a concrete slab.

Inactive Spaceports (Cont'd)	
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 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.
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.

COMMERCIAL HUMAN SPACEFLIGHT TRAINING

Introduction

Commercial human spaceflight vehicles under development are stimulating interest in training services for flight crew and participants. Within the United States, a handful of training services are emerging. These organizations offer a range of services including medical screening and flight preparation, flight simulation training, flights in high performance aircraft, devices that simulate the stresses of space launch and re-entry, or zero-g (gravity) parabola flights that simulate microgravity. This chapter focuses on the capabilities and milestones developed in 2009 for organizations that are creating 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 are designed to help prepare and screen spaceflight participants. Finally, training is offered as entertainment for those seeking to experience simulated spaceflight or the astronaut training experience. This chapter includes organizations that focus on one or more types of training.

Aurora Aerospace

Aurora Aerospace offers customized courses on spaceflight training and medical screening for spaceflight.[1] These courses are 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 spatial disorientation training in a multi-axis disorientation machine ("MAD Machine") and a spacecraft simulator where students can learn orbital and suborbital flight procedures. High altitude/hypoxia training is offered as a standalone training option for pilots. Aurora Aerospace facilities and equipment include an L-39 Albatross jet, Rockwell 700 Zero Gravity aircraft, "MAD Machine," and a spacecraft simulator with hypoxia/high altitude equipment. Aurora Aerospace also offers type ratings in their L-39 jet as well as upset training for pilots.

A zero-gravity flight

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, High Altitude/Hypoxia Training, Spatial Disorientation Training, Simulator Training, Unusual Attitude Training, High-g (gravity), and High Performance Glider Training.

The company officially launched its full range of space training services at the 2009 Space Investment Summit in association with the National Space Society. Aurora Aerospace donated free space training to the Space Frontier's Foundation New Space 2009 auction and a "Space Camp Day" for CAP cadets. The organization attended public events such as Sun'n Fun and various air shows and the 2009 Aircraft Owners and Pilots Association (AOPA) Aviation Summit. Aurora Aerospace was recognized as the official space training facility for the non-profit organization "Americans-in-Orbit 50 Years".

Barrios Technology

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 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]

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.

Civilian Aero and Space Training Academy

The company began operating in the state of Washington on October 4, 2006, and has plans for highly reusable launch vehicle operations at the proposed Washington Spaceport. In 2008, the Civilian Aero and Space Training Academy (CASTA) entered into a joint venture to use an existing centrifuge with multi-RLV platform simulation and spatial disorientation training software.

In 2009, CASTA expanded its six-day training program in a joint venture with Alphajetsusa.com and added a wilderness survival training program using helicopter drop off. CASTA developed a zero-gravity flight program in house under Title 14 Part 91 of the Code of Federal Regulations. CASTA now offers access to supersonic and training jets that provide high-G/high-altitude flights. Training on

Wilderness training helicopter

helicopters, gliders, and other light aircraft following traditional American and Russian methods are still offered. Each six-day CASTA training 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 an FAA flight surgeon before graduation, and qualification certificates will be issued.[3]

Location	Arlington, Paine Field, and Moses Lake, Washington
Company Description	The Civilian Aero and Space Training Academy (CASTA), under the direction of D 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, parachute training, and FAA medical screening.

Executive Aerospace Physiology Training

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 30,000 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.

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 consultations.

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. He has served on national and international panels advising NASA on 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.[4]

IEEM investigators have been actively involved in almost every dedicated life-sciences mission on the Space Shuttle, as well as the largest medical experiment in the International Space Station.

FAA Civil Aerospace Medical Institute (CAMI)

The Federal Aviation Administration's Civil Aerospace Medical Institute's (CAMI) Aerospace Medical Education Division is responsible for: 1) Safety-related education programs in aerospace physiology, global survival, cabin safety, and human factors, 2) Aerospace medical publications and other didactic materials (training manuals, multimedia products, presentation materials, etc.) used to disseminate medical/human factors information to promote aerospace safety, 3) A highly specialized aerospace medical library, 4) A centralized program for the selection, designation, training, and management of Aviation Medical Examiners appointed to conduct physical examinations and issue FAA medical certificates to civil pilots (including commercial space crews) throughout the U.S. and around the world.

CAMI's Aerospace Human Factors Research Division conducts an integrated program of field and laboratory performance research on organizational and human factors aspects of aerospace work environments. Research includes, but is not limited to, human performance under various conditions of impairment, human error analysis and remediation, impact of advanced automated systems on personnel requirements and performance, human factors evaluations of performance changes associated with advanced multifunction displays and controls, and the psycho-physiological effects of workload and work scheduling on job proficiency and safety in aerospace human-machine systems.

Location	Oklahoma City, Oklahoma
Organization Description	The mission of the Federal Aviation Administration's Civil Aerospace Medical Institute (CAMI) is to create, apply, manage, and transfer aerospace medicine and human factors knowledge. CAMI's vision is to advance flight safety through world leadership in aerospace medicine. CAMI is part of the the Office of Aerospace Medicine and is located at the Mike Monroney Aeronautical Center (MMAC) in Oklahoma City, Oklahoma.
Overview of Services	CAMI provides services in aerospace medical/safety/human factors education, medical certification, human factors research, medical research, and occupational health. These aerospace services are provided by a workforce including biologists, computer specialists, engineers, nurses, physicians, physiologists, psychologists, and other professional and technical personnel.

The Aerospace Medical Research Division: 1) Evaluates human performance and safety (including safety, security and health) in aerospace environments, both simulated and actual, by applying multidisciplinary medical, physiological, pharmacological, bioengineering, and biochemical/molecular studies, 2) Conducts protection and survival research, 3) Conducts research related to improving performance, and 4) May participate in select onsite visits to investigate and analyze major problem areas associated with the human in the aerospace environment.

Through FAA Cooperative Research Development Agreements (CRDA), CAMI can share facilities, equipment, services, intellectual property, personnel resources and other cooperation with private industry, academia, or state/local government agencies. CRDAs are implemented to develop an idea, prototype, process, or product for direct application to the civil aerospace community and/or indirect application for commercial exploitation.

CAMI provides an aviation physiology DVD course and offers a one-day physiological training course at the FAA Mike Monroney Aeronautical Center in

Oklahoma City, OK. The following topics are covered during the training course:

- Physics of the atmosphere
- Respiration and circulation
- Inflight decompression effects
- Self-imposed stress
- Hypoxia
- Hyperventilation
- Acceleration, noise, vibration & thermal effects
- Pressure equalization difficulties & trapped gases
- Aviation oxygen equipment
- Altitude chamber and aviation oxygen equipment familiarization
- Altitude chamber flight including rapid decompression and hypoxia demonstrations
- Spatial orientation and disorientation demonstration using a Barany Chair, GAT-II, GAT-II HELO, Gyro-I, Gyro-II, or VRSDD

FAA physiological training courses are also offered at the following locations:

- Andrews AFB, MD
- Beale AFB, CA
- Brooks AFB, TX
- Columbus AFB, MS
- Fairchild AFB, WA
- Ft. Rucker, AL
- Holloman AFB, NM
- Langley AFB, VA
- Little Rock AFB, AR
- Moody AFB, GA
- Peterson AFB, CO
- Randolph AFB, TX
- Shaw AFB, SC
- Tyndall AFB, FL
- Vance AFB, OK

CAMI also provides an aviation survival DVD course and offers a one-day aviation survival training course. The following topics are covered during the training course:

- Surviving a crash
- Psychology of survival
- Survival medicine
- Signaling equipment and techniques
- Fire starting equipment and techniques
- Obtaining food and water
- Emergency shelter
- Hot-land survival procedures
- Cold-land survival procedures
- Water survival procedures
- Post-crash emergency evacuation procedures
- Assembling customized survival kits
- Cold survival demonstration using an indoor cold exposure facility
- Emergency cabin evacuation/egress demonstration using a re-configurable evacuation facility
- Emergency water ditching demonstration using an indoor water egress facility

Evacuation research

During 2009, CAMI provided safety-related training to more then 6,000 students and implemented the following new capabilities: 1) A portable multi-place normobaric hypoxia demonstration facility to support user requests for hypoxia training anywhere across the U.S., 2) Portable fixed-based flight simulators (fixed-wing and rotary-wing) to support user requests for practical demonstrations on the effects of hypoxia and/or alcohol consumption during flight, 3) A Night Vision Goggle (NVG) facility to provide NVG familiarization workshops of civil aerospace personnel, and 4) An aerospace medicine/physiology/human factors course curriculum in support of commercial space transportation stakeholders.

National Aerospace Training and Research (NASTAR™) Center

Spaceflight simulation

The National Aerospace Training and Research (NASTAR™) Center's (NASTAR) equipment and training curriculum can accommodate a range of training and research requirements. Academic instruction is provided by experienced industry professionals and incorporates advanced simulation technology for interactive, "hands on" training. NASTAR Center can offer the services of its in-house Institutional Review Board and can provide human test subjects. The NASTAR Center facilities include: classroom, control room, theatre room, VIP/observation lounge, high performance human centrifuge with interchangeable cockpits, spatial disorientation / upset recovery simulator, general aviation trainer, 4+2 degrees of freedom flight simulator, hypobaric chamber, hyperbaric chamber, ejection seat simulator, advanced disaster management simulator, and a night vision and night vision goggle trainer.

The NASTAR Center is the Official Space Training Provider to commercial space flight company Virgin Galactic, having trained over 150 space flight passengers since 2007.[5] NASTAR hosts "Orange Flag" events where international and domestic military pilots can fly simulated air combat engagements. The NASTAR Center's AeroMedical Training Institute (AMTI) conducts training for international physicians and aeromedical instructors and has provided training to 87 countries worldwide. NASTAR Center has performed upset recovery research in contracts for the

Location	Southampton, Pennsylvania
Company Description	The National AeroSpace Training And Research (NASTAR) Center (www.nastarcenter.com) is a non-government aerospace training facility that houses high performance simulation equipment and offers training courseware and professional services to support the research and educational needs of the aerospace industry.
Overview of Services	1. Flight Training: Rapid & Sustained G Acceleration (Multi-axis), Medical Screening, Sub-Orbital Space Flight Training, Spatial Disorientation Training, Aircraft Upset Recovery (Loss of Control) Training, Tactical Flight Simulation & Training, Motion Desensitization, High Altitude Exposure and Rapid Decompression Training, Ejection Seat / Emergency Egress Training, Night Vision and Night Vision Goggle Training, Land/Water Survival Training, and the Space Training System Model 400 (STS-400). 2. Human Factors & Component Research: Research can be supported on all equipment including Medical Monitoring, Flight Profile Development & Test, Combined Environments Testing (Sustained G with Vibration) for HF and Component, and Hyperbaric Research Lab. 3. Educational and Entertainment programs are available for all ages.

FAA and NASA. NASTAR is the first spaceflight training organization to apply for an FAA Safety Approval. The FAA is evaluating this application for NASTAR's Space Training Simulator (STS-400). NASTAR Center has introduced science, technology, engineering, and math programming for K-12 local school districts and has launched new space education courses with the International Space University.

Orbital Commerce Project

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, Altitude Chamber (hypobaric), Unusual, Attitude Training, High-g (gravity), High Altitude Flight, Pressure, Suit Training, High Performance Glider, and High Performance Jet.

Orbital Commerce Project (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 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.[6] In February of 2009, OCP completed all requirements of the RocketShip Tours Space Tourism University and will be offering tickets for flights on the XCOR Aerospace-developed Lynx suborbital rocket vehicle.[7]

Project Odyssey – Space Florida and Andrews Institute

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 Florida and the Andrews Institute for Orthopedics and Sports Medicine announced a partnership in December 2008 to offer medical diagnostic and training services to private spaceflight passengers and crewmembers.[8] 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.[9] The list of organizations that are now cooperating in support of Project Odyssey currently 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.

The vision for Project Odyssey is for the program to be recognized as the definitive world leader in optimizing human performance in both orbital and suborbital spaceflight environments. The mission of Project Odyssey is to capture a large share of the international market for educating and training the passengers and crewmembers of commercial and civil space flight participants in the orbital and suborbital space flight markets. This would include gold-standard biomedical, physiological, and psychological assessment and conditioning, as well as exposure to certain environmental factors that are intrinsic to human spaceflight. According to a Space Florida representative, there are no major updates for Project Odyssey in 2009.[10]

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. In 2009, Space Medicine Associates worked to establish relationships with organizations within the commercial human spaceflight industry.[11]

Starfighters Aerospace

Starfighters Aerospace (a flight services corporation), operates a fleet of former military aircraft, notably the two-seat Lockheed Martin F-104 Starfighter and two-seat Northrop - Grumman T-38 Talon, both airframes NASA used for astronaut space flight training that total more than 80 years of service.[12]

Starfighters trainer

For 15 years, Starfighters Aerospace has operated high performance aircraft, totaling some 3,000+ sorties with a 99.3% Fully Mission Capable (FMC) rate during contract flights for the United States Navy, Air Force, and NASA. The flight services corporation are subject to both annual and bi-annual flight reviews by the Federal Aviation Administration, the Department of Defense, NASA's Kennedy Space Center in Florida, Johnson Space Center in Texas, and Wallops Flight Facility in Virginia.[13] Starfighters Aerospace's commitment to safety has ensured 4,500+ flight hours have remained incident free.

In October 2009, Starfighters Aerospace and Space Florida announced the formal signing of a Space Act Agreement with NASA enabling Starfighters to use the Shuttle Landing Facility to conduct daily flight operations for commercial purposes. The agreement also generally supports research and development, test, and

engineering to benefit the emerging commercial space industry and to advance aerospace and space related technology in Florida.[14]

Location	NASA John F. Kennedy Space Center, Florida
Company Description	Starfighters Aerospace is a flight services organization that conducts training flights in supersonic former military aircraft for the Department of Defense and both commercial and private industry.
Overview of Services	Commercial services: High Performance Jet (Supersonic Flight), High Altitude Flight, High-G Flight (Gravity), Unusual Attitude / Upset Recovery Training, Micro-Satellite Air Launch, Aerospace Medical Evaluation, Flight Physiology Training, Altitude Chamber (Hypobaric), Aircrew Life Support & Egress / Ejection Systems Training, Parachute Training, Pressure Suit Training. Department of defense services: Offensive & Defensive Counter Air, Advanced Electronic Jamming, WIC Support, NSAWC / Top Gun / SFTI, Large Force Exercise Participation (Flags), High Altitude Interception, Carrier Battle Group Threat Simulation / Ship Self Defense Targeting.

Starfighters Aerospace currently offers a four-day commercial space flight training program at Kennedy Space Center. The course consists of two days of classroom instruction and safety briefings using modern training equipment to prepare and qualify students for a supersonic training flight in the F-104 Starfighter on day three. The F-104 flight profile is designed to simulate a journey to the edge of space and includes a maximum performance vertical climb and maneuvers that replicate the mid range g-forces (Gz and Gx) and weightlessness of space travel.

United Space Alliance LLC and USA Space Operations LLC

Headquartered in Houston, Texas, United Space Alliance (USA) was established in 1996 as a limited liability company. USA 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.

Flight crew training

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 to 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.

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 , deorbit, and entry
- Complex on-orbit assembly and repair
- Landing and post-landing

USA and its 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 spaceflight 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.[15]

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.

In addition to USA training facilities and equipment, USA continues to develop Questus™, a new and innovative technology designed to improve productivity and lower overall life cycle costs. Questus™ is an integrated web-based tool-set that implements or facilitates end-to-end ground and flight 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.

Significant 2009 training related accomplishments include: (1) training of all astronauts, flight controllers, and ground support personnel assigned to shuttle and ISS missions that flew in 2009 and will fly in 2010, (2) training of flight controllers and ground personnel assigned to the successful Ares-1X test flight, (3) deployment of the Questus™ INSTRU™ scheduling tool in support of the NASA Desert Rats training and simulation exercise in Arizona, and (4) extensive training support (plans, capabilities development, and implementation) to the NASA human Exploration Program via the Integrated Mission Operations Contract (IMOC) and the Facilities Development Operations Contract (FDOC).[16]

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.[17] Wyle has also supported several of the Space Adventures clients who have flown to the International Space Station.

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 Integrated Science and Engineering 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, and 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. In 2009, NASA exercised a $201-million second option on its bioastronautics contract with Wyle. The option is an extension of the previous contract until April 30, 2013. The extension assumes that Space Shuttle will be retired and no longer supported.[18]

Zero Gravity Corporation

G-FORCE ONE

ZERO-G offers a unique opportunity for individuals to experience true "weightlessness" without going to space. ZERO-G flies a specially 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. ZERO-G's aircraft has gone through additional modifications to meet NASA's requirements and has since conducted over 30 flights for NASA's research.

Location	Vienna, Virginia
Company Description	Founded in 1993, Zero Gravity Corporation (ZERO-G) is a privately held space entertainment and tourism company whose mission is to make the excitement and adventure of space accessible to the public. ZERO-G has since flown more than 6,000 passengers aboard 240 flights.
Overview of Services	ZERO-G was awarded a contract by NASA to conduct research and training on board its Boeing 727-200. ZERO-G provides variety of programs including education, research, corporate incentives, and promotion. ZERO-G has astronauts and former NASA KC-135 employees on staff.

In 2009, ZERO-G teamed up with Northrop Grumman Foundation for the fourth consecutive year to provide its education program to more than 120 educators in four cities. To date, the program has provided its training to more than 1000 educators from 50 states and 22 countries.[19]

REGULATORY AND LEGISLATIVE DEVELOPMENTS

The FAA Office of Commercial Space Transportation has accepted the challenge of two new programs in 2009. These programs will allow a new level of encouragement and facilitation that the office can offer the commercial space transportation industry.

The two programs are:

- Center of Excellence for Commercial Space Transportation
- Commercial Space Grant Program

Center of Excellence for Commercial Space Transportation

Background

On August 18, 2009, FAA Administrator Randy Babbitt approved the creation of a Center of Excellence for Commercial Space Transportation (COE CST). The office of primary interest for COE CST is the FAA Office of Commercial Space Transportation (AST). The goal for this COE is to create a cost sharing partnership of academia, industry, and government that will focus research areas of interest to the FAA and the U.S. commercial space transportation industry as a whole. AST had proposed research in four major commercial space transportation areas: space traffic management and operations, launch vehicle systems, private human space flight, and space commerce.

Based on the FAA COE structure, the COE CST is planned to be funded at a level of $1 million annually for 10 years. According to the FAA COE authorizing legislation, COE members are required to match the federal grant funding from industry sources to support their COE research activities.

Research Areas

The four major research areas for the COE CST will address specific topics:

Space Traffic Management and Operations

- Emergency Response
- Ground Safety
- Spaceports
- Space Traffic Control
- Training
- Space Environment

Launch Vehicle Systems

- Safety Management and Engineering

- Flight Safety Analysis
- Avionics
- Flight Safety Systems
- Materials
- Sensors
- Software Safety
- Testing
- Vehicle Design

Human Space Flight

- Aerospace Physiology
- Environmental Control and Life Support Systems and Habitability
- Human Factors
- Personnel Training
- Space Medicine

Space Commerce

- Business
- Law
- Regulation
- Policy
- International Competitiveness

Commercial Space Grant Program

A core mission of the Office of Commercial Space Transportation (AST) is "to encourage, facilitate, and promote U.S. commercial space transportation." In the past, the office has addressed this mission in a variety of ways. However, Congress recently appropriated funding for the FAA to facilitate the commercial space transportation industry through a grant program. The intent is to provide Federal funding to encourage the development of commercial space infrastructure and capabilities.

Background

In July 1994, the United States Congress authorized expending up to $10,000,000 to support the development of non-federal commercial spaceports. The vehicle for this support is specified as a Space Transportation Infrastructure Grant under the auspices of the Federal Aviation Administration. While a program was authorized by Congress, funding was never appropriated.

Congress took no further action until passage of the Fiscal Year 2010 appropriation bill, which identified $500,000 to begin funding this effort.

The authorization falls under Title 49 USC, Subtitle IX – Commercial Space Transportation – Chapter 703 – Space Transportation Infrastructure Matching Grants, Section 70305, Authorization of appropriations.

Under current law, not more than $10,000,000 may be appropriated to the Secretary of Transportation to make grants under this chapter. Amounts appropriated under this section remain available until expended. (Source: Pub. L. 103-272, Sec. 1(e), July 5, 1994, 108 Stat. 1345.)

A Grant Program

On December 13, 2009, Congress passed appropriations legislation (P.L. 111-117) that launched the Commercial Space Grant program with $500,000 appropriated for the first year. The legislation was signed into law on December 16, 2009.

States and public agencies may now submit applications to the FAA AST to propose projects that the appropriation might fund. There are some conditions attached to this funding. The FAA may make a project grant only if:

- At least 10 percent of the total cost of the project will be paid by the private sector, and
- The grant will not be for more than 50 percent of the total cost of the project

In addition, the authorizing legislation directs that the FAA consider:

- The contribution of the project to industry capabilities that serve the United States Government's space transportation needs
- The extent of industry's financial contribution to the project
- The extent of industry's participation in the project
- The positive impact of the project on the international competitiveness of the United States space transportation industry
- The extent of State local government, or non-profit agency contributions to the project
- The impact of the project on launch operations and other activities at Government launch ranges

The FAA's Office of Commercial Space Transportation will publish a notice in the Federal Register announcing the establishment of this grant program and the availability of grant application information and resources. The notice also will outline the application process. An informational guide on the process for applying for a grant and a handbook outlining the program will be published to the AST's website: faa.ast.gov.

For further information on the program, questions on the application process please contact the Federal Aviation Administration, Office of Commercial Space Transportation Suite 331, 800 Independence Ave S.W., Washington D.C. 20591

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PHOTO CREDITS

Cover art lower image:
Inside Spaceport Terminal, courtesy of URS/Foster+Partners

Page 9 Google Lunar X PRIZE LEGO MINDSTORMS challenge poster, courtesy of Google Lunar X PRIZE

Page 10 Masten Team's qualifying level 2 completion, courtesy of X PRIZE Foundation

Page 11 Winning teams at NGLLC awards ceremony, courtesy of X PRIZE Foundation

Page 11 A view of the excavators awaiting their opportunity to perform, courtesy of NASA

Page 12 KC Space Pirates prepare to launch their climber, courtesy of NASA

Page 12 Torque test being performed on the glove designed by Ted Southern, courtesy of NASA

Page 13 Atlas V, courtesy of United Launch Alliance

Page 15 Delta II, courtesy of United Launch Alliance

Page 15 Delta IV, courtesy of United Launch Alliance

Page 16 Falcon 1, courtesy of Space Exploration Technologies Corporation (SpaceX)

Page 16 Minotaur I, courtesy of Orbital Sciences Corporation

Page 17 Pegasus XL rocket and Stargazer carrier aircraft, courtesy of Orbital Sciences Corporation

Page 17 Taurus, courtesy of Orbital Sciences Corporation

Page 18 Zenit 3SL lifts off from Odyssey Launch Platform, courtesy of Sea Launch Company, LLC

Page 19 Cutaway view of Eaglet and Eagle, courtesy of E'Prime Aerospace

Page 20 Falcon 9, courtesy of Space Exploration Technologies Corporation (SpaceX)

Page 22 Prospector-13A Test Flight, courtesy of Garvey Spacecraft Corporation

Page 23 NEPTUNE design concept, courtesy of Interorbital Systems

Page 24 Minotaur IV, courtesy of Orbital Sciences Corporation

Page 25 Horizontal Test Stand (HTS-2), courtesy of AirLaunch LLC

Page 26 Taurus II in flight (artist's rendering), courtesy of Orbital Sciences Corporation

Page 27 Ares 1-X Launch, October 2009, courtesy of NASA

Page 28 Artist conception of Ares V, courtesy of NASA

Page 29 Black Brant V sounding rocket, courtesy of Bristol Aerospace Limited

Page 30 Oriole sounding rocket, courtesy of DTI Associates

Page 31 Spaceloft XL, courtesy of UP Aerospace

Page 31 A Shadow I sounding rocket launches from a French naval vessel, courtesy of Lunar Rocket and Rover Company

Page 32 Terrier Orion sounding rocket, courtesy of DTI Associates

Page 33 Scorpius Super Mod, courtesy of Armadillo Aerospace

Page 34 Blue Origin's Goddard prototype vehicle on launch pad in 2006, courtesy of Blue Origin

Page 35 The XA0.1E Xoie vehicle after completing one leg of the Level Two NGLLC, courtesy of 2009 Nothroup Grumman Lunar Lander Challenge

Page 36 SilverDart quarter-scale prototype, courtesy of PlanetSpace

Page 36 Artist's conception of RocketplaneXP, courtesy of Rocketplane Global

Page 37 SpaceShipTwo and WhiteKnightTwo, courtesy of Virgin Galactic

Page 38 DreamChaser and Atlas V, design concept, courtesy of SpaceDev

Page 39 Laramie Rose, courtesy of SpeedUp

Page 39 MICHELLE-B Concept, courtesy of TGV Rockets

Page 40 Unreasonable Rocket's Silver Ball prototype, courtesy of Unreasonable Rocket

Page 40 Lynx windtunnel model with U.S. quarter (for scale), courtesy of XCOR Aerospace

Page 41 Space Shuttle on launch pad, courtesy of NASA

Page 43 Artist rendition of the Ares V departure stage in orbit with the Orion capsule docked with the Altair lander, courtesy of NASA/MSFC

Page 44 Concept of the abort flight tests of the Orion crew exploration vehicle's launch abort system at the White Sands Missile Range in New Mexico, courtesy of NASA

Page 46 The SpaceX Dragon Lab vehicle in orbit, courtesy of SpaceX

Page 47 Artist rendition of Orbital's Cygnus spacecraft approaching the ISS, courtesy of Orbital Sciences

Page 48 Artist's concept of an X-37 vehicle, similar to the X-37B in development, courtesy of NASA/MSFC

Page 49 Artist rendition of Bigelow's planned space complex in orbit, courtesy of Bigelow Aerospace

Page 51 Display model of a proposed FAST booster, courtesy of Air Force Research Lab

Page 52 Testing of SpaceX's PICA heat shield material, courtesy of SpaceX

Page 52 Microcosm's composite propellant tank, courtesy of Microcosm

Page 53 The VASIMR engine, courtesy of AdAstra

Page 54 SpeedUp's Laramie Rose prototype vehicle, courtesy of SpeedUp

Page 54 ATK's September 10 test of the 5-segement solid rocket booster Courtesy of ATK

Page 55 Test runs of the Firestar monoprop engine, courtesy of Firestar

Page 55 Garvey Aerospace's P-13 rocket, courtesy of Garvey Spacecraft Corp.

Page 56 The J-2X engine, courtesy of Pratt & Whitney Rocketdyne, Inc.

Page 57 The Merlin 1C Vaccum engine on the test stand, courtesy of SpaceX

Page 57 Microcosm's ablatively-cooled engine, courtesy of Microcosm

Page 58 ATK's November 20, 2008 test of the launch abort system, courtesy of ATK

Page 58 Artist concept of the X-51A in flight, courtesy of USAF

Page 59 Damage to the first stage of the Ares 1-X following the parachute malfunction, courtesy of NASA

Page 59 DragonEye's test aboard STS-127, courtesy of SpaceXPage 55

Page 63 SLC-8, courtesy of California Spaceport

Page 64 RPT Lift-off from LP 1 at Kodiak, courtesy of Kodial Launch Complex

Page 65 Pad 0-B, courtesy of MARS

Page 66 Mojave Air and Space Port, courtesy of Mojave Air and Space Port

Page 67 Oklahoma Spaceport, courtesy of Oklahoma Spaceport

Page 68 Runway construction, courtesy of Bob Martin, KQRE TV

Page 69 Delta IV Heavy on SLC 37B, courtesy of ULA; photo by Pat Corkery

Page 70 Atlantis takes off from EAFB, courtesy of NASA; photo by Carla Thomas

Page 71 Ares I-X rocket on pad 39B, courtesy of Kennedy Space Center

Page 72 Falcon 1 launch from Omelek, courtesy of SpaceX

Page 73 Tower roll back at SLC-2, courtesy of Air Force; photo by Senior Airman Stephanie Longoria

Page 74 Wallops Flight Facility, courtesy of Wallops Flight Facility

Page 74 Orion launch abort test pad, courtesy of U.S. Army

Page 75 RLV hangar, Space Florida Spaceport, courtesy of Space Florida Spaceport

Page 81 A zero-gravity flight, courtesy of Aurora Aerospace

Page 82 Wilderness training helicopter, courtesy of Rocket Ranch Academy

Page 85 Evacuation research, courtesy of the FAA Civil Aerospace Medical Institute

Page 86 Spaceflight simulation, courtesy of the NASTAR Center

Page 88 Starfighters trainer, courtesy of Starfighters Aerospace

Page 89 Flight crew training, courtesy of United Space Alliance

Page 91 G-FORCE ONE, courtesy of Zero Gravity Corporation

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