# 2005 U.S. Commercial Space Transportation Developments and Concepts: Vehicles, Technologies, and Spaceports

Federal Aviation Administration
Office of Commercial Space Transportation
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# About the Office of Commercial Space Transportation

The Federal Aviation Administration's Office of Commercial Space Transportation (FAA/AST) licenses and regulates U.S. commercial space launch and reentry activity, as well as the operation of non-federal launch and reentry sites, as authorized by Executive Order 12465 and Title 49 United States Code, Subtitle IX, Chapter 701 (formerly the *Commercial Space Launch Act*). FAA/AST's mission is to ensure public health and safety and the safety of property while protecting the national security and foreign policy interests of the United States during commercial launch and reentry operations. In addition, FAA/AST is directed to encourage, facilitate, and promote commercial space launches and reentries. Additional information concerning commercial space transportation can be found on FAA/AST's web site at http://ast.faa.gov.

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# List of Acronyms

AADC – Alaska Aerospace Development Corporation, Anchorage, Alaska

ACES – Air Collection and Enrichment System

AFB – Air Force Base

AFRL – Air Force Research Laboratory, Edwards Air Force Base, California

APO – Announcement of Partnership Opportunities

AST – Office of Commercial Space Transportation

C/NOFS – Communication/Navigation Outage Forecasting System

CAIB – Columbia Accident Investigation Board

CALVEIN – California Launch Vehicle Initiative

CCAFS – Cape Canaveral Air Force Station, Florida

CEV – Crew Exploration Vehicle

CRV – Crew Rescue Vehicle

CSIA – Clinton-Sherman Industrial Airpark, Burns Flat, Oklahoma

CSULB – California State University, Long Beach

CTV – Crew Transfer Vehicle

DARPA – Defense Advanced Research Projects Agency

DART – Demonstration of Autonomous Rendezvous Technology

DoD – U.S. Department of Defense

EAFB – Edwards Air Force Base, Edwards, California

EELV – Evolved Expendable Launch Vehicle

EIS – Environmental Impact Statement

ELV – Expendable Launch Vehicle

ERV – Expendable Rocket Vehicle

FAA – Federal Aviation Administration

FALCON – Force Application and Launch from CONUS

FSA – Florida Space Authority

GEO – Geosynchronous Earth Orbit

GPS/INS – Global Positioning System/Inertial Navigation System

GSC – Garvey Spacecraft Corporation, Huntington Beach, California

GTO – Geosynchronous Transfer Orbit

HTPB – Hydroxyl Terminated Polybutadiene

HX – Hydrocarbon X

HYSR – Hybrid Sounding Rocket

ICBM – Intercontinental Ballistic Missile

IOS – Interorbital Systems, Mojave, California

IPD – Integrated Powerhead Demonstrator

IPF – Integrated Processing Facility

ISS – International Space Station

ISTP – Integrated Space Transportation Plan

JSC – Johnson Space Center, Houston, Texas

KSC – Kennedy Space Center, Florida

LAP – Launch Assist Platform

LC – Launch Complex

LEO – Low Earth Orbit

LOX – Liquid Oxygen

MARS – Mid-Atlantic Regional Spaceport, Wallops Island, Virginia

MAV – Mojave Aerospace Ventures, Mojave, California

MDA – Missile Defense Agency

MEO – Medium Earth Orbit

MIPCC – Mass Injected Pre-Compressor Cooling

MPV – MIPCC-Powered Vehicle

MSFC – Marshall Space Flight Center, Huntsville, Alabama

MTA – Mojave Test Area, Mojave, California

NASA – National Aeronautics and Space Administration

NCSS – National Coalition of Spaceport States

NGLT – Next Generation Launch Technology

NLV – Nanosat Launch Vehicle

NTPS – National Test Pilot School

ORS – Operationally Responsive Spacelift

OSIDA – Oklahoma Space Industry Development Authority

OSP – Orbital Space Plane

PDR – Preliminary Design Review

QRLV – Quick Reaction Launch Vehicle

R&D – Research and Development

RASCAL – Responsive Access, Small Cargo, Affordable Launch

RFI – Request for Information

RLV – Reusable Launch Vehicle

RSTS – Range Safety and Telemetry System

RTS – Reagan Test Site, Republic of the Marshall Islands

SBIR – Small Business Innovation Research

SLC – Space Launch Complex

SLEP – Service Life Extension Program

SLI – Space Launch Initiative

SLV – Small Launch Vehicle

SRS – Southwest Regional Spaceport, New Mexico

SSI – Spaceport Systems International, L.P., VAFB, California

SSME – Space Shuttle Main Engine

SSO – Sun-synchronous Orbit

STS – Space Transportation System

UAV – Unmanned Aerial Vehicle

USAF – U.S. Air Force

VAFB – Vandenberg Air Force Base, Lompoc, California

VCSFA – Virginia Commercial Space Flight Authority

WFF – Wallops Flight Facility, Wallops Island, Virginia

WFNA – white fuming nitric acid

# Introduction

"Kitty Hawk, move over." That's how FAA Administrator Marion Blakey described the historic flight of SpaceShipOne on October 4, 2004, that launched a new commercial space industry that might someday rival that of the commercial airlines industry.[1] For commercial space transportation, 2004 was a banner year in which this achievement was just one of the highlights.

The U.S. Space Exploration Policy, dated January 14, 2004, outlines the President's Vision for Space Exploration, establishing a national priority to extend human presence in space. This plan would retire the Space Shuttle and develop a new vehicle that would carry astronauts into space. Starting with a return to the Moon by 2020, the effort would continue with human exploration of Mars and other destinations. On December 21, 2004, a new U.S. Space Transportation Policy, emphasizing the importance of maintaining robust U.S. space transportation infrastructure and capabilities in order to assure access to space was authorized. This policy states a U.S. government commitment to encouraging and facilitating a viable U.S. commercial space transportation industry.

Additionally, two important pieces of legislation were signed into law. On November 30, the AST Indemnification Bill, HR 5245 was signed into law (Public Law 108-428). The purpose of the bill is to examine the liability risk-sharing regime between the government and private sector for commercial space transportation. It also extends the current indemnification regime through 2009. The Commercial Space Launch Amendments Act of 2004, signed into law on December 23 (Public Law 108-492), amends Federal law concerning commercial space transportation to make such law applicable to spaceflight crews and spaceflight participants.

The private sector plays a prominent role in managing, developing, and funding commercial space transportation activities. Additionally, the federal government and several state governments substantially contribute to or provide leadership for many of the technologies and facilities needed to advance this nascent industry. While the first privately developed reusable launch vehicles (RLVs) are suborbital, many organizations expect to eventually develop an orbital RLV. Even though the Ansari X-Prize has already been claimed, other X-Prize competitors continue developing their suborbital RLV concepts.

This report reviews major events relating to U.S. commercial space transportation in 2004. Current and planned U.S. commercial and commercially oriented activities are showcased. The Federal Aviation Administration, Office of Commercial Space Transportation (FAA/AST), first published the *U.S. Commercial Space Transportation Developments and Concepts: Vehicles, Technologies, and Spaceports* in 1998. That edition focused exclusively on RLVs. In addition to reviewing RLVs, this report addresses expendable launch vehicles (ELVs), propulsion technologies, and launch and reentry sites – commonly referred to as spaceports. Space transportation programs and projects that will impact and support the development of commercial space activities and applications are also reviewed.

Always full of new developments, commercial space transportation is a fast-paced, rapidly evolving industry. Providing a well-rounded picture of today's space transportation industry requires addressing a broad range of topics. Information presented in this document was compiled from direct communications with academic, federal, civil, and corporate organizations and open sources. Because many of the statements herein are forward looking, current information should be obtained by contacting the relevant organizations.

## Space Competitions

A number of competitions were born in 2004, pushing the envelope of space innovation and exploration. The Ansari X Prize – a challenge to create a craft without government support to fly to the edge of space twice within two weeks – has provided the inspiration for other competitions to advance the commercial space industry. The creators of the $10 million Ansari X Prize created a new competition based on the X Prize model: the X Prize Cup. This time, however, several challenges are involved, and the games will take place annually. The idea behind this contest is to get the rest of the public involved with the newly emerging space industry.

Another competition, America's Space Prize, the brainchild of Robert Bigelow, can be considered the next step beyond the original Ansari X Prize. Bigelow's challenge seeks vehicles that will go farther beyond the boundary of space and stay in orbit. Bigelow's company, Bigelow Aerospace, plans to use the competition to find a spacecraft that will dock with its inflatable habitat modules that it plans to have orbiting the Earth in the future.

With its announcement of the Centennial Challenges, the National Aeronautics and Space Administration (NASA) has also jumped into the excitement of the new commercial space era. Many of NASA's challenges will be geared toward space exploration in and beyond the orbit of Earth. The main benefit of the Centennial Challenges hinges on the fact that NASA is seeking assistance from the commercial sector through these competitions.

## Expendable Launch Vehicle Industry

U.S. commercial launch activity increased from recent years. In 2004, FAA/AST licensed 9 orbital launches out of 15 total commercial orbital launches worldwide. Lockheed Martin had six Atlas launches, including five commercial missions, and one Titan 4 launch. Boeing launched seven Delta 2 rockets and one Delta 4 Heavy. Orbital Sciences launched one commercial Taurus rocket. Also, Sea Launch performed three commercial Zenit-3SL launches.

As the market for commercial launches continues to expand, so does the demand for inexpensive, innovative rockets. Therefore, a number of commercial ELVs are under development to serve smaller payloads. Small entrepreneurial companies focusing on specific market niches, such as small government payloads, are primarily developing these ELVs. These companies are exploring various technologies, including new propellants and pressure-fed engines, which have the potential to reduce the cost of these vehicles. A number of key developments for these types of ELVs emerged in 2004, thus assisting the pursuit of private investment. Throughout 2004, design and development of reduced cost and increased performance ELVs continued toward completion; some seeking to use such pioneering technologies as hybrid propulsion systems. Some of these new technologies are slated for launch in 2005.

## Reusable Launch Vehicle Industry

The appeal of RLVs rests in their ability not only to launch from but also to return to Earth for reuse – a quality desirable for various types of missions, including human trips to and from space. In addition, construction cost of an RLV could be amortized over multiple launches, thus potentially reducing the cost of access to space for government and commercial users. With current advances in RLV technology and commercial RLV success, regular RLV space travel is closer to becoming a reality.

Government and commercial developers have been striving for innovations that aid the development of low-cost, high-performance RLVs. Though RLV development has historically been hindered by a number of factors, 2004 proved favorable for this endeavor, primarily because of the Ansari X Prize competition. Other non-governmental entities – non-Ansari X Prize contenders – have also been researching and developing RLVs for commercial use. In September, SpaceDev signed an agreement with the NASA Ames Research Center for technology collaboration in designing a high-performance, commercial, manned suborbital vehicle. Also, the Space Exploration Technologies Corporation (SpaceX) Falcon 1, a partially reusable launch vehicle, was placed on the SpaceX launch pad at Vandenberg Air Force Base (VAFB), California, and it is currently undergoing final tests and awaiting final approval.

One great accomplishment in RLV development in 2004 was Mojave Aerospace Ventures (MAV) winning the Ansari X Prize. On September 29 and October 4, SpaceShipOne flew past the boundary of Earth and space to claim the $10-million prize. Successful completion of the Ansari X Prize competition proved that private companies can develop ways to travel to space without the extreme expense of government-funded programs. Another positive result is that interest in the future of commercial space travel has greatly increased. Sir Richard Branson, founder of Virgin Airlines, teamed up with MAV to create his new visionary company, Virgin Galactic. This company will develop large ships capable of carrying spaceflight participants (passengers) to space.

## Enabling Technologies

Efforts to develop new propulsion technologies for launch vehicles, including ELVs and RLVs, continued to expand. These efforts include government-funded research projects as well as engines and motors being developed by companies for use in their launch vehicles and for sale to other companies. A trend toward development of new liquid-propellant engines that use room-temperature propellants instead of cryogens or pressure-fed systems instead of turbopumps has emerged. These engines are considerably less complex and potentially less expensive than engines that use turbopumps and cryogenic propellants. SpaceX's Falcon 1 is to use both of its liquid engines, Merlin and Kestrel, to launch.

Other innovative propulsion technologies in development include hybrid propulsion and air-breathing engines. Hybrid propulsion combines the solid fuel propellant of conventional rockets with liquid or gaseous oxidizers. Advantages of hybrid propulsion over solid rocket propulsion include increased thrust, throttle capability, and shut-off and restart capabilities. SpaceShipOne made its historic flights using one such hybrid engine. The engine ran on basically nothing other than a mixture of laughing gas and rubber. Air-breathing engines work in a manner similar to conventional turbine jet engines, igniting a compressed air and fuel mixture for thrust; however, the turbines are not needed. The air is already compressed because of the supersonic speeds these vehicles travel. In March, NASA's X-43A became the world's fastest air-breathing vehicle in history, reaching a speed of Mach 6.83.

Bigelow Aerospace is developing commercial inflatable space modules, with technical assistance from the NASA Johnson Space Center (JSC), Texas. Such modules will offer improved living conditions and ability to conduct experiments while in orbit. NASA hopes to use the Bigelow technology to place the inflatable modules on the Moon or Mars.

## Spaceports

Launch and reentry sites – often referred to as "spaceports" – may house launch pads and runways as well as the infrastructure, equipment, and fuels needed to process launch vehicles and their payloads before launch. While U.S. military and civil government agencies were the original and still are the primary developers and users of launch facilities, commercial launch activity now comprises a substantial portion of federal launch site operations. A number of significant developments occurred at major U.S. launch sites in 2004, including the licensing of a new launch site by FAA/AST. On June 17, 2004, FAA/AST awarded a launch site operator license to the East Kern Airport District to cover suborbital spaceflight activities at Mojave Airport.

The commercial dimension of U.S. space activity is evident not only in the number of commercially procured launches but also in the list of non-federal launch sites supplementing federally operated sites. FAA/AST has licensed the operations of five spaceports in four U.S. states. These sites are available to serve commercial as well as government payload owners. These spaceport operators are also seeking new opportunities, such as payload processing and space research facility development. Organizations in several states see the potential of spaceports to accommodate future launch vehicles, and they are actively working to turn their spaceport visions into reality. Based on projections for increased launch rates and historic milestones in RLV activity reached in 2004, future spaceports may prosper from new businesses that are ready to bloom.

# Significant 2004 Events

**January 10:** A Sea Launch Zenit 3SL rocket successfully launches the Telstar 14/Estrela do Sul 1 communications satellite from Odyssey platform, Pacific Ocean (154° West, 0° North).

**January 14:** President Bush announces the nation's new Space Exploration Initiative. The President committed the United States to a long-term human and robotic program to explore the solar system, starting with a return to the Moon that will ultimately enable future exploration of Mars and other destinations.

**February 5:** Lockheed Martin's Atlas 2AS rocket launches the AMC 10 communications satellite for SES Americom from CCAFS.

**March 13:** Lockheed Martin's Atlas 2A rocket, AC-202, launches the MBSAT satellite for Japan's Mobile Broadcasting Corporation from CCAFS.

**March 27:** Reaching the speed of Mach 6.83, the X-43A flies into history and the Guinness Book of World Records for the world's fastest free-flying, air-breathing aircraft.

**April 1:** SpaceShipOne receives the first RLV license ever issued from the FAA/AST.

**April 8:** The first licensed launch for SpaceShipOne takes place after the White Knight carrier aircraft takes off from Mojave Airport, California, launching the private spaceship in the air and returning to land at the airport.

**April 16:** Lockheed Martin's Atlas 2AS rocket launches the Japanese Superbird 6 communications satellite from CCAFS.

**April 23:** XCOR Aerospace receives its first RLV license from FAA/AST for the Sphinx vehicle.

**May 4:** A Sea Launch Zenit 3SL rocket launches the DirecTV 7S direct-to-home TV broadcasting satellite from Odyssey platform, Pacific Ocean (154° West, 0° North).

**May 13:** The second FAA/AST-licensed launch of SpaceShipOne occurs. The Tier One Program achieves an altitude of approximately 64 kilometers (40 miles), setting the world record for the highest altitude reached by a piloted, non-government space program. SpaceShipOne flight 14P was the third powered flight of this RLV.

**May 17:** An Orbital Sciences Corporation Taurus XL rocket launches the ROCSAT 2 remote sensing satellite for the Republic of China's National Space Program Office from VAFB.

**May 20:** Lockheed Martin's Atlas 2AS rocket launches the AMC 11 communications satellite for SES Americom from CCAFS.

**June 15:** NASA holds workshop for its Centennial Challenges, a set of competitions to propel technology and increase interest in order to further the field of space exploration.

**June 17:** FAA/AST issues a license for the first inland launch site to Mojave Airport to conduct suborbital launch activities.

**June 21:** Mike Melvill pilots SpaceShipOne to 100 kilometers (62 miles) above the Earth, marking the historic first non-governmental manned rocket flight to suborbital space. Associate Administrator for Commercial Space Transportation, Patricia G. Smith, awards Melvill the first U.S. Department of Transportation/FAA Commercial Astronaut Wings.

**June 28:** A Sea Launch Zenit 3SL rocket launches the Telstar 18 communications satellite from Odyssey platform, Pacific Ocean (154° West, 0° North).

**August 31:** Lockheed Martin's final Atlas 2AS rocket launches a classified payload for the U.S. National Reconnaissance Office.

**September 16:** A team of aerospace companies led by Microcosm, Inc., of El Segundo, California, announces winning a Phase 2 award from the Defense Advanced Research Projects Agency (DARPA) for the development of a small launch vehicle.

**September 17:** ZERO-G, the first and only FAA-approved provider of weightless flight, announces that it flew its first research customer, Tethers Unlimited, an aerospace company based in Seattle, Washington, on a modified Boeing 727-200.

**September 20:** SpaceDev signs an agreement with NASA Ames Research Center for technology collaboration in designing a high-performance, commercial, manned suborbital vehicle capable of carrying 3-5 people to an altitude of approximately 160 kilometers (100 miles).

**September 26:** DARPA and U.S. Air Force (USAF) award approximately $42 million in development contracts for research and design of a rapid launch capability.

**September 27:** Sir Richard Branson, Virgin Atlantic Airways founder, in agreement with Scaled Composites founder Burt Rutan and Microsoft co-founder Paul G. Allen, announces a plan for a new commercial spaceflight company called Virgin Galactic.

**September 29:** SpaceShipOne, piloted by Mike Melvill, flew past the boundary of space for the first attempt at claiming the $10 million Ansari X Prize.

**October 1:** NASA puts out a call for the aerospace industry to provide more launch services for satellites, cargo – even astronauts.

**October 1:** Rocketplane Limited, Inc., and Incredible Adventures join forces in a marketing agreement in order to start taking reservations for Rocketplane's suborbital spaceflight experience, scheduled to start launching in 2007.

**October 4:** Brian Binnie pilots SpaceShipOne to 112 kilometers (69 miles), winning the $10 million Ansari X Prize and smashing the 108-kilometer (67-mile) altitude record set by the X-15 airplane in the 1960s. FAA Administrator, Marion Blakey, awards Binnie DOT/FAA Commercial Astronaut Wings.

**October 8:** SpaceDev is awarded approximately $1.5 million to proceed with Phase 2 of an Air Force Research Laboratory (AFRL) contract to continue its hybrid rocket small launch vehicle project.

**November 5:** NASA releases two Requests for Information (RFI) and an Announcement of Partnership Opportunities (APO) for its Centennial Challenges, a series of prize competitions.

**November 15:** NASA holds Centennial Challenges Day to discuss the two RFIs and the APO it released on November 5, 2004.

**November 17:** X-43A breaks its March 27, 2004, record by reaching approximately Mach 9.7 during its second flight.

**November 30:** AST indemnification bill, HR 5245 was signed into law (Public Law 108-428). The purpose of the bill is to examine the liability risk sharing regime between the government and private sector for commercial space transportation.

**December 8:** SpaceTEC, the national center of excellence for aerospace technician training, enters into partnerships with two key federal agencies – the FAA and U.S. Department of Labor. These agreements underscore the importance of SpaceTEC's mission to train the next generation of space industry workers.

**December 17:** Lockheed Martin successfully launches an Atlas 5, carrying an AMC-16 payload, from CCAFS.

**December 21:** Boeing Launch Services conducts a test launch of the first Delta 4 Heavy launch vehicle, from CCAFS. The launch was only partially successful since there was an early cut-off of the main engine leaving the test payload in a lower-than-intended orbit.

**December 23:** Commercial Space Launch Amendments Act of 2004 signed into law (Public Law 108-492; 118 Stat. 3974; 10 pages). Amends Federal law concerning commercial space transportation to make such law applicable to spaceflight crews and spaceflight participants.

# Space Competitions

Prizes have long been used to inspire innovations and advances in aviation. Examples include the Orteig Prize claimed by Charles Lindbergh for crossing the Atlantic in 1927. Today, this proud tradition continues in the commercial space transportation arena. In 2004, the $10-million Ansari X Prize was awarded to MAV – an outgrowth of Scaled Composites, LLC, – led by Burt Rutan. In part because of the success of this prize, founders of new challenges decided to further the call for non-governmental space innovation, and new prize competitions were created. These competitions include the X Prize Cup, America's Space Prize, and NASA's Centennial Challenges.

## X Prize Cup

Before the competition for the Ansari X Prize ended, the founders of the challenge decided to establish the X Prize Cup. This annual 5-day event is geared toward bringing forth new concepts and technologies which will enable development of commercial human spaceflight. A yearly set of competitions will also enable the public to learn about advancements in spaceflight technology. People will have chance to speak with the famous aviation and aerospace pioneers who are working to reduce the high cost and increase the safety and viability of commercial human space travel within this generation's lifetime. Teams from all over the world will compete in five categories to win the overall cup.[2] These categories are as follows: fastest turnaround time between the first launch and second landing, maximum number of passengers per launch, total number of passengers during the competition, maximum altitude, and fastest flight time.[3] The first competition – mainly an exhibitionary kick-off event – is scheduled for the summer of 2005 at White Sands Missile Range, New Mexico. In 2006, the Southwest Regional Spaceport (SRS) in New Mexico will be the official site for the full event.

## America's Space Prize

Robert Bigelow, founder of Bigelow Aerospace, proposed his own competition: America's Space Prize. This prize challenges developers and engineers to design a craft capable of ferrying passengers into orbital flight. According to the rules, American competitors will have to build a spacecraft capable of taking a crew of no fewer than five people to an altitude of 400 kilometers (240 miles) and complete two orbits of the Earth at that altitude. Then, they have to repeat that accomplishment within 60 days. The first flight need not carry any extra passengers, but the second is required to carry a full crew.[4] Furthermore, the vehicles will have to be able to dock with Bigelow's inflatable modules. Bigelow Aerospace plans to have a full-scale model orbiting Earth by 2008 at the earliest. The competition deadline is slated for January 10, 2010. The proposed purse for the competition is $50 million, funded fully by Bigelow Aerospace.

## Centennial Challenges

Yet another idea for space technology advancement has been proposed by NASA. The Centennial Challenges is based on creating several competitions that will further the exploration of space. While launch vehicles may not be a large part of initial prize competitions, future prize proposals may include missions with launch vehicles as funding becomes available. For now, some of the proposals involving launch craft include orbital and suborbital human spaceflight challenges and suborbital scientific payload flight challenges. NASA held a workshop in June to gather proposals for competitions to include in the Centennial Challenges. Following up, two RFIs and one Partnership Opportunity were released on November 5. Additionally both topics were discussed on Centennial Challenges Day, November 15. Final confirmation of which challenges will be sponsored and the rules governing these efforts are forthcoming.

# Expendable Launch Vehicles

This survey of U.S. ELVs is divided into three sections. The first section reviews the ELVs currently available to serve a wide range of commercial and government payloads. The second section reviews a number of proposed commercial ELVs under study or development that will primarily serve small commercial payloads at prices that are potentially much lower than available today. The final section reviews suborbital sounding rockets manufactured and operated by U.S. companies.

## Current Expendable Launch Vehicle Systems

Table 1 lists the ELV systems available in the United States today. Two ELVs, the Minotaur and Titan 4B, are restricted to government payloads, and Boeing is currently marketing the Delta 4 only to government customers. Once the final two Titan 4 vehicles are launched, all large U.S. government payloads will be launched on Atlas 5 or Delta 4 variants. Atlas 5, Delta 2, Pegasus, and Taurus vehicles are available for both commercial and U.S. government launches, and the Zenit 3SL is available only to commercial customers. The two newest members of the U.S. launcher supply, the Atlas 5 and Delta 4 evolved expendable launch vehicles (EELV), debuted in 2002. Because of a new national vision to undertake manned missions to the Moon and eventually Mars, NASA may require vehicles that exceed the capabilities of the Atlas 5 and Delta 4 EELVs in order to launch CEVs and accomplish other missions. To date, however, plans for such vehicles have not been announced.

### Atlas 5 – Lockheed Martin Corporation

The Atlas launch vehicle family traces its roots to the development of the Atlas Intercontinental Ballistic Missile (ICBM) in the 1950s. Today, the Atlas family is in transition. Older versions of the vehicle (Atlas 2A, Atlas 2AS, Atlas 3A, and Atlas 3B) are being retired to make way for the Atlas 5. Lockheed Martin retired its Atlas 2 launch vehicle in 2004 and plans to retire the Atlas 3 in 2005.

The last Atlas 2AS launched in 2004 (giving the Atlas 2AS family the remarkable record of 63 successful launches without a failure).[5] One Atlas 3A vehicle also launched in 2004, and the last Atlas 3 vehicle is scheduled to fly in early 2005.

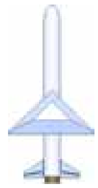
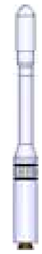
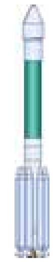
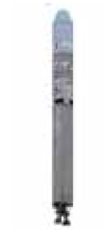
Atlas 5 launch

The maiden flight of the Atlas 5 took place on August 21, 2002, when an Atlas 5 401 vehicle successfully launched the Eutelsat Hot Bird 6 spacecraft from CCAFS. The Atlas 5 is now Lockheed Martin's sole commercial launch vehicle for the foreseeable future. The Atlas 5 family of launch vehicles is based on a common first stage design – known as the Common Core Booster™ – and uses the NPO Energomash RD-180 engine introduced on the Atlas 3. The stretched version of the Centaur upper stage, introduced on the Atlas 3B, is also used on single- and dual-engine versions of the Atlas 5.

The Atlas 5 also marks a significant departure in launch preparations compared to previous Atlas versions. The Atlas 5 program uses a "clean pad" concept at Launch Complex (LC) 41 at CCAFS. The launch vehicle is prepared for launch "off pad" vertically in the Vertical Integration Facility near the pad. Hours before a launch, the fully-prepared vehicle is moved to the pad. The Atlas 5 will be operational from LC-3E at VAFB in mid-2005, and will be standardized to the operating processes at LC-41 except for the use of the more traditional "stack on pad" concept from the heritage launch vehicle programs.

The Atlas 5 is available in the 400 and 500 series and accommodates 4-meter (13.1 foot) and 5-meter (16.4-foot) fairings and up to five strap-on solid rocket motors. The Atlas 400 series can place payloads between 4,950 and 7,640 kilograms (10,910 and 16,843 pounds) into geosynchronous transfer orbit (GTO). The Atlas 500 series can place payloads between 3,970 and 8,670 kilograms (8,750 and 19,120 pounds) into GTO. Lockheed Martin is currently finalizing its design of the Atlas 5 Heavy Lift Vehicle with a target initial operational capability in late 2006. One commercial Atlas 5 launch took place on December 17, 2004, and at least one commercial Atlas launch is scheduled for 2005.

Table 1: Currently Available Expendable Launch Vehicles

| | Small | | | Medium | |
|---|---|---|---|---|---|
| |  |  |  |  |  |
| **Vehicle** | Minotaur | Pegasus XL | Taurus XL | Delta 2 | Titan 2 |
| **Company** | Orbital Sciences | Orbital Sciences | Orbital Sciences | Boeing | Lockheed Martin |
| **First Launch** | 2000 | 1990 | 1994 | 1990 | 1988* |
| **Stages** | 4 | 3 | 4 | 3 | 2 |
| **Payload Performance (LEO)** | 640 kg (1,410 lbs.) | 440 kg (970 lbs.) | 1,360 kg (3,000 lbs.) | 5,100 kg (11,245 lbs.) | N/A |
| **Payload Performance (LEO polar)** | 340 kg (750 lbs.) (SSO) | 190 kg (420 lbs.) (SSO) | N/A | 3,895 kg (8,590 lbs.) | 1,905 kg (4,200 lbs.) |
| **Payload Performance (GTO)** | N/A | N/A | 430 kg (950 lbs.) | 1,870 kg (4,120 lbs.) | N/A |
| **Launch Sites** | VAFB | VAFB, Wallops, CCAFS | VAFB | CCAFS, VAFB | VAFB |

* First launch of refurbished Titan 2 ICBM. Titan 2 was also used for Gemini program launches, 1964-1966.

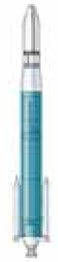
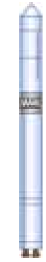
### Delta 2 – The Boeing Company

Delta 2 launch

The Delta family of launch vehicles traces its heritage to the Thor missile program of the 1950s. Like the Atlas program, the Delta family is undergoing a transition prompted by the introduction of the Delta 4 vehicles developed under the EELV program.[6]

The Delta 2 uses a liquid-oxygen (LOX)/kerosene first stage and a nitrogen tetraoxide and hydrazine second stage. An optional solid-propellant upper stage is available. The Delta 2 also uses between three and nine strap-on solid rocket motors, depending on the performance required. A “heavy” version of the Delta 2 entered service on August 25, 2003, with the launch of NASA’s Spitzer Space Telescope spacecraft. This vehicle uses the larger graphite-epoxy motor 46 strap-on boosters developed for the now-defunct Delta 3. Although small payload capacity has limited its usefulness for commercial GTO payloads, the Delta 2 is expected to remain in

Table 1: Currently Available Expendable Launch Vehicles

| | Intermediate | | Heavy | | |
|---|---|---|---|---|---|
| |  |  |  |  |  |
| **Vehicle** | Delta 4 | Atlas 5** | Delta 4 Heavy | Titan 4B | Zenit 3SL |
| **Company** | Boeing | Lockheed Martin | Boeing | Lockheed Martin | Sea Launch |
| **First Launch** | 2002 | 2002 | 2004 | 1997 | 1999 |
| **Stages** | 2 | 2 | 2 | 2 | 3 |
| **Payload Performance (LEO)** | 8,870 kg (19,555 lbs.) (Delta 4M) 13,330 kg (29,390 lbs.) (Delta 4M+ (5,4)) | 12,500 kg (27,560 lbs.) (Atlas 5-400) 20,520 kg (45,240 lbs.) (Atlas 5-500) | 23,260 kg (51,280 lbs.) | 21,680 kg (47,800 lbs.) | N/A |
| **Payload Performance (LEO polar)** | 6,870 kg (15,150 lbs.) (Delta 4 M) 10,400 kg (22,930 lbs.) (Delta 4 M+ (5,4)) | N/A | 20,800 kg (45,860 lbs.) | 17,600 kg (38,800 lbs.) | N/A |
| **Payload Performance (GTO)** | 3,930 kg (8,665 lbs.) (Delta 4 M) 6,410 kg (14,130 lbs.) (Delta 4M+ (5,4)) | 4,950 kg (10,910 lbs.) (Atlas 5-400) 8,670 kg (19,110 lbs.) (Atlas 5-500) | 12,370 kg (27,270 lbs.) | 5,760 kg (12,700 lbs.) (GEO) | 6,000 kg (13,230 lbs.) |
| **Launch Sites** | CCAFS, VAFB | CCAFS | CCAFS, VAFB | CCAFS, VAFB | Pacific Ocean |

** Atlas 5 launches from VAFB are scheduled to begin in 2005.

service through 2010, primarily launching military and civil government payloads. Seven government Delta 2 launches occurred in 2004; eight are planned for 2005.

## Delta 4 – The Boeing Company

The Delta 4 family of launch vehicles has a common booster core first stage that uses the first new large liquid rocket engine developed in the United States since the Space Shuttle Main Engine (SSME) was developed in the 1970s. This engine, the Rocketdyne RS-68, is based on the J-2 engine used on the second stage of the Saturn 5 launch vehicle and technology from the SSME. However, the RS-68 is larger and simpler than the SSME. Depending on customer needs, two or four solid-fuel strap-on boosters, two types of upper stages, and three payload fairings can supplement the RS-68 engine. This vehicle will be launched from VAFB and CCAFS. The first Delta 4 launch took place on November 20, 2002, successfully lofting the Eutelsat W5 spacecraft from CCAFS.[7]

Delta 4 launch

A distinctive design feature of the Delta 4 is its use of horizontal integration. The vehicle is assembled, tested, and prepared for launch horizontally, away from the launch pad. When integration is complete, the vehicle is moved to the pad, raised, and launched in a relatively short period. In addition to making the launch vehicle easier to work on by keeping it closer to the ground, this integration method greatly reduces time spent occupying the launch pad. Boeing expects to reduce pad time from Delta 2's 24 days to a period of about a week for the Delta 4. Because availability of launch pads acts as a factor limiting launch rates, Boeing's integration process contributes to the economic advantages that are a major part of the EELV program's goals.

Boeing offers five versions of the Delta 4 to address a broad range of payload mass classes. These include four medium versions, each with one common booster core, and one heavy-lift version that uses three parallel common booster core stages. Three of these versions, the Delta 4 Medium-Plus vehicles, were originally optimized for commercial use. The Medium and Heavy versions are largely intended for government use. Payload capacities to low Earth orbit (LEO) range from 8,120 kilograms (17,905 pounds) for the Medium to 23,040 kilograms (50,800 pounds) for the Heavy. GTO capacities range from 4,210 to 13,130 kilograms (9,285 to 28,950 pounds). The Delta 4 has also replaced the Delta 3. The first Delta 4 Heavy was launched on December 21, 2004. It was the only Delta 4 variant launched last year. Seven Delta 4 launches are planned for 2005, including one Delta 4 Heavy.

### Minotaur – Orbital Sciences Corporation

Minotaur launch

The Orbital/Suborbital Program Space Launch Vehicle, also known as Minotaur, was developed by Orbital Sciences Corporation under contract to the USAF to launch small government payloads. This booster uses a combination of rocket motors from decommissioned Minuteman 2 ICBMs and upper stages from Orbital's Pegasus launch vehicle. The Minotaur's first two stages are Minuteman 2 M-55A1 and SR-19 motors. The upper two stages are Orion 50 XL and Orion 38 motors from the Pegasus XL. All four stages use solid propellants. Orbital Sciences will also operate the Minotaur 4, which uses stages from former U.S. Peacekeeper missiles. Minotaur 4 can deliver a 1,750-kilogram (3,860-pound) payload to LEO.

In its January 26, 2000, debut, the Minotaur successfully launched the FalconSat and JAWSAT satellites from VAFB. This vehicle's only other launch occurred on July 19, 2000, when it launched an AFRL MightySat 2.1 spacecraft from VAFB. No Minotaur launches occurred in 2004; however, up to three missions are scheduled for 2005.

### Pegasus – Orbital Sciences Corporation

Pegasus in flight

Pegasus is an air-launched ELV used to place small payloads into a variety of low Earth orbits. Developed by Orbital Sciences Corporation in the late 1980s, Pegasus became the first commercial air-launched system. The Pegasus booster has three solid propellant stages and an optional hydrazine monopropellant upper stage.

The booster is carried aloft under Orbital Sciences' "Stargazer" L-1011 carrier aircraft to an altitude of 11,900 meters (39,000 feet), where it is released. (Early Pegasus launches used a B-52 aircraft leased from NASA.) The booster drops for 5 seconds before igniting its first stage motor and beginning ascent to orbit. The original Pegasus booster entered service in 1990. Orbital Sciences created a new version of the Pegasus, the Pegasus XL, with stretched first and second stages to enhance the payload capacity of the booster. While the first Pegasus XL launch was in 1994, the first successful Pegasus XL flight did not occur until 1996. The original, or standard, version of the Pegasus was retired in 2000, and only the Pegasus XL is used today. The air-launched nature of the Pegasus permits launches from a number of different facilities, depending on the orbital requirements of the payload. Pegasus launches have been staged from seven sites to date: Edwards Air Force Base (EAFB) and VAFB, California; CCAFS and Kennedy Space Center (KSC), Florida; NASA WFF, Virginia; Kwajalein Missile Range, Marshall Islands; and Gando AFB, Canary Islands.

NASA certified Pegasus to carry the highest value satellites (Category Three Certification) because of its excellent demonstrated reliability record. Pegasus has launched its last 21 missions successfully. No Pegasus XL vehicles flew in 2004. Two Pegasus XL missions are scheduled for 2005, carrying the Demonstration of Autonomous Rendezvous Technology (DART)[8] flight demonstrator vehicle for NASA and the Communication/Navigation Outage Forecasting System (C/NOFS),[9] a USAF payload whose launch will be licensed by FAA/AST.

### Taurus – Orbital Sciences Corporation

Taurus launch

The Taurus ELV is a ground-launched vehicle based on the air-launched Pegasus. Orbital Sciences Corporation developed the Taurus under the sponsorship of DARPA to develop a standard launch vehicle to be set up quickly in new locations to launch small satellites that are too large for 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 that serves as the Taurus' first stage.[10]

The Taurus successfully completed six of seven launch attempts since entering service in 1994. A commercial Taurus XL derived from the XL version of Pegasus successfully launched Taiwan's ROCSAT -2 spacecraft in 2004.

### Titan 4 – Lockheed Martin Corporation

Titan 4 launch

The Titan 4 program dates back to 1985, when the USAF commissioned Martin Marietta (now Lockheed Martin) to develop an upgraded version of the existing Titan 34D ELV that could launch Space Shuttle-class payloads as an alternative to the Shuttle. The Titan 4A was based on the Titan 34D, but it featured stretched first and second stages, two more powerful solid rocket motors, and a larger payload fairing. The Titan 4A was used between 1989 and 1998. The Titan 4B, introduced in 1997, was the most powerful ELV used in the United States for many years until the inaugural flight of the Delta 4 Heavy. Titan 4A used upgraded solid rocket motors that increase the payload capacity of the vehicle by 25 percent. The Titan 4B is used solely for U.S. military payloads, with the exception of the October 1997 launch of NASA's Cassini mission. Titan 4B is being phased out in favor of the heavy Delta 4 and Atlas 5 variants. One Titan 4B launch occurred in 2004, and the final two Titan 4B missions are scheduled for 2005.

### Zenit 3SL – Sea Launch Company, LLC

Zenit 3SL launch

The Zenit 3SL is a Ukrainian-Russian launch vehicle operated by Sea Launch, a multinational joint venture led by The Boeing Company. Ukrainian companies SDO Yuzhnoye and PO Yuzhmash provide the first two stages. A single engine, using LOX/kerosene propellants, powers each stage. These stages are 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, which also uses LOX/kerosene propellants. Boeing provides the payload fairing, interfaces, and operations management. Boeing Launch Services, Inc., manages marketing and sales.

The Zenit 3SL is launched from the Odyssey mobile launch platform, which travels from its 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. While Sea Launch conducts commercial launches with a license from the FAA/AST, the multinational nature of the system prevents it from carrying U.S. government payloads. Sea Launch completed three launches in 2004 and has six scheduled for 2005.

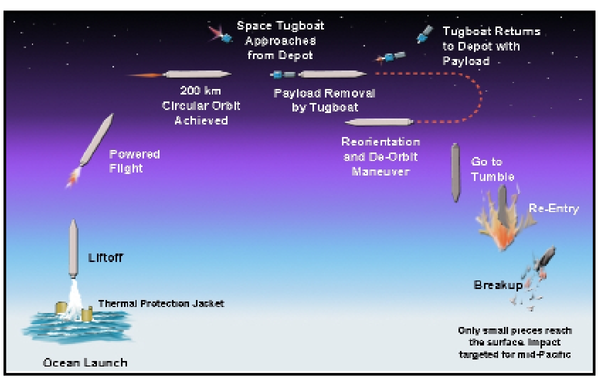
## ELV Development Efforts

A number of efforts by established corporations and startups are currently in progress to develop new ELVs. The majority of these designs focus on the small payload sector of the launch market, with the goal of placing payloads as small as a few hundred pounds into LEO. A limited market currently exists for such launches, so the success of these vehicles may rely on the ability to reduce launch costs enough to enable new markets.

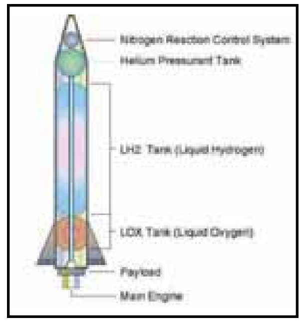
### Aquarius – Space Systems/Loral

| |
|---|
| **Vehicle:** Aquarius |
| **Developer:** Space Systems/Loral |
| **First launch:** To be determined |
| **Number of stages:** 1 |
| **Payload performance:** 1,000 kg (2,205 lbs.) to LEO |
| **Launch sites:** To be determined, water launch following float-off from a barge |

Space Systems/Loral of Palo Alto, California, has proposed Aquarius, a low-cost launch vehicle designed to carry small, inexpensive payloads into LEO. This vehicle is primarily intended to launch into orbit bulk products, such as water, fuel, and other consumables, that are inexpensive to replace. As currently designed, Aquarius will be a single-stage vehicle 43 meters (141 feet) high and 4 meters (13.1 feet) in diameter and powered by a single engine using liquid hydrogen and oxygen propellants. The vehicle is floated in the ocean before launch to minimize launch infrastructure and will be able to place a 1,000-kilogram (2,205-pound) payload into a 200-kilometer (125-mile), 52-degree orbit. Located in the base of the vehicle, the payload will be extracted by an orbiting space tug for transfer to its ultimate destination. After payload extraction is completed, the vehicle will deorbit and be destroyed.




Aquarius mission profile

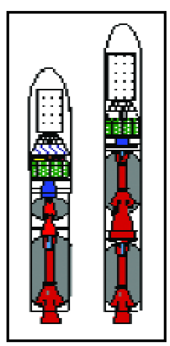



Aquarius

Space Systems/Loral studied Aquarius under a $110,000 grant awarded by the state of California in April 2001 and delivered a final report in June 2002. Space Systems/Loral teamed with Microcosm, Inc., of El Segundo, California, and Wilson Composite Technologies of Folsom, California, for the study. Funding of $1 million was provided in the fiscal year 2004 Defense Appropriations Act to develop a prototype of the low-cost engine for the vehicle. The engine would provide 1.8 million newtons (400,000 pounds) of thrust, using liquid hydrogen and oxygen as propellants.[11] For engine development, Space Systems/Loral partnered with Aerojet, a GenCorp Company based in Sacramento, California, and Microcosm. This program is expected to proceed under the auspices of the AFRL. Space Systems/Loral has submitted a proposal for development of the large lightweight liquid hydrogen tank required for this vehicle, which is currently being considered for federal funding.

### Eagle S-series – E'Prime Aerospace Corporation

| |
|---|
| **Vehicle:** Eaglet/Eagle |
| **Developer:** E'Prime Aerospace |
| **First launch:** To be determined |
| **Number of stages:** 2 |
| **Payload performance:** 580 kg (1,280 lbs.) to LEO (Eaglet); 1,360 kg (3,000 lbs.) to LEO (Eagle) |
| **Launch sites:** KSC, WFF, CCAFS, Kodiak |



Eaglet and Eagle

E'Prime Aerospace of Titusville, Florida, is developing a family of launch vehicles, called the Eagle S-series, based on the LGM-118A Peacekeeper ICBM design. Like the Peacekeeper, this vehicle will be ejected from a ground-based silo, using a compressed gas system. At an altitude of 61 meters (200 feet), the vehicle's engines will ignite. The smallest vehicle, the Eaglet, could launch 580 kilograms (1,280 pounds) into LEO. A somewhat larger version, the Eagle, could put 1,360 kilograms (3,000 pounds) into LEO. Both vehicles will use solid propellant lower stages and liquid propellant upper stages. E'Prime has also proposed larger vehicles, designated S-1 through S-7, with the ability to place considerably larger payloads into LEO and to add a geosynchronous Earth orbit (GEO) capability. The Eagle S-series concept dates back to 1987 when the company signed a commercialization agreement with the USAF to use Peacekeeper technology for commercial launch vehicles.

E'Prime signed an agreement with NASA in February 2001 that gives the company use of available property and services on a non-interference basis.[12] For equatorial orbits, the company plans to launch the Eaglet and Eagle, and the company's entire canister launch program from facilities at NASA KSC that the company has yet to construct. Plans to launch from Virginia Space Flight Center for equatorial orbits and from the Kodiak Launch Complex for polar orbits are also under consideration.

### Falcon SLV – Lockheed Martin

**Vehicle:** Falcon SLV
**Developer:** Lockheed Martin
**First launch:** To be determined
**Number of stages:** 2
**Payload performance:** To be determined
**Launch sites:** To be determined


Falcon

Lockheed Martin was awarded one of four DARPA Force Application and Launch from CONUS (FALCON) contracts to develop concepts for a low-cost launch vehicle. DARPA is expected to award a contract no later than 2007 to develop a concept through flight tests. Lockheed Martin's Falcon SLV approach uses an all-hybrid propulsion approach and a mobile launch system.

### Nanosat Launch Vehicle – Garvey Spacecraft Corporation

**Vehicle:** NLV
**Developer:** Garvey Spacecraft Corporation
**First launch:** 2007
**Number of stages:** 2
**Payload performance:** 10 kg (22 lbs.) to LEO
**Launch sites:** Mobile (or Multiple)


NLV

Garvey Spacecraft Corporation (GSC), based in Huntington Beach, California, is a small research and development (R&D) company, focusing on the development of advanced space technologies and launch vehicle systems. As part of the California Launch Vehicle Initiative (CALVEIN), GSC and California State University, Long Beach (CSULB), are jointly conducting 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. As part of this initiative, GSC and CSULB are pursuing advanced aerospike engine technology for use on the NLV first stage.[13] Their current work builds upon the first-ever powered liquid propellant aerospike flight that the team conducted using several of its LOX/ethanol Prospector research vehicles. GSC's most visible accomplishments include the first-ever flight of a composite LOX tank (conducted in partnership with Microcosm, Inc.), the first-ever powered flights of a liquid-propellant aerospike engine, and the launch and 100-percent recovery of several prototype reusable test vehicles.

Efforts during 2004 focused on refining the basic vehicle design while also maturing assembly, integration, check-out, and launch operation plans and coordinating with the user community to optimize the payload accommodations. CSULB students have developed a full-scale NLV mockup and have assembled the initial flight test vehicle for the NLV first stage. In December 2004, GSC conducted the initial flight test with a full-scale "Flight Development Unit" of the first stage at the Mojave Test Area (MTA), with a successful recovery.[14]

### Eagle SLV – Microcosm, Inc.

**Vehicle:** Eagle SLV
**Developer:** Microcosm, Inc.
**First launch:** Early 2007
**Number of stages:** 3
**Payload performance:** 670 kg (1,470 lbs.) to LEO, 330 kg (720 lbs.) to SSO
**Launch sites:** VAFB, WFF, and CCAFS

Eagle SLV

Microcosm, Inc. of El Segundo, California, is developing the Scorpius family of ELVs. Several prototypes are under consideration or in testing, and two suborbital test models, SR-S and SR-XM-1, flew successfully from White Sands Missile Range, New Mexico, in 1999 and 2001, respectively. Eventually Microcosm plans to market up to eight Scorpius variants: two suborbital vehicles, the SR-S and SR-M launchers; three light-lift orbital vehicles, the Sprite Mini-Lift, the Eagle SLV, and the Liberty Light-Lift launchers; one intermediate-lift orbital vehicle, the Antares Intermediate-Lift launcher; one medium-lift vehicle, the Exodus Medium-Lift launcher; and one heavy-lift vehicle, the Space Freighter. Despite the wide range in their sizes and lift capacities, each Scorpius variant is based on a scaleable modular design featuring simple LOX/Jet-A pressure-fed motors without turbopumps and low-cost avionics equipped with GPS/INS (global positioning system/inertial navigation system). The orbital variants are three stages and feature thick fuel tanks for added durability during flight.

The Scorpius system is designed simply in order to maximize the cost savings and quick launch pad turnaround times sought by government-sponsored responsive space initiatives. As a first step, the test launches of the suborbital SR-S and SR-XM-1 vehicles demonstrated Scorpius' ability to be ready for flight within 8 hours of arrival at the launch pad, using a crew of under 15. When marketed, the SR-S vehicle is advertised as able to loft 200 kilograms (440 pounds) suborbitally. The SR-M would loft 1,089 kilograms (2,400 pounds) suborbitally.

The Sprite Mini-Lift vehicle is projected to loft up to 318 kilograms (700 pounds) to LEO. Eagle SLV would loft up to 667 kilograms (1,470 pounds) to LEO. The Liberty Light Lift vehicle would loft up to 1,270 kilograms (2,800 pounds) to LEO.

Microcosm's intermediate-, medium-, and heavy-lift Scorpius variants will be able deploy payloads to LEO and GTO. The Antares Intermediate-Lift vehicle will be able to deploy up to 2,676 kilograms (5,900 pounds) to LEO and up to 885 kilograms (1,950 pounds) to GTO. The Exodus Medium-Lift vehicle would deploy up to 6,713 kilograms (14,800 pounds) to LEO and up to 2327 kilograms (5,130 pounds) to GTO. Specifications for the heavy-lift Space Freighter are not yet available.

Of the Scorpius variants, the Sprite Mini-Lift and Eagle SLV are furthest along in development. Microcosm currently plans test flights for one or both of those vehicles in the third quarter of 2007.

### QuickReach – AirLaunch, LLC

**Vehicle:** QuickReach
**Developer:** AirLaunch, LLC
**First launch:** To be determined
**Number of stages:** 3 (including the launch aircraft)
**Payload performance:** 454 kg (1,000 lbs.) to LEO
**Launch sites:** To be determined

QuickReach

AirLaunch, LLC, and its team of contractors is one of four recipients of the DARPA FALCON contracts to develop concepts for a low-cost launch vehicle. QuickReach uses two liquid-fueled stages and deploys from the cargo bay of a C-17 or Antonov-124 aircraft. DARPA is expected to select a contractor no later than 2007 to further develop their concept and to conduct flight tests.

### SLC-1 – Space Launch Corporation

**Vehicle:** SLC-1
**Developer:** Space Launch Corporation
**First launch:** 2008
**Number of stages:** 3 (including the launch aircraft)
**Payload performance:** 150 kg (330 lbs.) to LEO
**Launch sites:** To be determined

The Space Launch Corporation of Irvine, California, is in the initial development stages of its SLC-1 launch system. The SLC-1 will use a small expendable booster, consisting of multiple, custom-built stages based on existing technology. The booster will be deployed from a turbojet-powered aircraft and be able to place payloads of up to 150 kilograms (330 pounds) into a 500-kilometer (311-mile) orbit inclined at 28.5 degrees.[15] The company is targeting microsatellites and other small payloads that would otherwise be launched as secondary payloads on larger vehicles.

The Space Launch Corporation was also selected as the sole prime contractor for DARPA's Responsive Access, Small Cargo, Affordable Launch (RASCAL) program in March 2003. RASCAL is a new tactical launch system that will provide the U.S. military with the ability to launch time critical space-based assets within hours of detection of an emerging threat. Under the DARPA RASCAL program, Space Launch expects to achieve mission recurring costs of less than $10,000 per kilogram.

In November 2004, the Space Launch Corporation announced successful completion of the second phase of the DARPA RASCAL program. The goal of Phase 2 was to advance the design of the RASCAL system concept and mitigate the technical risks identified in Phase 1. The RASCAL system consists of two major elements; the MIPCC-Powered Vehicle (MPV), a new aircraft employing mass injection pre-compressor cooled turbojet engine technology, and a multi-stage expendable rocket vehicle (ERV). Phase 2 ended with a successful system preliminary design review (PDR). Phase 3 of the RASCAL program, scheduled to begin in the first quarter of 2005, will culminate in the fabrication and integration of a prototype RASCAL system and two flight demonstrations where a small payload will be launched into LEO. The first RASCAL demonstration launch is expected to take place in 2008.[16]

### Zenit 3SLB – Sea Launch Company, LLC, and Space International Services

**Vehicle:** Zenit 3SLB
**Developer:** Space International Services
**First launch:** 2006
**Number of stages:** 2 (Zenit 2SLB), 3 (Zenit 3SLB)
**Payload performance:** 2,000 to 3,500 kg (4,410 to 7,718 lbs.) to GTO
**Launch sites:** Baikonur


Zenit 3SLB

The Sea Launch Board of Directors voted on September 30, 2003, to offer launch services from Baikonur Cosmodrome in Kazakhstan, in addition to its sea-based launches at the Equator. The new offering, Land Launch, is based on the collaboration of Sea Launch Company and Space International Services, of Russia, to meet the launch needs of commercial customers with medium weight satellites. The Land Launch system uses a version of the Sea Launch Zenit-3SL rocket, the Zenit-3SLB, to lift commercial satellites in the 2,000 to 3,500-kilogram (4,410 to 7,718-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, with the only significant difference between two being the fairing.[17] A two-stage configuration of the same rocket, the Zenit-2SLB, is also available for launching heavy payloads, or groups of payloads, to LEO. Payloads and vehicles will be processed and launched from existing Zenit facilities at the Baikonur launch site. Initial launch capability is slated for 2006. Expanding on its Sea Launch marketing efforts, Boeing Launch Services, Inc., manages marketing and sales for this new offering.

## Sounding Rockets

In addition to orbital launch vehicles, a number of suborbital ELVs, or sounding rockets, are in use today. These vehicles, which use solid propellants, support a variety of applications, including astronomical observations, atmospheric research, and microgravity experiments.

### Black Brant – Bristol Aerospace Limited (a Magellan Aerospace Company)


Black Brant launch

Over 800 Black Brant rockets have been launched since 1962, when manufacture 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 Nihka motors used on some Black Brant versions are manufactured in Canada by Bristol Aerospace Limited (a Magellan Aerospace Company). The Nike, Talos, and Taurus motors used on other Black Brant versions are built in the United States. These vehicles are integrated by the launch operator. 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 5, 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 5 motor is used as the second or third stage in larger, multi-stage versions of the Black Brant. The most powerful, Black Brant 12, is a four-stage vehicle that uses the Black Brant 5 motor as its third stage. This vehicle can launch a 113-kilogram (249-pound) payload to an altitude of at least 1,400 kilometers (870 miles), or a 454-kilogram (1,001-pound) payload to an altitude of at least 400 kilometers (249 miles).

### Oriole – DTI Associates


Oriole

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 6 to 9 minutes of microgravity during flight. Additionally, it can be combined with other motors to create two-stage sounding rockets (with the Oriole serving as the second stage).

On July 7, 2000, the first Oriole launch took place from NASA WFF. The launch used a two-stage configuration, with the Oriole serving as the second stage and a Terrier Mk 12 motor serving as the first stage. The Oriole sounding rocket reached a peak altitude of 385.6 kilometers (229 miles) 315 seconds after launch during the 10-minute test flight.

In July 2001, SPACEHAB's Astrotech Space Operations sold the Oriole program to DTI Associates of Arlington, Virginia, which integrates the vehicle and offers it commercially.

### Terrier-Orion – DTI Associates


Terrier-Orion

The Terrier-Orion is a two-stage, spin-stabilized sounding rocket. It uses a Terrier Mk 12 Mod 1 engine for its first stage and an improved Orion motor for its second stage. The Terrier Mk Mod 1 is a surplus U.S. Navy missile motor; Orion is a surplus U.S. Army missile motor. The Terrier-Orion is 10.7 meters (35.1 feet) long. The Terrier stage is 46 centimeters (18 inches) in diameter, and the Orion is 36 centimeters (14 inches) in diameter. The Terrier-Orion can loft payloads weighing up to 290 kilograms (639 pounds) to altitudes up to 190 kilometers (118 miles).

A more powerful version of the Terrier-Orion rocket uses the Terrier Mk 70 motor as its first stage. This version was used for two FAA/AST-licensed suborbital launches performed by Astrotech Space Operations/DTI at the Woomera Instrumented Range in Australia in 2001 and 2002. The second flight, in July 2002, successfully flew the HyShot scramjet engine experiment.

DTI Associates of Arlington, Virginia, now markets and offers integration services for the Terrier-Orion after purchasing all intellectual property rights to the rocket from SPACEHAB in July 2001.

### Hybrid Sounding Rocket Program – Lockheed Martin-Michoud

HYSR

Lockheed Martin-Michoud is developing a hybrid sounding rocket (HYSR) program with NASA Marshall Space Flight Center (MSFC). A Space Act Agreement between NASA MSFC and Lockheed Martin-Michoud Operations enabled collaboration on this new technology. Development ground testing (hardware qualification) occurred at NASA Stennis Space Center between 2000 and 2001. This testing concluded with a successful demonstration flight of a prototype sounding rocket from NASA WFF in December 2002. The flight demonstration vehicle was a 17.4-meter (57-foot) long sounding rocket using liquid oxygen and solid fuel, a rubberized compound known as hydroxyl terminated polybutadiene (HTPB). The rocket generated 27,216 kilograms (60,000 pounds) of thrust during a burn time of 31 seconds, and reached an altitude of approximately 43 miles.

In 2004, there was further testing of the HYSR motors at NASA Stennis Space Center. The tests demonstrated the structural integrity of Lockheed Martin-Michoud's fuel-grain design and are facilitating development of advanced state-of-the-art hybrid rocket motors.

### Norwegian Sounding Rocket Program – Lockheed Martin-Michoud

Lockheed Martin-Michoud is also engaged in the Pantera Program, which provides a laser enabled in-flight targeting system for Norway's air force. The single-stage rocket will be built by the Norwegian company Nammo Raufoss AS, but the design, engineering schematics, and vehicle assembly plan will be provided by Lockheed Martin-Michoud. The hybrid rocket will use liquid oxygen and rubberized HTPB as fuel. It will have a 3,175-kilogram (7,000-pound) thrust and a burn time of 30 to 35 seconds. Its peak altitude is expected to be between 55 and 75 kilometers (34 and 57 miles). Lockheed Martin-Michoud obtained an International Traffic in Arms Regulations (ITAR) Manufacturing License Agreement from the U.S. Government to gain approval for the 17-month design and handoff project. The sounding rocket is expected to launch from Norway's Andoya Rocket Range in 2005.[18]

# Reusable Launch Vehicles

This section describes active and emerging RLV programs in the United States. Emphasis is placed on vehicles being developed by private companies without the assistance of the government. Many of these companies are developing space hardware for the first time. Government RLV programs are also included to provide context, particularly since the Space Shuttle is considered a first-generation RLV and is a precursor of what may become a long line of government next-generation systems. Experiences gained by operating the Space Shuttle for more than 20 years have helped solve, as well as highlight, crucial problems related to the design of efficient RLV systems. The first section addresses commercial RLV projects underway or in development. A discussion of government RLV development efforts comprises the balance of this section.

## Commercial RLV Development Efforts

### Black Armadillo – Armadillo Aerospace

**Vehicle:** Black Armadillo
**Developer:** Armadillo Aerospace
**First launch:** 2005
**Number of stages:** 1
**Possible launch sites:** White Sands, New Mexico
**Targeted markets:** Public space transportation and other emerging markets

Armadillo Aerospace continues development of its vehicle, Black Armadillo, which was previously planned as the company's Ansari X Prize entrant. Armadillo Aerospace plans to continue pursuing suborbital passenger flights and microgravity research. The vehicle will consist of an autonomously guided single stage powered by a single engine fueled by a bi-modal monopropellant hydrogen peroxide/ methanol mixture and will use guide vanes for the thrust-vectored attitude control system (ACS). The vehicle is approximately 1.83 meters (6 feet) in diameter, 9.14 meters (30 feet) in height, and 771 kilograms (1,700 pounds) dry weight. Recovery is by way of a fully autonomous powered landing.

In 2004, Armadillo conducted numerous engine tests and flight tests. One test on August 8 resulted in the loss of the test vehicle. Much of the rest of 2004 was focused on rebuilding and testing hardware. The company switched from a 90 percent hydrogen peroxide fuel to a mixed monopropellant design because of lack of availability of the original fuel. The switch has introduced delays in the program.

### Sea Star – Interorbital Systems

**Vehicle:** Sea Star MSLV
**Developer:** Interorbital Systems
**First launch:** 2005
**Number of stages:** 3
**Payload performance:** 45 kg (100 lbs.) to LEO, (21°, 402 km (250 mi)), 29 kg (65 lbs.) to polar orbit
**Launch sites:** Pacific Ocean near California and Kingdom of Tonga

Interorbital Systems (IOS) of Mojave, California, is developing the Sea Star MSLV microsatellite launch vehicle for microsatellite payloads and as a testbed for its larger Neptune orbital launch vehicle. These vehicles are constructed for design simplicity. Sea Star MSLV consists of three stages. Each stage has one hypergolic engine, burning white fuming nitric acid (WFNA) and a proprietary fuel formulation that IOS calls Hydrocarbon X (HX). The first two stages each have four gimbaled low-thrust rockets for steering, and stage 3 is spin-stabilized. The rocket body is constructed of aluminum and composite materials. Sea Star does not require land-based launch infrastructure. Taking advantage of design elements derived from submarine-launched ballistic missiles, this vehicle will float in sea water and launch directly from the ocean. IOS plans to launch Sea Star MSLV near California or in waters near the Kingdom of Tonga.

IOS aims to be the first company to launch a satellite into orbit using a vehicle developed totally with private financing. This launch is slated for 2005.

## Neptune – Interorbital Systems

**Vehicle:** Neptune

**Developer:** Interorbital Systems

**First launch:** 2006

**Number of stages:** 3

**Payload performance:** 4,082 kg (9,000 lbs.) to LEO (21°, 402 km (250 mi), 2,898 kg (6,390 lbs.), SSO (644 km (400 mi), 1,224 kg (2,700 lbs.) GTO, 816 kg (1,800 lbs.) lunar orbit

**Launch sites:** Pacific Ocean near California and Kingdom of Tonga

Neptune

IOS' Neptune will support a number of human spaceflight and other payload launch missions. In November 2004, IOS entered as a competitor for America's Space Prize, the $50-million contest sponsored by Bigelow Aerospace for a privately developed launch of a piloted vehicle to orbit. Neptune will be powered by two high-thrust bipropellant liquid rocket engines. Like Sea Star, Neptune is designed to launch from the sea using a two-stage booster and an orbital stage. Its first two booster stages will each use a single hypergolic engine, burning WFNA and HX, with four steering rockets per stage. The orbital stage will use a single cryogenic LOX/HX engine. The booster stages are designed to be water-recoverable with a parachute landing and reusable. The orbital stage and crew capsule will allow for stays on orbit of up to 7 days. Fuel tanks of the orbital stage can be outfitted for habitation and may even serve as future modules for an orbiting space hotel. The crew capsule can be reused after a parachute landing. The crew compartment includes an aft escape and service module to pull passengers away from the vehicle and to a safe landing in the event of vehicle failure.

## K-1 – Kistler Aerospace Corporation

**Vehicle:** K-1

**Developer:** Kistler Aerospace Corporation

**First launch:** To be determined

**Number of stages:** 2

**Payload performance:** 5,700 kg (12,500 lbs.) to LEO; 3,200 kg (7,000 lbs.) to ISS and 900 kg (2,000 lbs.) from ISS; 1,570 kg (3,460 lbs.) to GTO, 900-1,400 kg (2,000-3,000 lbs.) to interplanetary targets

**Planned launch sites:** Woomera, Australia; U.S. launch site under evaluation

**Targeted markets:** Deployment of payloads to LEO, MEO, and GTO; interplanetary orbits (with K-1 Active Dispenser); ISS cargo re-supply and return missions.

K-1

Kistler Aerospace Corporation has been developing the fully reusable K-1 for launches of government and commercial payloads to orbit. The first vehicle is 75 percent complete. The K-1 design was developed in the mid-1990s as a two-stage-to-orbit (TSTO) vehicle with a payload capacity of approximately 5,700 kilograms (12,500 pounds) to LEO. The K-1 will be able to launch multiple small payloads and conduct technology demonstrations on dedicated LEO missions or as secondary payloads.

Kistler has completed a conceptual design for an Active Dispenser that will deploy payloads to medium Earth orbits (MEO), GTO, and interplanetary trajectories. The Active Dispenser will expand the K-1's capability beyond LEO (approximately 1,570 kilograms (3,462 pounds) to GTO or 900 to 1,400 kilograms (2,000 to 3,000 pounds) to interplanetary targets). The K-1's inherent reusability enables it to provide cargo re-supply and return services for the International Space Station (ISS), delivering approximately 3,200 kilograms (7,000 pounds) up-mass and recovering a minimum of 900 kilograms (2,000 pounds) down-mass to the launch site. The K-1 will launch vertically like a conventional ELV, but it will use a unique combination of parachutes and air bags to recover its two stages. Designed to operate with a small complement of ground personnel, this vehicle will be transported to the launch site and erected with a mobile transporter. The K-1 will measure approximately 37 meters (121 feet) in height and have a launch mass of 382,300 kilograms (843,000 pounds).

The K-1 employs off-the-shelf technology and components in its design. The first stage, known as the Launch Assist Platform (LAP), is powered by three LOX/kerosene GenCorp Aerojet AJ26 engines. These engines are U.S. modifications of the fully developed, extensively tested core of the NK-33/NK-43 engines. These engines were originally designed for the Soviet lunar program in the 1960s and subsequently placed in storage for over two decades. After launch, the LAP separates from the second stage and restarts its center engine to put the stage on a return trajectory to a landing area near the launch site. The LAP deploys parachutes and descends to the landing area where air bags are deployed to cushion its landing. The second stage, or orbital vehicle, continues into LEO where it releases its payload. A single Aerojet AJ26-60 engine powers the orbital vehicle. Following payload separation, the orbital vehicle continues on orbit for approximately 24 hours. Then, a LOX/ethanol Orbital Maneuvering System performs a deorbit burn. Lastly, the orbital vehicle ends its ballistic reentry profile by deploying parachutes and air bags in a manner similar to the LAP.

Kistler expects to operate the K-1 from two launch sites: Woomera, Australia, and a U.S. domestic launch site. Kistler Woomera Pty., Ltd., a wholly owned subsidiary of Kistler Aerospace Corporation, will operate the K-1 from Woomera. Kistler received authorization from the Australian government to begin construction of launch facilities at Woomera in April 1998 and held a groundbreaking ceremony at the site several months later. The launch pad design is complete, and Kistler will conduct its initial K-1 flights and commercial operations from Woomera. In 1998, Kistler signed an agreement with the Nevada Test Site Development Corporation to permit Kistler to occupy a segment of the U.S. Department of Energy's Nevada Test Site for its launch operations. The FAA/AST environmental review process was completed for the Kistler project in 2002. In addition, Kistler continues to explore potential U.S. launch and landing sites (subject to regulatory approval), such as at CCAFS, VAFB, and EAFB. In 2003, Kistler filed to reorganize under Chapter 11 of the U.S. Bankruptcy Code, and it is in the final stages of the reorganization process. Kistler plans to emerge from Chapter 11 and restart the K-1 program in 2005.[19]

### Rocketplane XP – Rocketplane Limited, Inc.

**Vehicle:** Rocketplane XP

**Developer:** Rocketplane Limited, Inc.

**First launch:** 2007

**Number of stages:** 1

**Payload performance:** 408 kg (900 lbs.) to 100 km (62.5 miles)

**Planned launch sites:** Oklahoma Spaceport (primary) and KSC (alternate)

**Targeted markets:** Suborbital space tourism, microgravity research, small satellite deployment


Rocketplane XP

Rocketplane Limited is developing the Rocketplane XP, a scaled-down version of its original Pathfinder vehicle concept. The Rocketplane XP is a four-seat fighter-sized vehicle powered by two jet engines and one pressure-fed LOX/kerosene rocket engine, enabling it to reach altitudes of 107 kilometers (66 miles). In 2004, Rocketplane Limited signed a marketing agreement with Incredible Adventures to sell suborbital tourist flights. The company is currently taking reservations for Rocketplane flights and hopes to make its first tourist flight in 2007.

The spaceflight experience as currently envisioned includes 5 days of training and team social events, with the spaceflight on the sixth day. In addition to space tourism flights, the company is pursuing other markets, including microgravity research and military applications, including small satellite deployment.[20]

### SpaceShipOne – Scaled Composites, LLC

**Vehicle:** SpaceShipOne
**Developer:** Scaled Composites
**First launch:** 2003
**Number of stages:** 1
**Payload performance:** 3 people to 100 km (62.5 miles)
**Planned launch sites:** Mojave Airport
**Targeted markets:** Research and development, space tourism


SpaceShipOne

Scaled Composites, the winner of the ground-breaking Ansari X Prize, and the team that made the first historic, non-governmental manned-rocket flight to suborbital space, unveiled its vehicle on April 18, 2003. SpaceShipOne is a three-person vehicle designed to be air-launched at an altitude of 15,240 meters (50,000 feet) from a carrier aircraft, called White Knight. On April 1, 2004, FAA/AST issued the first commercial RLV mission-specific launch license (LRLS 04-067) to Scaled. Including the September 29 and October 4 Ansari X Prize-winning flights, SpaceShipOne successfully completed five licensed flights in 2004.

On September 27, 2004, Sir Richard Branson of the Virgin Group announced Virgin Galactic, a space tourism company, will use the technology developed in the creation of SpaceShipOne to carry paying passengers into space. Virgin Galactic expects to launch its first flight around 2007, with full commercial service by the end of the decade.

The spaceflight experience as currently envisioned will last approximately 6 days, including preflight training, social events, dinners with astronauts and guest speakers, and luxury accommodations. Flight into suborbital space will allow customers to experience the acceleration of a rocket flight, to feel weightlessness, and to see the Earth from space. In addition, 7-UP™, the official beverage of the Ansari X Prize, announced plans to offer consumers the first free ticket into space aboard a Virgin Galactic craft.[21]

### Falcon 1 – Space Exploration Technologies Corporation

**Vehicle:** Falcon 1
**Developer:** Space Exploration Technologies Corporation
**First launch:** 2005
**Number of stages:** 2
**Payload performance:** 670 kg (1,477 lbs.) to LEO
**Planned launch sites:** VAFB, CCAFS, Marshall Islands
**Targeted markets:** Commerical small satellites


Falcon 1

Space Exploration Technologies Corporation (SpaceX) of El Segundo, California, is developing the partially reusable Falcon 1 launch vehicle, which can place up to 670 kilograms (1,477 pounds) into LEO. The first stage of this vehicle is designed to be recovered from the ocean after a parachute landing, refurbished, and reused.

Falcon's first launch is scheduled for 2005 from VAFB to loft the TacSat-1 data communications satellite for DoD. Up to two other launches of Falcon 1 are planned for 2005 from a launch site at the Marshall Islands in the Pacific Ocean. SpaceX anticipates two to three launches annually, eventually ramping up to five or six flights a year. SpaceX is privately developing the entire two-stage vehicle from the ground up, including the engines, cryogenic tank structure, and guidance system. The SpaceX-developed first stage engine, known as Merlin, uses pump-driven LOX/kerosene. The second stage engine, called Kestrel, uses a pressure-fed LOX/kerosene system.

In September 2004, SpaceX was one of four companies to receive a contract from DARPA and the USAF to demonstrate low-cost, highly responsive launch technology. Under this contract, SpaceX is to demonstrate the ability to reduce on-pad processing time by 50 percent compared to the standard Falcon 1 launcher.

### Falcon 5 – Space Exploration Technologies Corporation

**Vehicle:** Falcon 5

**Developer:** Space Exploration Technologies Corporation

**First launch:** Mid-2006

**Number of stages:** 2

**Payload performance:** Up to 6,020 kg (13,274 lbs.) to LEO

**Planned launch sites:** VAFB, CCAFS, Marshall Islands. (Agreements are also in place to determine feasibility from Alaska and Virginia.)

**Targeted markets:** GEO communications satellites; interplanetary missions

The Falcon 5 vehicle is based on much of the same technology developed for Falcon 1. The larger Falcon 5 uses five SpaceX-developed Merlin engines in the first stage with an engine-out capability to enhance reliability. The second stage will use one Merlin engine, instead of two Kestrel engines as previously planned. The first Falcon 5 launch is expected in mid 2006 from VAFB. For subsequent Falcon 5 flights, SpaceX is developing the Merlin 2 engine that is expected to enable greater lift capacity, up to 6,020 kilograms (13,274 pounds) to LEO.

### Michelle-B – TGV Rockets, Inc.

**Vehicle:** Michelle-B

**Developer:** TGV

**First launch:** To be determined

**Number of stages:** 1

**Payload performance:** 1,000 kg (2,200 lbs.) to 100 km (62.5 miles)

**Planned launch sites:** Oklahoma Spaceport and other possible sites

**Targeted markets:** Microgravity research, suborbital space tourism

Michelle-B

TGV Rockets, Incorporated (TGV), is developing Michelle-B, a fully reusable, piloted suborbital vehicle designed to carry up to 1,000 kilograms (2,205 pounds) to an altitude of 100 kilometers (62 miles). This vehicle uses a vertical take-off and landing design, 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 *g* during any phase of flight. Six pressure-fed LOX/kerosene engines for use on both 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. Flight testing of the Michelle-B is slated to begin in 2007.[22]

### Xerus – XCOR Aerospace

**Vehicle:** Xerus

**Developer:** XCOR Aerospace

**First launch:** To be determined

**Number of stages:** 1

**Payload performance:** 10 kg (22 lbs.) to LEO

**Possible launch sites:** Mojave Airport

**Targeted market:** Suborbital space tourism, microgravity research, microsatellite launch

XCOR Aerospace: Xerus vehicle concept

In April 2004, XCOR Aerospace received a license from FAA/AST to perform flights from Mojave Airport in Mojave, California. These flights of the Sphinx demonstration vehicle are designed to fly within the Earth's atmosphere. For suborbital flight, XCOR is developing Xerus to conduct a variety of suborbital missions including microgravity research, suborbital tourism, and even the launch of very small satellites into orbit. Xerus is expected to have the ability to launch a 10-kilogram (22-pound) payload to LEO. XCOR is not currently disclosing its schedule or certain design details of the Xerus, except that it will take-off and land from a conventional runway without a booster stage or carrier vehicle. Xerus will be powered by XCOR's own liquid rocket engines.

## Government RLV Development Efforts

Throughout the 1980s and 1990s, both NASA and the U.S. Department of Defense (DoD) 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. None of these concepts, however, resulted in a fully operational vehicle.

In 2002, both NASA and the military reevaluated their RLV efforts. NASA implemented a revised Integrated Space Transportation Plan (ISTP) to better coordinate its space transportation efforts with its ISS, science, and research needs. The revised ISTP continued to support the Space Shuttle with a Service Life Extension Program (SLEP), and it restructured the Space Launch Initiative (SLI) to accommodate the development initially of an ISS CRV (crew rescue vehicle), and then the development of a CTV (crew transfer vehicle) called the Orbital Space Plane (OSP). The restructured SLI also has a component called the Next Generation Launch Technology (NGLT) to continue development of next generation and subsequent generations of launch vehicle technology.

On January 14, 2004, President George W. Bush announced a new vision to retire the Space Shuttle and develop a new vehicle capable of carrying astronauts to the ISS and explore space beyond LEO. After the announcement of the new Vision for Space Exploration in January 2004, NASA shut down both the OSP and NGLT programs as it shifted resources to Project Constellation, an effort to develop a new CEV and related mission architectures. The SLEP is now focused on near-term Shuttle upgrades given NASA's plan to retire the Space Shuttle fleet in 2010.

In November 2004, the U.S. Congress authorized full funding of NASA's $16.2 billion budget for fiscal year 2005 that NASA needed in order to return the Shuttle to flight and get the CEV development off to a good start.

### Space Shuttle

**Vehicles:** Discovery, Atlantis, 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:** April 12, 1981

**Number of stages:** 1.5

**Payload performance:** 24,900 kg (54,890 lbs.) to LEO

**Launch site:** KSC

**Markets served:** Non-commercial payloads and ISS access

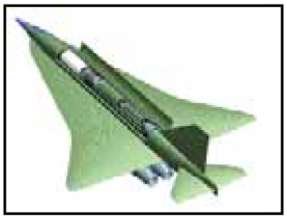
Space Shuttle

Consisting of an expendable external tank, two reusable solid rocket boosters, and a reusable Orbiter, NASA's STS (Space Transportation System), commonly referred to as the Space Shuttle, has conducted 113 launches from its introduction in 1981 through the final flight of the *Columbia* in 2003.

The three remaining orbiters – *Discovery, Atlantis*, and *Endeavour* – have been grounded since the *Columbia* accident. The Space Shuttle is the only means available today 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 responsibilities constructing the ISS are complete. NASA's SLEP will support and maintain the Shuttles and associated infrastructure through the remainder of the Shuttle program. NASA will consider factors including safety, reliability, supportability, performance, and cost reduction in prioritizing improvement projects.

The Space Shuttle's day-to-day operations have been managed by United Space Alliance, a Boeing-Lockheed Martin joint venture, since 1996. NASA exercised two extension options to the contract and United Space Alliance is now supported through the end of fiscal year 2006. NASA is working on developing a new operations contract for fiscal year 2007 through the end of the Shuttle program.

## RASCAL



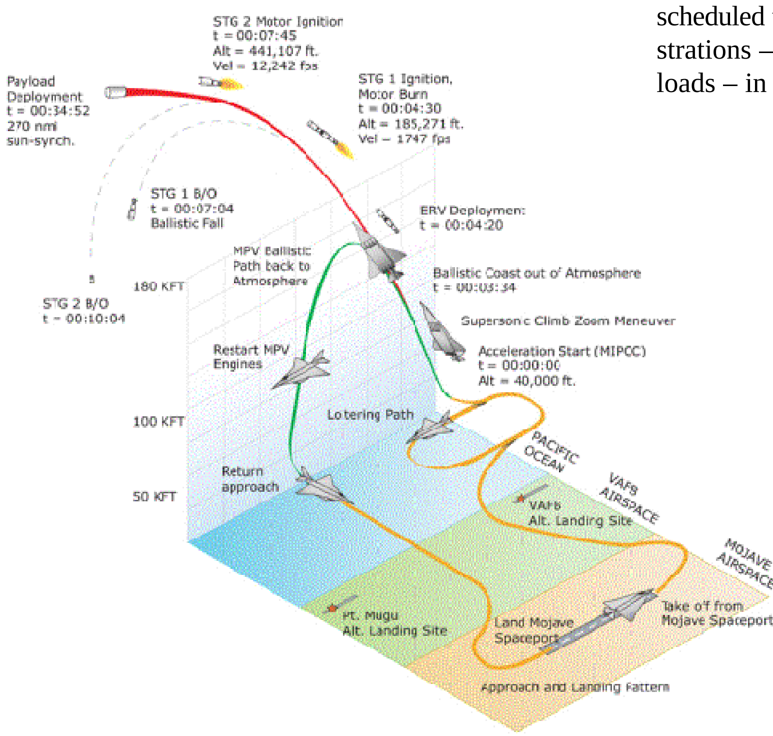
MPV deploying ERV

ERV first stage ignition

DARPA started work in 2002 on a project to create a low-cost, partially-reusable launch vehicle for small payloads. The project was seen as a potential solution to the U.S. military's need for operationally responsive spacelift (ORS). This ORS requirement was expressed in a USAF mission need statement in 2001. The RASCAL program seeks to develop a two-stage air launch system that can place payloads weighing up to 100 kilograms (221 pounds) into LEO. The RASCAL first stage will be an air-breathing jet aircraft that flies to an altitude of at least 55 kilometers (34 miles). The aircraft will then deploy an expendable rocket to place the payload into orbit. The vehicle will be able to put at least 50 kilograms (110 pounds) into any inclination, including 75 kilograms (165 pounds) into Sun-synchronous orbit (SSO) and heavier payloads into equatorial orbits. The RASCAL vehicle will be able to take off within 1 hour of a launch command and refly again within 24 hours at a cost of no more than $10,000 per kilogram per flight.

To achieve these performance goals, RASCAL will use an engine technology called Mass Injected Pre-Compressor Cooling (MIPCC) on its aircraft stage. A MIPCC engine is a conventional turbojet with an additional stage that injects a coolant, such as water or liquid oxygen, into the engine inlet.

Six competitors were awarded Phase 1 contracts in April of 2002. The teams were led by Coleman Research Corp., Northrop Grumman Corp., Pioneer Rocketplane Corp., Space Launch Corp., Space Access LLC, and Delta Velocity. In 2003, DARPA selected Space Launch Corporation as the only RASCAL Phase 2 award winner. Ansari X Prize winner Scaled Composites is on the Space Launch Corporation team and is designing the RASCAL airframe. Phase 2 was an 18-month design phase that advanced the RASCAL system to preliminary design level and validated system design feasibility that was completed in 2004. Phase 3 will serve as the detailed design, construction, test, and demonstration launch phase of the RASCAL program. Flight tests are scheduled to begin in 2006 with final system demonstrations – including the launch of two orbital payloads – in 2008.




Typical RASCAL mission profile

# In-Space Technology

## Crew Exploration Vehicle (CEV)

On January 14, 2004, President George W. Bush announced a new Vision for Space Exploration. Dubbed Project Constellation, this vision calls for retiring the Space Shuttle, developing a new vehicle capable of carrying astronauts to the ISS, and exploring space beyond LEO. Initially, the United States will return the Space Shuttle to flight in accordance with the recommendations of the CAIB (*Columbia* Accident Investigation Board) to complete its work on the ISS by 2010. Then, the Shuttle will be retired. The CEV is envisioned as a modular space transportation system that will be able to carry crews beyond LEO, such as to the Moon or other destinations. Plans call for completing the first test flight of a CEV by 2008 and carrying human crews by 2014. The CEV will transport astronauts and scientists to the ISS after the Shuttle is retired. Following a series of robotic missions, extended manned missions to the Moon could begin as early as 2015. Knowledge gained through extended visits to the Moon will be used to develop technology for human missions beyond the Moon, beginning with Mars. The plans are expected to cost $12 billion over the first 5 years. The majority of the funding would be derived from reallocations within the existing NASA budget. Using the advice of a new President's Commission on the Implementation of the U.S. Space Exploration Policy, NASA will review existing spaceflight and exploration programs and develop a plan for long-term implementation of the President's vision. In November 2004, the U.S. Congress authorized full funding of the $16.2 billion budget that NASA needed to return the Shuttle to flight and get the CEV development off to a good start.

In September 2004, NASA awarded study contracts to the following eight firms. These firms included large, established aerospace companies as well as small, entrepreneurial companies.

- Andrews Space & Technology, Inc.
- The Boeing Company
- Draper Laboratories
- Lockheed Martin Corporation
- Northrop Grumman Corporation
- Orbital Sciences Corporation
- Schafer Corporation
- Transformational Space Corporation, LLC (t/Space)

Several companies are building upon technology developed under previous NASA programs, such as SLI, OSP, and NGLT. Some designs are expected to fly on Atlas 5 or Delta 4 vehicles. Proposals for the test vehicle are expected to be submitted in 2005. To what extent components of the CEV will be reusable is unclear. That determination will depend on the individual design concepts.

CEV

# Enabling Technologies

Several efforts are underway to develop enabling technologies for expendable and reusable launch vehicles. These efforts include government research projects as well as engines and motors developed by companies for their launch vehicles and sale to other companies. Many of these companies are attempting to build considerably less complex and potentially less expensive rocket engines. Some designs use room-temperature propellants instead of cryogenics. Others use pressure-fed engines instead of turbopumps. Such enabling technologies as hybrid rocket motors, propulsion systems, liquid engines, propellant production, demonstrators, and hypersonic aircraft are described in this section.

## Hybrid Rocket Motors – SpaceDev, Inc.


SpaceDev hybrid propulsion system

In 1998, SpaceDev, Inc., of Poway, California, acquired exclusive rights to the intellectual property of the American Rocket Company, which had developed hybrid rocket motor systems in the 1980s. SpaceDev is currently developing a series of small hybrid motors, using HTPB rubber or polymethyl methacrylate (Plexiglas) as solid fuel and storable nitrous oxide as a gaseous oxidizer. SpaceDev completed tests in August 2001 of a small hybrid rocket motor that is designed for use in the company's Maneuver and Transfer Vehicle, an upper stage that can move small spacecraft, such as secondary payloads on larger launch vehicles, from GTO, LEO or GEO. In May 2002, the AFRL awarded SpaceDev a contract to develop a hybrid propulsion module to deploy small payloads from the Space Shuttle. In September 2003, Scaled Composites announced that it had selected SpaceDev for propulsion support for its SpaceShipOne project. In a series of flights in late 2004, Space Dev's hybrid rocket motor powered SpaceShipOne to suborbital space twice in 2 weeks, thus propelling it to win the Ansari X Prize. In October 2004, SpaceDev was awarded about $1.5 million to proceed with Phase 2 of its Small Business Innovation Research contract from the AFRL to continue its hybrid rocket motor-based small launch vehicle project.[23]

## Hybrid Propulsion Systems – Lockheed Martin-Michoud

Hybrid motors of the 1.1 million-newton (250,000 pounds-force) thrust class are being studied for possible use on current and future launch vehicles. Funding for the hybrid team came from the DoD Technology Reinvestment Program, NASA monetary and in-kind support, and contributions of industry team members.[24]

In Nov. 2003, Lockheed Martin-Michoud Operations was awarded a 6-month study contract from DARPA as part of the USAF FALCON program to assess hybrid propulsion applications for a responsive small launch vehicle. This study concluded in May 2004. In September 2004, FALCON competitors began a 10-month design phase to be followed by a down-select to possibly two competitors, and a winning design to be selected in 2007. Lockheed Martin-Michoud's all-hybrid two-stage vehicle will deliver a payload up to 454 kilograms (1,000-pounds) to LEO and, if selected, will establish hybrid propulsion as a viable space launch booster technology. The core booster stage will generate approximately 1.4 million newtons (320,000 pounds-force) of thrust and the second stage approximately 133,333 newtons (30,000 pounds-force) of thrust to meet mission objectives using a HTPB and LOX motor.

Staged combustion hybrid technologies have been demonstrated on the ground by Lockheed Martin-Michoud Operations in over 600 ground tests of small and large diameter motor firings at the NASA Stennis Space Center and MSFC. Lockheed Martin-Michoud has six patents and more than $10 million of internal R&D invested to date.

## Liquid Engines – RS-84 – Rocketdyne Propulsion & Power


RS-84 liquid engine

Rocketdyne Propulsion & Power, a division of The Boeing Company in Canoga Park, California, is developing new technologies and engines for space launch vehicles. Rocketdyne is developing advanced health management systems, new materials, advanced processes, and new components that enable rocket engines to be safer and more reliable. These technologies are being demonstrated on development engines, such as the Integrated Powerhead Demonstrator engine with the USAF and NASA and on the new MB-XX upper stage engine to verify their characteristics.

NASA refocused its 2003 efforts onto the Vision for Space Exploration in 2004, halting work on the RS-84 to study and determine the type of vehicle and propulsion required to return the U.S. to the Moon and prepare to go to Mars. Rocketdyne is evaluating various propulsion options to meet the Vision for Space Exploration requirements and to enable significant improvements in current ELVs. Areas under consideration include the reliable SSME; the proven J-2S Saturn engines from the Apollo era; a derivative of the Delta 4 launch vehicle engine, RS-68; RS-84 technology; and the MB-XX upper stage engine.[25]

The MB-XX is being demonstrated on funding from Boeing and Mitsubishi Heavy Industries for potential application to the Vision for Space Exploration launch vehicle or upgrades to today's EELVs. Rocketdyne completed PDR on the RS-84 rocket engine, the first reusable hydrocarbon staged-combustion rocket engine. This engine is designed to produce 4,728,889 newtons (1,064,000 pounds-force) of thrust at sea level with a design life of 100 missions.

Rocketdyne successfully tested a key component of the RS-84 engine. In the test, a subscale preburner, achieved a chamber pressure in excess of 46,884 kiloPascals (6,800 pounds per square inch), well beyond the levels seen in current domestic LOX/kerosene rocket engines. This preburner produces high-pressure, oxidizer-rich combustion gases to spin the oxidizer and fuel turbopumps of the engine.

## Aerospike Liquid Engine – Garvey Spacecraft Corporation


Aerospike engine static fire test

During the past year, GSC and CSULB conducted several notable small launch vehicle R&D activities through their partnership in the California Launch Vehicle Education Initiative. Using a single-chamber, liquid propellant, annular aerospike engine concept developed by CSULB, the GSC/CSULB team validated the basic design and ignition sequence with a successful static fire test at the Reaction Research Society's MTA in June 2003. The team then mounted one of these 4,444-newton (1,000-pounds-force) thrust LOX/ethanol ablative engines onto their Prospector 2 vehicle and proceeded to conduct the first-ever powered liquid-propellant aerospike flight test at the MTA in September. In response to several issues observed during that flight, modifications were made to the engine fabrication process. Another flight test with the Prospector 4 vehicle followed in December. Performance was entirely nominal, resulting in complete recovery of the vehicle and key trajectory data.

These CALVEIN flight tests represent the first steps toward obtaining the critical empirical data needed to validate whether the predicted benefits of such aerospike engines versus those equipped with standard bell-shaped nozzles can be achieved. This goal had been one of the primary objectives of the X-33 program, which featured the XRS-2200 linear aerospike engine.

The CSULB students are now investigating a next generation aerospike engine design, featuring a more traditional multi-chamber design. This design will enable the large expansion ratios required to fully evaluate engine performance throughout the entire flight regime of an orbital launch vehicle.

As part of an evaluation of fuels for the NLV that could provide greater performance than the ethanol used in the current CALVEIN research vehicles, the team has identified propylene as a promising candidate meriting further attention. Liquid oxygen and propylene have the potential to provide higher specific impulse than the traditional LOX/RP-1 propellant combination. Unlike another alternative hydrocarbon that has received extensive discussion (methane), propylene can achieve comparable densities to that of RP-1 when chilled to cryogenic temperatures. A widely available commodity because of its role as a feedstock in the plastics industry, propylene also has favorable characteristics with respect to toxicity and environmental hazards. Some of the potential concerns about propylene, most notably its potential for polymerization, are only relevant for turbopump-fed regenerative engines. Therefore, those concerns are not issues for the pressure-fed NLV stages that feature ablative and radiative engine chambers.

The GSC/CSULB conducted a series of static fire tests at the MTA to identify logistics and handling issues associated with propylene and to evaluate a preliminary engine design for the NLV second stage. Preliminary results confirm that the ignition sequence is more susceptible to a hard start than liquid oxygen and ethanol. For this initial phase of testing, the propylene has been at ambient temperatures. A round of follow-on testing will evaluate several different ignition sequences and engine performance with propylene at cryogenic conditions. Upon successful completion of that phase of research, the team plans to conduct a LOX and propylene flight test using a modified version of the Prospector-class vehicles.[26]

## Liquid Engines – Microcosm, Inc.

Microcosm's liquid engine

Microcosm is developing a family of liquid-propellant rocket engines for its Scorpius series of ELVs and other users (see the ELV section for a description of Scorpius). The company has built a pressure-fed, ablatively cooled, 22,250-newton (5,000-pounds-force) thrust engine using liquid oxygen and jet fuel as propellants. This engine was successfully tested on the company's SR-S and SRXM-1 sounding rockets launched in January 1999 and March 2001. The engine will also be used as the upper stage engine for the Sprite Mini-Lift orbital vehicle should that vehicle move into final development.[27]

A larger version, an 89,000-newton (20,000-pounds-force) engine is in development. This engine will be used on the booster pods and sustainer stage of the Eagle SLV included in the DARPA and USAF FALCON Program.

In addition, a new 356,000-newton (80,000-pounds-force) engine has started development under an AFRL Small Business Innovation Research, Phase 1, contract. Both the 89,000-newton (20,000-pounds-force) and 356,000-newton (80,000-pounds-force) engines are follow-on developments to the successful 22,250-newton (5,000-pounds-force) engines. All are ablative chamber, LOX/Jet A propellant engines designed for very low-cost, robust design margins, moderate chamber pressures, high reliability, and expendable applications.

## Liquid Engines – Space Exploration Technologies Corporation

SpaceX Merlin engine

SpaceX of El Segundo, California, is developing two new liquid-propellant engines for use on its Falcon launch vehicle. The first stage engine, known as Merlin, is a 320,300-newton (72,000-pounds-force) thrust engine that is turbopump fed with a gas generator cycle. The second stage engine, known as Kestrel, is a pressure-fed engine that produces a 31,400-newton (7,000 pounds-force) vacuum thrust. Both engines use LOX/kerosene propellants. SpaceX began testing the Merlin in March 2003 and began testing the Kestrel in August 2003. Flight qualification of both engines is scheduled for completion by March 2005.[28]

## Liquid Engines – XCOR Aerospace

XCOR 5,000 pound-thrust LOX/kerosene engine

XCOR Aerospace, located in Mojave, California, specializes in developing engines and propulsion systems for use on launch vehicles and spacecraft. The company has developed and extensively tested five liquid-propellant engines. XCOR's largest engine currently in active development, designated XR4K5, is an 8,000-newton (1,800 pounds-force) engine that is pump-fed, LOX/kerosene regeneratively cooled with fuel. This engine may be used to power the prototype Xerus vehicle for initial flight testing, but XCOR has not yet decided on this approach.

The XR4A3 is a fully operational 1,780-newton (400-pounds-force), pressure-fed, regeneratively cooled, liquid oxygen and alcohol engine. Four such engines have been built and, combined, have been run 558 times for over 6,434 seconds. These engines have also been flown on the EZ-Rocket, a modified Long-EZ aircraft fitted with two of the engines. The EZ-Rocket has completed 15 successful flight tests since July 2001, including two flights at the Experimental Aircraft Association's AirVenture 2002 air show in Oshkosh, Wisconsin, in July 2002.

XCOR has built three smaller engines. A 67-newton (15-pounds-force) engine, designated XR2P1, using nitrous oxide and ethane as propellants, was initially built to test the design of proposed larger engines. With a cumulative burn time of 103 minutes, this engine has completed in excess of 1,189 runs. It continues to serve as a workhorse engine for a wide variety of experiments, crew training activities, and educational demonstrations. The XR2P1 has run on oxygen and nitrous oxide oxidizers, with propane, ethane, kerosene, turpentine, and a variety of alcohols. The XR3A2 700 newton (160 pounds-force) was the first LOX/alcohol engine, accumulating 61 brief runs in the course of injector concept development, which led to later engines. The XCOR XR3B4 regeneratively cooled engine is capable of a 220-newton (50-pounds-force) thrust, using nitrous oxide and isopropyl alcohol as propellants. This engine has completed 216 runs with a cumulative burn time of more than 812 seconds. XCOR designed this engine for use as a maneuvering thruster on spacecraft.[29]

In April 2002, XCOR acquired selected intellectual property assets of the former Rotary Rocket Company. These assets included a 22,250-newton (5,000-pounds-force) LOX/kerosene engine developed and tested by the company as well as hydrogen peroxide engine technology. XCOR has completed development of their fourth-generation igniter with integral valves and is now developing composite LOX tank technology with inherent materials compatibility and superior structural effectiveness. A piston pump suitable for use with LOX/kerosene, alcohol, or both, fuels is currently under development and will be merged with the XR4K5 engine.

## Propellant Production – Andrews Space, Inc.

Gryphon with orbiter

Andrews Space, Inc., of Seattle, Washington, has proposed a propulsion/propellant system to generate LOX propellant from the atmosphere. The Alchemist™ Air Collection and Enrichment System (ACES) takes high-pressure air from turbofan jet engines flying at subsonic speeds and liquefies it by passing the air through a series of heat exchangers cooled by liquid nitrogen, liquid hydrogen, or both. Then, using a fractional distillation process, liquid oxygen is separated into its constituent parts and stored in propellant tanks for use by liquid hydrogen and LOX rocket engines. Alchemist™ ACES allows horizontal take-off and landing launch vehicles to leave the ground without oxidizer, dramatically reducing their take-off weight, increasing payload capability, or both. The company has proposed Alchemist™ ACES in conjunction with its two-stage-to-orbit RLV design – known as Gryphon – as well as for use in other horizontal take-off launch vehicles. Andrews Space carried out initial studies of the Alchemist™ ACES technology using internal funds, then under a NASA SBIR contract. Detailed feasibility studies and risk analyses were carried out under a NASA SLI contract. Andrews also participated on an integrated, cooperative NASA/industry team for the NGLT program to study the Gryphon architecture as one of several promising concepts. The NGLT studies included additional Alchemist ACES design and configuration studies.[30]

### Integrated Powerhead Demonstrator – NASA


IPD test at NASA Stennis Space Center

The Integrated Powerhead Demonstrator (IPD) is a joint venture between NASA and the Integrated High Payoff Rocket Propulsion Technologies program, managed for DoD by the AFRL at EAFB. This project is the first phase of a full-scale effort to develop a flight-rated, full-flow, hydrogen-fueled, staged combustion rocket engine in the 1.1 million-newton (250,000-pounds-force) thrust class. The IPD will employ dual preburners that provide both oxygen-rich and hydrogen-rich staged combustion. Such combustion is expected to keep engines cool during flight, achieve high system efficiency, and reduce exhaust emissions. Boeing's Rocketdyne Propulsion & Power is developing the liquid-hydrogen fuel turbopump and the demonstrator's oxygen pump, main injector, and main combustion chamber. Aerojet Corporation of Sacramento, California, designed and tested the oxidizer preburner, which initiates the combustion process with oxygen-rich steam. Aerojet also is responsible for development of the demonstrator engine's fuel preburner, designed to supply the fuel turbopump's turbine with hot, hydrogen-rich steam. Boeing-Rocketdyne will lead overall system integration once component-level development and testing are complete. Integrated testing of IPD is ongoing at Stennis Space Center from late 2004 through September 2005.

### Hyper-X Series Vehicles – NASA


X-43A/Hyper X

On March 27, 2004, four decades of supersonic-combustion ramjet propulsion research culminated in a successful flight of the X-43A hypersonic technology demonstrator, the first time a scramjet-powered aircraft had flown freely. On November 16, 2004, an identical scramjet-powered X-43A repeated this feat.

Chemical rocket systems combust a fuel and oxygen mixture to produce thrust. By carrying everything needed for combustion, these engines can operate in the vacuum of space. Conventional turbojets also burn fuel and an oxidizer, but the oxidizer comes from the atmosphere. Without the need for oxidizer tankage, these engines are lighter than rockets but cannot operate in rarified air or a vacuum. For vehicles intended to conduct powered flight from the Earth's surface up to space and back, such as RLVs, an engine capable of operating throughout changing atmospheric conditions is the ideal propulsion solution.

NASA's Langley Research Center in Hampton, Virginia, has managed the Hyper-X program to develop air-breathing rocket technology since 1997. The vehicle is the result of collaboration between ATK-GASL, which built the airframe and engine, and Boeing Phantom Works, which constructed the thermal protection system.

Other technology efforts have flown scramjet engines, but those engines were permanently affixed to the carrier rockets. Supersonic combustion ramjets, or scramjets, are air-breathing engines with no moving parts, similar to ramjets. Unlike ramjets, however, scramjets only operate at supersonic speeds. The gaseous hydrogen burning engines of the X-43A were enclosed in a 3.7-meter (12-foot) long airframe and propelled the vehicle at velocities of approximately Mach 7 and Mach 10. The 3.7-meter (12-foot) long vehicle is accelerated to Mach 7 (for the first two flights) or Mach 10 (for the third flight) by the first stage of an Orbital Sciences Corporation Pegasus XL launch vehicle. Then, the X-43A separates from the booster for independent flight at high speed.[31] The whole stack was dropped from NASA's B-52B carrier aircraft.

During this year's successful flights, the NASA B-52 aircraft released the vehicle at an altitude of 12.2 kilometers (7.6 miles) to reduce the aerodynamic loads on the control surfaces of the booster. The X-43A was boosted to a test flight altitude of 29 kilometers (18 miles) by a modified Pegasus XL rocket. Then, it separated for a 10-second period of scramjet-powered flight. The flight achieved a speed of Mach 6.83.

The Hyper-X program not only proved the maturity of scramjet technology but also recorded valuable environmental data on hypersonic flight. During the second and final X-43A flight in November 2004, a speed of Mach 9.8 was reached. The resulting vehicle skin temperatures of 3,600 degrees Fahrenheit were far above the melting point of conventional aircraft structures and required a thermal protection system. Because existing wind tunnels are incapable of generating Mach 10 airflow, the final X-43A flight provided a one-of-a-kind opportunity for research into this flight regime. The X-43A proved that the United States can produce air-breathing vehicles capable of sustained actively controlled flight at hypersonic speeds.

This program was originally intended to feature two additional vehicles. As envisioned, the X-43B would demonstrate an engine capable of operating in several modes. The X-43B's combined cycle engine would function as a normal turbojet at low altitudes and switch to scramjet mode at high altitudes and speeds. Planned X-43B flights were to occur sometime in 2009 after the completion of another Hyper-X test vehicle, the X-43C. The X-43C was intended to demonstrate the operation of a solid hydrocarbon-burning scramjet engine at speeds between Mach 5 and 7 sometime in 2008. Both vehicles were cancelled in March 2004 because of a shift in NASA's strategic goals following the announcement of the President's Vision for Space Exploration in January of that year. However, because of the success of the X-43A , the U.S. Congress added $25 million to the NASA 2005 budget to continue development of the X-43C research vehicle. Hypersonic vehicles promise to enable future RLV systems, such as two-stage-to-orbit systems. In addition to serving as RLV propulsion, hypersonic engines may enable production of hypersonic munitions for the military.

# Spaceports

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

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 spaceports as well. 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.

FAA/AST has licensed the operations of five non-federal launch sites. These spaceports have served both commercial and government payload owners. Table 2 shows which states have non-federal, federal, and proposed spaceports.

This section describes efforts to develop a national space transportation infrastructure plan. The non-federal and federal spaceports capable of supporting launch and landing activities that currently exist in the United States are also described. A subsection detailing state and private proposals for future spaceports with launch and landing capabilities is included.

**Table 2: Spaceport Summary by State**

| State | Non-federal | Federal | Proposed |
|---|---|---|---|
| Alabama | | | ☑ |
| Alaska | ☑ | ☑ | |
| California | ☑ | ☑ | |
| Florida | ☑ | ☑ | |
| Kwajalein | | ☑ | |
| Nevada | | | ☑ |
| New Mexico | | ☑ | ☑ |
| Oklahoma | | | ☑ |
| Texas | | | ☑ |
| Utah | | | ☑ |
| Virginia | ☑ | ☑ | |
| Washington | | | ☑ |
| Wisconsin | | | ☑ |

## National Coalition of Spaceport States

In 2004, the National Coalition of Spaceport States (NCSS) worked with Federal agencies and Congressional leadership to begin identifying key considerations and laying the groundwork for developing a national space transportation infrastructure plan. This plan is intended to identify all infrastructure elements necessary to support both the emerging private enterprise space transportation industry and the new national space exploration initiative enacted by the President. The plan is intended to provide a roadmap for establishing non-federal space infrastructure assets, such as a network of intermodal spaceports providing bureaucratically unfettered access to and from space. The plan will provide recommendations for streamlining concept-to-operation development of space transportation infrastructure from a regulatory standpoint. In addition to spaceport facility development, the plan is expected to cover other considerations, such as space traffic control, and federal R&D assistance to non-federal and private sector space systems efforts.

## Non-federal Spaceports with FAA/AST Licenses

While the majority of licensed launch activity still occurs at U.S. federal ranges, much future launch and landing activity may originate from private or state-operated spaceports. 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 FAA/AST. To date, FAA/AST has licensed the operations of five non-federal launch sites, all of which are described in this subsection. Four of these are co-located with federal launch sites, including the California Spaceport at VAFB, Florida Space Authority (FSA) at Cape Canaveral, Florida, MARS (originally the Virginia Space Flight Center) at WFF, Virginia, Mojave Airport at Mojave, California, and Kodiak Launch Complex at Narrow Cape on Kodiak Island, Alaska. The first orbital launch from an FAA/AST-licensed site occurred on January 6, 1998, when a Lockheed Martin Athena 2, carrying NASA's Lunar Prospector spacecraft, successfully

U.S. Spaceport Locations


lifted off from FSA's LC-46. Table 3 summarizes the characteristics of FAA/AST licensed spaceports.

## California Spaceport

California Spaceport

On September 19, 1996, the California Spaceport became the first Commercial Spaceport licensed by FAA/AST. In June 2001, FAA/AST renewed the spaceport's license for another five years. The California Spaceport offers commercial launch and payload processing services and is operated and managed by 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 latitude 34º North, the California Spaceport can support a variety of mission profiles to low-polar-orbit inclinations, with possible launch azimuths ranging from 220 degrees to 165 degrees.

Initial construction at the California Spaceport, Commercial Launch Facility began in 1995 and was completed in 1999. The design concept is based on a "building block" approach. Power and communications cabling was routed underground to provide a launch pad with the flexibility to accommodate a variety of launch systems. Additional work was completed in 2004 to build a rolling access gantry to support Minuteman and future Peacekeeper space booster derivatives. Although the facility is configured to support solid propellant vehicles, plans are in place to equip the launch facility with support systems/commodities required by liquid-fueled boosters. The current SLC-8 configuration consists

Table 3: Licensed Non-federal Spaceports: Infrastructure and Status

| Spaceport | Location | Owner/Operator | Launch Infrastructure | Development Status |
|---|---|---|---|---|
| California Spaceport | Lompoc, California | Spaceport Systems International | Existing launch pads, runways, payload processing facilities, telemetry and tracking equipment. | Work completed in 2004 to build a rolling access gantry to support Minuteman and future Peacekeeper space booster derivatives. |
| Kodiak Launch Complex | Kodiak Island, Alaska | Alaska Aerospace Development Corporation | Launch control center, payload processing facility, and integration and processing facility. Limited range support infrastructure (uses mobile equipment). | Construction of the launch control center, payload processing facility, and integration and processing facility was completed in 2000. |
| Spaceport owned by Florida Space Authority | Cape Canaveral, Florida | Florida Space Authority | One launch complex, including a pad and a remote control center; a small payload preparation facility; and an RLV support facility. | Has invested over $500 million to upgrade launch sites, build an RLV support complex adjacent to the Shuttle landing facilities, and develop a new space operations support complex. |
| Mid-Atlantic Regional Spaceport | Wallops Island, Virginia | Virginia Commercial Space Flight Authority | Two orbital launch pads, payload processing and integration facility vehicle storage and assembly buildings, on-site and downrange telemetry and tracking, and payload recovery capability. | Currently completing $6.6 million in launch range improvements. Invested $1.3 million to design and build a new Mobile Service Structure. Construction of a $4 million logistics and processing facility at NASA Wallops underway. MARS is adding a new mobile Liquid Fueling Facility capable of supporting a wide range of liquid-fueled and hybrid rockets. |
| Mojave Airport | Mojave, California | East Kern Airport | Air control tower, runway, rotor test stand, engineering facilities, high bay building. | FAA/AST approved site license. Scaled Composites' SS1 has launched from this site for the Ansari X Prize competition. |

of the following infrastructure: pad deck, support equipment building, launch equipment vault, launch duct, launch stand, access tower, communications equipment, and Integrated Processing Facility (IPF) launch control room as well as the required Western Range interfaces needed to support a launch. The final SLC-8 configuration awaits future customer requirements. When fully developed, the SLC-8 Launch Facility will accommodate a wide variety of launch vehicles, including the Minuteman-based Minotaur and Castor 120-based vehicles, such as Athena and Taurus.

Originally, the focus of the California Spaceport's payload processing services was on the refurbishment of the Shuttle Payload Preparation Room. Located near SLC-6, this large clean room facility was originally designed to process three Space Shuttle payloads simultaneously. It is now leased and operated by the California Spaceport as the IPF. Today, payload-processing activities occur on a regular basis. The IPF has supported booster processing, upper stage processing, encapsulation and commercial, civil, and USAF satellite processing and their associated administrative activities. The IPF can handle all customer payload processing needs. This includes Delta 2, Delta 4, and Atlas 5 class payloads as well as smaller USAF and commercial payloads as required.

The spaceport has received limited financial support from the state in the form of grants. In 2000, it received about $180,000 to upgrade the east breech load doors in the IPF transfer tower. The modification was completed in March 2001. The new transfer tower can accommodate 18-meter (60-foot) payloads. This will enable SSI to process and encapsulate satellites in support of the EELV program. In May 2001, SSI received approximately $167,000 to upgrade the satellite command and telemetry systems. The state of California has also provided some support for California Spaceport business. In 2001, legislation was passed to remove the "sunset" clause on tax exemptions for commercial satellites and boosters launched from VAFB, including California Spaceport.

The California Spaceport provides payload processing and orbital launch support services for commercial, civil, and government users. The California Spaceport provided payload-processing services for NASA satellites including Landsat 7 (1996); TIMED/Jason (2001); and Aqua (2002). The California Spaceport's first polar launch was JAWSAT, a joint project of the Air Force Academy and Weber State University, on a Minotaur space launch vehicle in July 2000. To date, the site has launched two Minotaur launch vehicles. In 2002, SSI won a 10-year USAF satellite-processing contract for Delta 4 class 4- and 5-meter (13- and16-foot) payloads. This contract complements an existing 10-year NASA payload-processing contract for Delta 2 class 3-meter (10-foot) payloads. SSI is working with several launch providers for National Missile Defense support.

The National Reconnaissance Office has contracted with SSI to provide space vehicle processing until 2011. This includes Delta 4 and Atlas 5 EELV-class payload processing support for multiple missions to be launched from VAFB. NASA and commercial Delta-class payloads are also processed at the IPF for launch on the Delta 2 and launched from SLC-2W on VAFB. In 2003 through 2004, the California Spaceport continued improvements to the IPF and supported USAF Pathfinders, including the EELV 5 M Pathfinder. In 2004, SSI was awarded three new Minotaur launches for 2005 and a new Indefinite Delivery/Indefinite Quantity contract to support future Minotaur task orders.[32]

### Kodiak Launch Complex


Kodiak Launch Complex

In 1991, the Alaska state legislature created the Alaska Aerospace Development Corporation (AADC) as a public company to develop aerospace-related economic, technical, and educational opportunities for the state of Alaska. In 2000, the AADC completed the $40-million, 2-year construction of the Kodiak Launch Complex at Narrow Cape on Kodiak Island, Alaska. The first licensed launch site not co-located with a federal facility, Kodiak Launch Complex was also the first new U.S. launch site built since the 1960s. Owned by the state of Alaska and operated by the AADC, the Kodiak Launch Complex received funding from the USAF, U.S. Army, NASA, the state of Alaska, and private firms. The launch complex is located on a 12.4-square kilometer (4.8-square mile) site about 419 kilometers (260 miles) south of Anchorage and 40 kilometers (25 miles) southwest of the city of Kodiak. The launch site itself encompasses a nearly 5-kilometer (3-mile) area around Launch Pad 1.

Kodiak facilities currently include the Launch Control Center; the Payload Processing Facility, which includes a class-100,000 clean room, an airlock, and a processing bay; the Integration and Processing Facility/Spacecraft Assemblies Transfer Facility; and the Launch Pad and Service Structure. These facilities allow the transfer of vehicles and payloads from processing to launch without exposure to the outside environment. This capability protects both the vehicles and the people working on them from exterior conditions, and allows all-weather launch operations. The Kodiak Launch Complex Range Safety and Telemetry System (RSTS) was delivered in September 2003. The RSTS consists of two fully redundant systems: one for on-site, the other for off-axis. Each part of the RSTS consists of two 5.4-meter (17.7-foot) dishes with eight telemetry links featuring command destruct capabilities. The Kodiak RSTS number 1 system will be located on a newly constructed multi-elevation antenna field that also supports customer-unique instrumentation.

The AADC is also supporting development of ground station facilities near Fairbanks, Alaska, in cooperation with several commercial remote-sensing companies. The high-latitude location makes the Fairbanks site favorable for polar-orbiting satellites, which typically pass above Fairbanks several times daily.

Located at latitude 57º North, Kodiak provides a wide launch azimuth and unobstructed downrange flight path. Kodiak's markets are military launches, government and commercial telecommunications, remote sensing, and space science payloads weighing up to 990 kilograms (2,200 pounds). These payloads can be delivered into LEO, polar, and Molniya elliptical orbits. Kodiak is designed to launch Castor 120-based vehicles, including the Athena 1 and 2, and has been used on a number of occasions to launch military suborbital rockets.

Kodiak has conducted seven launches to date. The first launch from Kodiak was a suborbital vehicle, atmospheric interceptor technology 1, built by Orbital Sciences for the USAF in November 1998. A second launch followed in September 1999. In March 2001, a Quick Reaction Launch Vehicle (QRLV) was launched from the Kodiak Launch Complex. A joint NASA-Lockheed Martin Astronautics mission on an Athena 1 was the first orbital launch from Kodiak, taking place on September 29, 2001. In November 2001, a Strategic Target System vehicle was launched. However, because of a launch anomaly, the vehicle was destroyed. In April 2002, Orbital Sciences launched a second QRLV for the USAF.

Most recently, on December 14, 2004, MDA launched the first of several rockets from Kodiak to test the U.S. missile defense system. This followed the 2003 signing of a 5-year contract between MDA and AADC to provide launch support services for multiple launches in connection with tests of the nation's missile defense system. The second launch under this contract is scheduled to take place in the spring of 2005.

### Mid-Atlantic Regional Spaceport

Mid-Atlantic Regional Spaceport

MARS[33] traces its beginnings to the Center for Commercial Space Infrastructure, created in 1992 at Virginia's Old Dominion University to establish commercial space research and operations facilities in the state. The Center for Commercial Space Infrastructure worked with WFF to develop commercial launch infrastructure at Wallops. In 1995, the organization became the Virginia Commercial Space Flight Authority (VCSFA), a political subdivision of the Commonwealth of Virginia, focused on promoting growth of aerospace business while developing a commercial launch capability in Virginia.

On December 19, 1997, FAA/AST issued VCSFA a launch site operator's license for the MARS. This license was renewed in December 2002 for another 5 years. The MARS is designed to provide "one-stop shopping" for space launch facilities and services for commercial, government, scientific, and academic users. In 1997, VCSFA signed with NASA a Reimbursement Space Act Agreement to use the Wallops center's facilities in support of commercial launches. This 30-year agreement allows VCSFA access to NASA's payload integration, launch operations, and monitoring facilities on a non-interference, cost reimbursement basis. NASA and MARS personnel work together to provide launch services, providing little, if any, distinction in the areas of responsibility for each.

VCSFA has a partnership agreement with DynSpace Corporation, a Computer Sciences Corp. company, of Reston, Virginia, to operate the spaceport. Funded by a contract with the state and through any spaceport revenues, DynSpace operates the MARS for the VCSFA. The state maintains ownership of the spaceport's assets. MARS is located at WFF under a long-term use agreement for real estate on which the Goddard Space Flight Center has made real property improvements. The VCSFA receives the majority of its funding from operations. The remainder of its support comes from the state.

VCSFA owns two launch pads at Wallops. Launch pad 0-B, its first launch pad, was designed as a "universal launch pad," capable of supporting a variety of small and medium ELVs with gross liftoff weights of up to 225,000 kilograms (496,000 pounds) that can place up to 4,500 kilograms (9,900 pounds) into LEO. Phase 1 construction of launch pad 0-B, including a 1,750-square-meter (18,830-square-foot) pad made of reinforced concrete, above-ground flame deflector, and launch mount, took place between March and December 1998. In 2003, MARS committed to the design and construction of a new 113-foot Mobile Service Structure. The new $1.3 million Mobile Service Structure offers complete vehicle enclosure, flexible access, and can be readily modified to support specific vehicle operations. The site also includes a complete command, control, and communications interface with the launch range.

A USAF OSP Minotaur mission is currently scheduled for this site.

In March 2000, MARS acquired a second pad at WWF, launch pad 0-A. EER Systems of Seabrook, Maryland, built this site in 1994 for its Conestoga launch vehicle. The Conestoga made one launch from launch pad 0-A in October 1995 but failed to place the METEOR microgravity payload into orbit. MARS started refurbishing launch pad 0-A and its 25-meter (82-foot) service tower in June 2000. Launch pad 0-A will support launches of small ELVs with gross liftoff weights of up to 90,000 kilograms (198,000 pounds) and that are capable of placing up to 1,350 kilograms (3,000 pounds) into LEO. Completion of the refurbishing project is pending future business opportunities. From its location on the Atlantic coast, MARS can accommodate a wide range of orbital inclinations and launch azimuths. Optimal orbital inclinations accessible from the site are between 38° and 60°; other inclinations, including SSO, can be reached through in-flight maneuvers. Launch pad 0-A can support a number of small solid-propellant boosters, including the Athena 1, Minotaur, and Taurus. Launch pad 0-B can support larger vehicles, including the Athena 2. MARS also has an interest in supporting future RLVs, possibly using its launch pads or three runways at WFF.

MARS also provides an extensive array of services including the provision of supplies and consumables to support launch operations, facility scheduling, maintenance, inspection to ensure timely and safe ground processing and launch operations, and coordination with NASA on behalf of its customers. Construction of Service Gantry Launch Pad 0B has been completed. MARS is in the process of constructing a $4 million logistics and processing facility at WFF, capable of handling payloads of up to 5,700 kilograms (12,600 pounds). The facility, which includes high bay and clean room environments, is currently in construction. In conjunction with WFF, MARS is adding a new mobile Liquid Fueling Facility capable of supporting a wide range of liquid-fueled and hybrid rockets. Construction of the LFF is in the final integration and test phase.[34]

## Mojave Airport

Mojave Airport

Mojave Airport in Mojave, California, became the first inland launch site licensed by the FAA on June 17, 2004, allowing Mojave Airport to support suborbital launches of RLVs. The East 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 Airport is owned and operated by the East Kern Airport District, which is a special district with an elected Board of Directors and a General Manager. The airport serves as a Civilian Flight Test Center, the location of the National Test Pilot School (NTPS), and a base for modifying major military jets and civilian aircraft. The NTPS operates various aircraft, including high-performance jets, single- and twin-engine propeller airplanes, and helicopters. Numerous large air carrier jet aircraft are stored and maintained at the Mojave Airport.

The Mojave Airport consists of three runways with associated taxiways and other support facilities, Runway 12-30, Runway 8-26, and Runway 4-22. Runway 12-30 is 2,896 meters (9,502 feet) long and is the primary runway for large air carrier jet and high-performance civilian and military jet aircraft. Runway 8-26 is 2,149 meters (7,050 feet) long and is primarily used by general aviation jet and propeller aircraft. Runway 4-22 is 1,202 meters (3,943 feet) long and is used by smaller general aviation propeller aircraft and helicopters.

Major facilities at the Mojave Airport include the terminal and industrial area, hangars, offices, maintenance shop, and fuel services facilities. Rocket engine test stands are located in the northern portion of the airport. Aircraft parking capacity includes 600 tie downs and 60 T-hangars. The Mojave Airport also includes aircraft storage and a reconditioning facility and is home to several industrial operations, such as BAE Systems, Fiberset, Scaled Composites, AVTEL, XCOR Aerospace, Orbital Sciences Corporation, IOS, and General Electric. Mojave Airport consists of several test stands, an air traffic control tower, a rocket test stand, some engineering facilities, and a high bay building.

In the last 2 years, XCOR Aerospace performed flight tests at this facility, including multiple successful tests with the EZ-Rocket. XCOR Aerospace had three Rocketplane test flights up to 3,657 meters (12,000 feet) in 2002. In addition, rocket engines of up to 133,000 newtons (30,000 pounds-force) of thrust were tested at the site in 2002 and 2003.

On the 100th anniversary of the Wright Brothers' first powered flight, December 17, 2003, Scaled Composites, LLC, flew SpaceShipOne from Mojave Airport, breaking the speed of sound in the first manned supersonic flight by an aircraft developed privately by a small company. On June 21, 2004, Scaled Composites flew its SpaceShipOne suborbital vehicle from the Mojave Airport, reaching 100 kilometers (62 miles) and becoming the first private, manned rocket to reach space. SpaceShipOne then flew from Mojave, past the boundary of space, fully loaded to meet the Ansari X-Prize qualifications, on September 29 and again on October 4. Brian Binnie piloted SpaceShipOne to 112 kilometers (69 miles), winning the $10 million Ansari X Prize and smashing the 107,960-meter (354,200-foot) altitude record set by the X-15 airplane in the 1960s.

SpaceShipOne rockets into history

**Spaceport Operated by Florida Space Authority**

Launch Compex-46 at the Cape Canaveral Spaceport

Established by the state of Florida as the Spaceport Florida Authority in 1989, FSA, renamed as such in January 2002, is empowered like an airport authority to serve the launch industry and is responsible for statewide space-related economic and academic development. The FSA owns and operates space transportation-related facilities on approximately 0.29 square kilometers (0.11 square miles) of land at CCAFS, which is owned by the USAF. FAA/AST first issued the state organization a license for spaceport operations on May 22, 1997, and renewed the license in 2002 for another 5 years.

Under an arrangement between the federal government and FSA, underused facilities at CCAFS have been conveyed to FSA for improvement and use by commercial entities on a dual-use, non-interference basis with USAF programs. FSA efforts have concentrated on the CCAFS LC-46, an old Trident missile launch site. The LC-46 has been modified to accommodate small commercial launch vehicles, as well as U.S. Navy Trident missiles. The philosophy guiding the development of LC-46 was to build a public transportation infrastructure for several competing launch systems rather than tailor a facility for a single launch system. As a result, LC-46 can accommodate the Athena 1 and Athena 2. In the future, LC-46 could accommodate vehicles carrying payloads in excess of 1,800 kilograms (4,000 pounds) to LEO.

Currently, LC-46 is configured for Castor 120 or similar solid-motor-based vehicles. The infrastructure can support launch vehicles with a maximum height of 36 meters (120 feet) and diameters ranging from 1 to 3 meters (3 to 10 feet). An Athena 2, carrying the NASA Lunar Prospector, was the first vehicle launched into orbit from the spaceport in January 1998. This was followed by launch of the ROCSAT satellite in January of 1999.

Thus far, FSA has invested over $500 million in new space industry development. FSA has upgraded LC-46, built an RLV support complex (adjacent to the Shuttle landing site on KSC grounds), and developed a new space operations support complex. Additionally, FSA financed $292 million for Atlas 5 launch facilities at CCAFS LC-41, financed and constructed the $24 million Delta 4 Horizontal Integration Facility for Boeing at LC-37, and provided financing for a Titan 4 storage and processing facility. SpaceX plans to use FSA's LC-46 for operations on the east coast.

As part of an overall effort to expand use of the Cape for R&D and educational activities, FSA obtained a 5-year license from the Air Force to use LC-47. The complex was upgraded to support a significant number of suborbital and small LEO launches carrying academic payloads for research and training purposes.

FSA published a Space Transportation Master Plan for the state of Florida in November 2002, detailing the status of intermodal, transportation-related functions and assets on and near the Cape Canaveral Spaceport. Based on the Space Transportation Master Plan, FSA developed a Five-Year Work Program in cooperation with the NASA/KSC and USAF 45th Space Wing to identify transportation-related improvements needed at the spaceport and its intermodal connections to the surrounding community. The plan was submitted in May 2004 to the Brevard Metropolitan Planning Organization (MPO) for inclusion in the county's Transportation Improvement Program. The Authority identified as its highest off-site priority an additional lane on the existing I-95 exit ramp (Eastbound) to State Road 407 from improved spaceport ingress and egress of space cargoes.

In collaboration with NASA and the state, FSA is helping develop the International Space Research Park on about 320 acres at NASA/KSC. The recently completed Space Life Sciences Lab, a $26 million state-of-the-art research facility financed by the state of Florida, serves as a magnet facility for the research park. The next phase of construction will address the enabling infrastructure for further development, such as roads, water, sewer and storm drainage. Ground breaking is expected in 2005.

## Federal Spaceports

Since the first licensed commercial orbital launch in 1989, the federal ranges have continually supported commercial launch activity. The importance of commercial launches is evident in the changes taking place at federal launch sites. Launch pads have been developed with commercial, federal, and state government support at the two major federal sites for U.S. orbital launches for the latest generation of the Delta and Atlas launch vehicles, including the EELVs. Cape Canaveral Spaceport (consisting of CCAFS and NASA KSC) hosts pads for Delta 4 and Atlas 5. VAFB currently accommodates the Delta 4 and a pad is under construction to accommodate the Atlas 5.

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 Range at CCAFS and portions of the Western Range at VAFB. The USAF, Department of Commerce, and FAA signed a Memorandum of Agreement in January 2002 that established a process for collecting commercial sector range support and modernization requirements, communicating them to the USAF, and considering them in the existing USAF requirements process. Table 4 summarizes the characteristics of federal spaceports.

### Cape Canaveral Spaceport

Cape Canaveral Spaceport

The Cape Canaveral Spaceport is geographically comprised of the USAF CCAFS and NASA KSC in Florida.

The 45th Space Wing, headquartered at nearby Patrick AFB, conducts launch operations and provides range support for military, civil, and commercial launches. The 45th Space Wing is the host organization for Patrick AFB, CCAFS, Antigua Air Station, Ascension Auxiliary Air Field, and many mission partners. The Wing is part of Air Force Space Command at Peterson AFB, Colorado, and reports to the 14th Air Force at VAFB.

The Wing manages the Eastern Range, provides launch and tracking facilities, safety procedures and test data to a wide variety of users. It also manages launch operations for DoD space programs. Users include the USAF, Navy, NASA, and various private industry contractors.

With its mission partners, the Wing processes a variety of satellites and launches them on Atlas, Delta, and Titan ELVs. The Wing also provides support for the Space Shuttle program and U.S. Navy submarine ballistic missile testing.

The 45th Space Wing was established Nov. 12, 1991. Its origins date back to 1950 with the Army and Air Force's establishment of the Joint Long Range Proving Ground. A year later, the Air Force assumed full control of the new facility, designating it the Air Force Missile Test Center. In 1964, it was renamed the Air Force Eastern Test Range, and in 1979 it became the Eastern Space and Missile Center. The Eastern Space and Missile Center became part of Air Force Space Command in October 1990 when the Air Force transferred space and launch responsibilities from Air Force Systems Command to Air Force Space Command.

Today, CCAFS encompasses six active launch complexes for Delta, Atlas, Titan, and sounding rocket launch vehicles. Plans are currently in work to deactivate two of those launch complexes (LC 40 for Titan 4 and LC 36 for Atlas 2/3) in 2005.

The Eastern Range is used to gather and process data on a variety of East Coast launches and deliver it to range users. To accomplish this task, the range consists of a series of tracking stations located at CCAFS, Antigua Air Station, and Ascension Auxiliary Air Field. The range also uses the Jonathan Dickinson and the Malabar Tracking Annexes on the Florida mainland. These stations may be augmented with a fleet of advanced range instrumentation aircraft as well as a site located in Argentia, Newfoundland. Major events at the Eastern Range in 2004 included the 50th launch of a GPS satellite, and the last Atlas launch from LC 36A on August 31. Runway improvements at CCAFS are continuing with a $4.5 million renovation. In June, the 8th Annual Cape Canaveral Spaceport Symposium was held to discuss recent developments and the future of commercial space transportation.

### Edwards Air Force Base

Edwards Air Force Base

Located in California, EAFB is the home of more than 250 first flights and about 290 world records. It was the original landing site for the Space Shuttle. The first two Shuttle flights landed on Rogers Dry Lake, a natural hard-pack riverbed measuring about 114 square kilometers (44 square miles). Unfortunately, the normally dry lakebed was flooded in 1982, rendering the site unavailable for the third Shuttle landing. (The Space Shuttle landed at White Sands, New Mexico instead.) Today, NASA prefers to use KSC as the primary landing site for the Space Shuttle and uses EAFB as a back-up site. Today EAFB is DoD's premier flight test center, leading in unmanned aerial vehicle (UAV), electronic warfare, and directed energy test capabilities.

Within the last 5 years, EAFB has been the home of more than 10 experimental projects, among them the X-33 airplane. Before its cancellation, the X-33 airplane was to use EAFB as a test site. In December 1998, NASA completed construction of a launch site at EAFB. The site consisted of an X-33-specifc launch pad, a control center to be used for launch monitoring and mission control, and a movable hangar where the vehicle was to be housed and serviced in a horizontal position. The site was equipped with hydrogen and nitrogen gas tanks, as well as liquid hydrogen and oxygen tanks capable of holding more than 1.1 million liters (291,000 gallons) of cryogenic materials.

Today Edwards is the home of the F/A-22 Raptor, the X-43 Hyper-X, the X-45 JUCAS, a UAV, and the Airborne Laser system.[35]

The federal government is investing several million dollars to refurbish and modernize two large-scale rocket test stands at the AFRL's Edwards Research Site. One is a component test stand and the other is an engine test stand. Plans are also being developed to continue refurbishing additional rocket stands in the future for purposes of rocket testing.

EAFB, along with NASA's co-located, premier aeronautical flight research facility, Dryden Flight Research Center, hosts other NASA reusable X-vehicle demonstration programs. In 2001, NASA used a Pegasus XL launch vehicle to conduct a drop test of the X-43A demonstrator. NASA used a helicopter to conduct seven successful X-40A flight tests during 2001. In 2004, NASA transferred the X-37 program to DARPA, which is expected to conduct drop tests in 2005.

Table 4: Federal Spaceports Infrastructure and Status

| Spaceport | Location | Owner/Operator | Launch Infrastructure | Development Status |
|---|---|---|---|---|
| Cape Canaveral Spaceport (CCAFS/KSC) | Cape Canaveral, Florida | USAF, NASA, FSA | Telemetry and tracking facilities, jet and Shuttle capable runways, launch pads, hangar, vertical processing facilities, and assembly building. | RLV and ELV spaceport is operational. |
| Edwards AFB | Edwards, California | USAF | Telemetry and tracking facilities, jet and Shuttle capable runways, Delta 4 launch pad, operations control center, movable hangar, fuel tanks, and water tower. | Site is operational. |
| Reagan Test Site | Kwajalein Island, Republic of the Marshall Islands | U.S. Army | Telemetry and tracking facilities, runway, control center. | Site is operational. |
| Vandenberg AFB | Lompoc, California | USAF | Launch pads, vehicle assembly and processing buildings, payload processing facilities, telemetry and tracking facilities, control center engineering, user office space, Shuttle-capable runways. | VAFB has started negotiations with several commercial companies. Existing infrastructure is operational. Upgrades may or may not be required depending on vehicle requirements. |
| Wallops Flight Facility | Wallops Island, Virginia | NASA | Telemetry and tracking facilities, heavy jet and Shuttle-capable runway, launch pads, vehicle assembly and processing buildings, payload processing facilities, range control center, blockhouses, large aircraft hangars, and user office space. | Wallops Flight Facility has not supported any orbital flights since the failure of the Conestoga in 1995. NASA is committed to maintaining the existing infrastructure. |
| White Sands Missile Range | White Sands, New Mexico | U.S. Army | Telemetry and tracking facilities, runway engine and propulsion testing facilities. | NASA flight test center is operational. RLV-specific upgrades will probably be required. |

### Reagan Test Site

Reagan Test Site – Omelek Island, possible launch home of SpaceX

Located in Kwajalein Island, part of the Republic of the Marshall Islands, the U.S. Army's Reagan Test Site (RTS) is within the DoD Major Range and Test Facility Base. The advantages of RTS include its strategic geographical location, unique instrumentation, and capability to support ballistic missile testing and space operations. With nearly 40 years of successful support, RTS provides a vital role in the research, development, test and evaluation effort of America's missile defense and space programs.[36] RTS will be working will be working with SpaceX, Orbital Sciences, and the Missile Defense Agency (MDA). Orbital Sciences will be launching a Pegasus rocket with the USAF C/NOFS payload in 2005.

### Vandenberg Air Force Base

In 1941, the U.S. Army activated this site in Lompoc, California, as Camp Cook. In 1957, Camp Cook was transferred to the Air Force, becoming the nation's first space and ballistic missile operations and training base. In 1958, it was renamed VAFB in honor of General Hoyt S. Vandenberg, the Air Force's second Chief of Staff. VAFB is currently the headquarters of the 30th Space Wing and the Air Force Space Command organization responsible for all DoD space and missile activities for the West Coast. All U.S. satellites destined for near-polar orbit launch from the Western Range at VAFB. The 30th Space Wing, Range Operations Control Center, provides flight safety, weather, scheduling, and instrumentation control, along with target designation information and tracking data to and from inter- and intra-range sensors in real or near-real-time for missile and space launch support. Range tracking capabilities extend over the Pacific Ocean as far west as the Marshall Islands, with boundaries to the north as far as Alaska and as far south as Central America.

VAFB infrastructure used for space launches includes a 4,500-meter (15,000-foot) runway, boat dock, launch facilities, payload processing facilities, tracking radar, optical tracking and telemetry facilities, and control centers. The 401-square-kilometer (155-square-mile) base also houses 53 government organizations and 49 contractor companies in 1,843 buildings. VAFB hosts a variety of federal agencies and attracts commercial aerospace companies and activities, including the California Spaceport effort. The 30th Space Wing supports West Coast launch activities for the USAF, DoD, NASA, and various private industry contractors. For the development of launch infrastructure for the EELV Program, VAFB has partnered with Boeing and Lockheed Martin. Boeing has renovated Space Launch Complex (SLC)-6 from a Space Shuttle launch pad into an operational facility for Delta 4. Construction at SLC-6 has included enlarging the existing mobile service tower and completing the construction of the West Coast Horizontal Integration Facility, where the Delta 4 is assembled. March 2005 is the schedule for the first Delta 4 launch from Vandenberg.

Lockheed Martin is renovating SLC-3E from an Atlas 2 launch pad into an operational facility for Atlas 5. The upgrades started in January 2004, which include adding 9 meters (30 feet) to the existing 61-meter (200-foot) mobile service tower to accommodate the larger rocket and replacing the crane capable of lifting 20 tons with a crane that


Vandenberg Air Force Base

can lift 60 tons. The first Atlas 5 launch from Vandenberg is planned for the Spring of 2006, and will deploy a classified payload for the National Reconnaissance Office (NRO).

VAFB is also upgrading its range instrumentation and control centers to support the space launch industry. Scheduled for completion by 2010, these upgrades will automate the Western Range and provide updated services to the customer.

Current launch vehicles using VAFB include Delta 2, Titan 4, Taurus, Minotaur, and Pegasus XL families. NASA operates SLC-2, from which Boeing Delta 2 vehicles are launched. Orbital Sciences' Taurus is launched from 576-E. Pegasus XL vehicles are processed at Orbital Sciences' facility at VAFB then flown to various worldwide launch areas. Minotaur is launched from the California Spaceport and has plans for three launches in the next two years. A new commercial launch vehicle, Falcon, being developed by SpaceX, plans to launch from VAFB in 2005.

The final Titan 2 launch from VAFB took place in October 2003. Under a $3 million Air Force contract, Lockheed Martin has "safed" and deactivated SLC-4 West, which served as the launch pad for Titan 2 since 1988. SLC-4 East, which hosts the Titan 4, will see its final launch in June 2005 after which it will also be safed. The Air Force will oversee efforts to dismantle the mobile service and umbilical towers for both launch vehicles starting in 2005. Also, the last Peacekeeper launch is scheduled for May 2005, after which the Peacekeeper program will be deactivated at 30th Space Wing.

At this time, VAFB has active partnerships with seven private commercial space organizations in which VAFB provides launch property and launch services. The private companies use the government facilities to conduct payload and booster processing work. VAFB houses three commercially-owned facilities/complexes: Boeing's Horizontal Integration Facility, Spaceport Systems International's (SSI) California Spaceport and Payload Processing Facility, and Astrotech's Payload Processing Facility.[37]

## Wallops Flight Facility

Wallops Flight Facility

The National Advisory Committee for Aeronautics, the predecessor of NASA, established an aeronautical and rocket test range at Wallops Island, Virginia, in 1945. Since then, over 15,000 rocket launches have taken place from the site, which is currently operated by the NASA Goddard Space Flight Center, Greenbelt, Maryland. The first orbital launch occurred in 1960, when a Scout launch vehicle deployed Explorer 9 to study atmospheric density. There have been 29 orbital flight attempts from Wallops. The retired Scout made its last orbital launch from WFF in 1985. Since then, WFF has supported the launch of the failed launch of the Conestoga 1620 in 1995, and six Pegasus missions, the most recent in 1999.

In April 1996, the Air Force designated Wallops as a launch site for converted Minuteman 2 missiles under the Orbital/Suborbital Program (along with Kodiak Launch Complex and the California Spaceport). The Near-Field Infra-Red Experiment is scheduled for launch from Wallops in 2006, and other Minotaur and Peacekeeper missions are under consideration.

In addition to orbital missions, NASA/Wallops supports the launch of approximately 20 suborbital missions per year for NASA, other government agencies, and commercial users. In particular, Wallops provides frequent support to the Navy's Surface Combat Systems Center, a NASA/Wallops tenant. Wallops also maintains a fully capable mobile launch range that enables missions to be conducted at other than established launch ranges. In addition to suborbital science campaigns, the Wallops Mobile

Range was used to support the launch of Pegasus from the Canary Islands in 1997 and the first orbital launch (Athena I) from Kodiak, Alaska in 2001. In addition to rocket launches, the Wallops Research Range provides support for numerous other types of missions including flights of UAVs, drones, missiles, aircraft tests, and downrange tracking support for launches from KSC and CCAFS.

The Mid-Atlantic Regional Spaceport (MARS) is co-located at WFF as a tenant and the organizations collaborate on certain projects to jointly provide mission services, particularly focusing on small commercial ELVs. Jointly, WFF and MARS offer two orbital and numerous suborbital launchers, a range control center, three blockhouses, numerous payload and vehicle preparation facilities, and a full suite of tracking and data systems. In support of its research and program management responsibilities, Wallops also contains numerous science facilities, a research airport, and flight hardware fabrication and test facilities.

In March 2002, approximately $10 million in launch range modernization and upgrade projects were initiated, involving range clearance radars, vehicle-tracking systems, launch data acquisition and management systems, and range control center interfaces. A new 1,115 square-meter (12,000 square-foot) payload processing and integration facility as well as a mobile liquid fueling system for small- to mid-sized vehicles are also under development.[38]

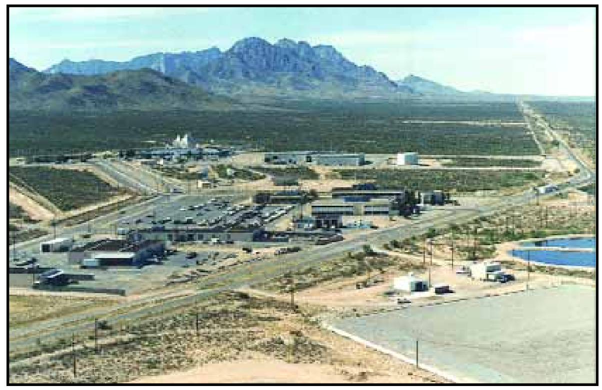
### White Sands Missile Range

Situated 26 kilometers (16 miles) northeast of Las Cruces, New Mexico, White Sands Missile Range, which includes the NASA White Sands Flight Test Center, covers 8,100 square kilometers (3,127 square miles). It is operated by the U.S. Army and is used mainly for launching sounding rockets. White Sands also supports MDA flight testing and is used as a test center for rocket engines and experimental spacecraft. Facilities at White Sands include seven engine test stands and precision cleaning facilities including a class-100 clean room for spacecraft parts.

Starting in 2003, all test operations were run out of the new J.W. Cox Range Control Center. This $28-million facility was designed to meet current and future mission requirements with the latest networking, computing, and communications for effective interaction between test operations and customers.

White Sands is also the Space Shuttle's tertiary landing site after KSC and EAFB. This landing site consists of two 11-kilometer (6.8-mile) long, gypsum-sand runways.

As of May 11, 2004, Governor of New Mexico Bill Richardson announced to the press that the X Prize Cup competition will be held at White Sands starting in 2005.[39]



White Sands Missile Range

## Proposed Non-federal Spaceports

Several states plan to develop spaceports offering a variety of launch and landing services. Two common characteristics of many of the proposed spaceports are inland geography – a contrast to the coastal location of all but one present-day U.S. spaceports – and interest in hosting RLV operations. Table 5 describes specific efforts to establish non-federal spaceports, which are in various stages of development.

### Gulf Coast Regional Spaceport

The Gulf Coast Regional Spaceport Development Corporation has proposed constructing a spaceport in Brazoria County, Texas, 80 kilometers (50 miles) south of Houston. The Corporation has identified undeveloped land currently used for agriculture as a potential site and is working with the private owner of the land to acquire or lease the property.

Local governments invested nearly $300,000 in the project between 1999 and 2001, primarily for site selection work. In February 2002, the state approved the Gulf Coast Regional Spaceport board's access to the first installment of $500,000 in state grant money. The initial $150,000 paid contractor fees for an in-depth safety analysis of the site based on the use of different types of launch systems. The draft development plan has greatly assisted in determining what infrastructure is necessary. The Amateur Spaceflight Association launched a 3.7-meter (12-foot) long amateur rocket from this site on May 3, 2003. Work with Brazoria County Commissioners Court for on site improvements will create a small suborbital capability in early 2005.[40] The web site for the spaceport is www.gulfcoastspaceport.org.

### Nevada Test Site


Map of Nevada Test Site

The Nevada Test Site, located 100 kilometers (62 miles) northwest of Las Vegas, is a remote, highly secure facility covered by restricted airspace. Kistler Aerospace Corporation selected it as a spaceport for the K-1 RLV in addition to its Woomera, Australia, facility to increase scheduling flexibility and widen the range of launch azimuths available to customers. Although it does not have any launch infrastructure, the Nevada Test Site has existing basic infrastructure, such as a paved runway, water, roads, and power that can be used to support launch and landing activities.

The Nevada Test Site Development Corporation obtained an economic development use permit in 1997 from the U.S. Department of Energy. Shortly thereafter, the Corporation issued a sub-permit allowing Kistler to operate a launch and recovery operation at the Nevada Test Site. The web site of the test site is http://www.nv.doe.gov/nts/default.htm.

### Oklahoma Spaceport

Oklahoma Spaceport

The state of Oklahoma is developing a broader space industrial base and a launch site. In 1999, the Oklahoma state legislature created the Oklahoma Space Industry Development Authority (OSIDA). Directed by seven governor-appointed board members, OSIDA promotes the development of spaceport facilities and space exploration, education, and related industries in Oklahoma. Currently, the state of Oklahoma provides operating costs for OSIDA, but the organization expects to be financially independent in less than 5 years. In 2000, the Oklahoma state legislature passed an economic incentive law offering tax credits, tax exemptions, and accelerated depreciation rates for commercial spaceport-related activities. In 2002, OSIDA, through a third party agreement with the FAA, awarded a contract to SRS Technologies and C.H. Guernsey to prepare an environmental impact statement (EIS). The analysis, expected to continue through June 2005, is a critical step toward receiving a launch site operator license from FAA/AST.

Clinton-Sherman Industrial Airpark (CSIA), located at Burns Flat, is the preferred site for a future launch site in Oklahoma. Existing infrastructure includes a 4,100-meter (13,500-foot) runway, large maintenance and repair hangars, utilities, rail spur, and 12.4 square kilometers (4.8 square miles) of open land. The city of Clinton has agreed to convey ownership of the CSIA to OSIDA upon issuance of a launch site operator license from FAA/AST. The FAA Southwest Region has reviewed and approved the transfer upon completion of the EIS and other contingencies. The launch activities proposed will not greatly impact the continued use of the CSIA

Table 5: Proposed Non-federal Spaceports: Infrastructure and Status

| Spaceport | Location | Owner/Operator | Launch Infrastructure | Development Status |
|---|---|---|---|---|
| Gulf Coast Regional Spaceport | Brazoria County, Texas | To be determined | No infrastructure at this time. | The Gulf Coast Regional Spaceport Development Corporation has proposed constructing a spaceport in Brazoria County, Texas, 80 kilometers (50 miles) south of Houston. |
| Nevada Test Site | Nye County, Nevada | Department of Energy/Nevada Test Site Development Corporation | No launch infrastructure at this time. Power and basic facilities available. | Kistler was issued a sub-permit allowing it to operate a launch and recovery operation. Nevada Test Site Development Corporation is actively promoting the site as a spaceport for both RLVs and conventional launchers. |
| Oklahoma Spaceport | Washita County, Oklahoma | Oklahoma Space Industry Development Authority | 4,115-meter (13,500-foot) runway, a 5,200-square-meter (56,000-square-foot) manufacturing facility, a 2,7850-square-meter (30,000-square-foot) maintenance and painting hangar, and 435 square kilometers (168 square miles) of land available for further construction. | The Clinton-Sherman AFB at Burns Flat was designated as the future spaceport. OSIDA is conducting a safety study of the proposed site and operations. An environmental impact study is underway. |
| South Texas Spaceport | Willacy County, Texas | To be determined | No infrastructure at this time. | The final Texas Spaceport site has not been selected. Three sites are being considered at this time. Suborbital rockets have been launched near the proposed site. |
| Southwest Regional Spaceport | Upham, New Mexico | New Mexico Office for Space Commercialization | No infrastructure at this time. | Plans for this site include a spaceport central control facility, an airfield, a maintenance and integration facility, a launch and recovery complex, a flight operations control center, and a cryogenic plant. Environmental and business development studies conducted. |
| Spaceport Alabama | Baldwin County, Alabama | To be determined | No infrastructure at this time. | The master plan phase 1 has been completed. Phase 2 is expected to be completed by October 2005. While no land has been acquired for Spaceport Alabama, a green field site is under consideration in Baldwin County, across the bay from the city of Mobile. |
| Spaceport Washington | Grant County International Airport, Washington | Port of Moses Lake | 4,100-meter (13,452-foot) main runway and a 3,200-meter (10,500-foot) crosswind runway. | The site is certified as an emergency-landing site for the Space Shuttle. No additional infrastructure has been planned for this site. |
| Utah Spaceport | Wah Wah Valley, Utah | Utah Spaceport Authority | No infrastructure at this time. | Plans for the proposed Utah Spaceport include a central administrative control facility, an airfield, maintenance and integration facilities for payloads and spacecraft, launch pads, a flight operation control center, and a propellant storage facility. State funding for development has not been provided since 2001. |
| West Texas Spaceport | Pecos County, Texas | To be determined | No infrastructure at this time. | The Pecos County/West Texas Spaceport Development Corporation, established in mid-2001, has proposed the development of a spaceport 29 kilometers (18 miles) southwest of Fort Stockton, Texas. Spaceport infrastructure will include a launch site with a 4,570- meter (15,000-foot) safety radius, an adjacent recovery zone 4,570 meters (15,000 feet) in diameter, and payload integration and launch control facilities. |
| Wisconsin Spaceport | Sheboygan, Wisconsin | Owner: City of Sheboygan; Operator: Rockets for Schools | A vertical pad for suborbital launches in addition to portable launch facilities, such as mission control. | Plans for developing additional launch infrastructure are ongoing and include creation of a development plan that includes support for orbital RLV operations. |

as an active airport for USAF training and for general aviation. Oklahoma Spaceport will provide launch and support services for horizontally launched RLVs and may become operational in late 2005 or early 2006.

Oklahoma offers several incentives, valued at over $128 million over 10 years, to attract space companies. For example, a jobs program provides quarterly cash payments of up to 5 percent of new taxable payroll directly to qualifying companies for up to 10 years. Organizations also may qualify for other state tax credits, tax refunds, tax exemptions, and training incentives. Rocketplane Limited and TGV Rockets, Inc. have located in Oklahoma for their launch vehicle developments. As the first corporation that meets specific qualifying criteria, including equity capitalization of $10 million and creation of at least 100 Oklahoma jobs, Rocketplane Limited has qualified for a $15-million, state-provided tax credit.

Besides state funding, NASA issued $241,000 to OSIDA for space-related educational grants to be used throughout the state. OSIDA has signed Memoranda of Understanding with several companies for use of the Burns Flat site.

### South Texas Spaceport

Willacy County Development Corporation was created in 2001 to manage the spaceport site evaluation and other technical and administrative elements of the project under a Texas Aerospace Commission grant. In February 2002, the Texas Aerospace Commission awarded a $500,000 contract to the South Texas Spaceport.

The proposed spaceport site is a 40-square-kilometer (15.4-square-mile) undeveloped portion of Willacy County adjacent to the Laguna Madre and Gulf of Mexico approximately 150 kilometers (93 miles) south of Corpus Christi and 65 kilometers (40 miles) north of Brownsville. The site initially may support the suborbital and small orbital launch systems currently in service or being developed for service in the near future, with a long term focus on RLVs.

In 2003, a 68-kilogram (150-pound) sounding rocket and a 3.4-meter (11-foot) Super Loki suborbital rocket were launched near the site in efforts to generate awareness and encourage state funding of the South Texas Spaceport.

To date, no infrastructure has been built. Initial planning will focus on the infrastructure needed to support activities of launch operators with current development programs.

Recently, Texas Spacelines, Incorporated, entered into negotiations with the Willacy County Development Corporation for Spaceport Facilities for the establishment of a permanent launch site in South Texas.[41] Willacy County is currently applying for a state grant for the Spaceport building next to Port Mansfield. It will include two launch pads and a building (all utilities such as water, sewer road to and from project).[42]

### Southwest Regional Spaceport

Southwest Regional Spaceport

The state of New Mexico continues to make progress in the development of the Southwest Regional Spaceport (SRS). In May 2004, New Mexico won its bid to host the X Prize Cup competition, a future international exhibition created by the X Prize Foundation. The SRS is being developed for use by private companies and government organizations conducting space activities and operations. The proposed site of the spaceport is a 70-square-kilometer (27-square-mile) parcel of open land in the south central part of the state at approximately 1,430 meters (4,700 feet) above sea level. The spaceport concept is to support all classes of RLVs serving suborbital trajectories as well as equatorial, polar, and ISS orbits and to provide support services for payload integration, launch, and landing. The facility will accommodate vertical and horizontal launches and landings as well as air and balloon launches. In addition, this facility will include multiple launch complexes, a runway, an aviation complex, a payload assembly complex, other support facilities, and, eventually a cryogenic fuel plant. The SRS is supported by the state through the New Mexico Office for Space Commercialization, part of the New Mexico Economic Development Department.

In 2001, the state legislature approved $1.5 million for fiscal years 2002 through 2004 for spaceport development, including environmental studies and land acquisition. In 2004, the state appropriated $10.5 million for infrastructure development, planning, analysis, and operations. The money was received July 1, 2004.

New Mexico provided several other incentives for the spaceport, including gross receipt deductions, industrial revenue bonds, and investment and job training credits. In 2002, the state of New Mexico and the U.S. Army White Sands Missile Range signed a Memorandum of Agreement supporting the development of the SRS. This agreement enables the spaceport to share resources and integrate launch scheduling and operations with the U.S. Army test range. In 2003, New Mexico performed a comprehensive analysis of the advantages of launching from high altitudes for vertical launch vehicles.[43]

### Spaceport Alabama

Proposed as a next generation spaceport, Spaceport Alabama will be a full-service departure and return facility supporting orbital and suborbital space access vehicles. Spaceport Alabama is in the planning phase under direction of the Spaceport Alabama Program Office at Jacksonville State University in Alabama. The Spaceport Alabama master planning Phase 1 is now complete, and Phase 2 has commenced. Phase 2 is expected to be completed by October 2005. Upon completion of the Spaceport Alabama master plan, which is expected to be by the end of 2006, a proposal will be presented to the Alabama Commission on Aerospace Science and Industry and the Alabama Legislature for formal adoption.[44] Under the current plan, the Alabama Legislature would establish the Spaceport Alabama Authority, which would oversee development of Spaceport Alabama. While no land has been acquired for Spaceport Alabama, a green field site is under consideration in Baldwin County, across the bay from the city of Mobile. This site is seen as ideal for supporting government and commercial customers operating next-generation reusable flight vehicles that are designed for access to LEO, MEO, and GEO.

Under the current spaceport development plan, a spaceport facility could become operational within 10 years, depending on market demand. This plan calls for the establishment of a "total spaceport enterprise" concept, consisting of a departure and return facility, processing and support facilities, and full support infrastructure. An R&D park, a commerce park, supporting community infrastructure, intermodal connectivity, and other services and infrastructure necessary for providing a "turn key" capability in support of space commerce, R&D, national security, science and related services are also included in this plan. Given that the site currently under consideration is adjacent to the Gulf of Mexico, Spaceport Alabama would service primarily RLVs; however, some suborbital ELVs involving scientific and academic missions could be supported.

### Spaceport Washington

Spaceport Washington

Spaceport Washington, a public/private partnership, has identified Grant County International Airport in central Washington, 280 kilometers (174 miles) east of Seattle, as the site of a future spaceport. The airport (formerly Larson AFB and now owned and operated by the Port of Moses Lake) is used primarily as a testing and training facility. Spaceport Washington proposes to use Grant County International Airport for horizontal and vertical take-offs and horizontal landings of all classes of RLVs. This airport has a 4,100-meter (13,452-foot) main runway and a 3,200-meter (10,500-foot) crosswind runway, and is certified as an emergency landing site for the Space Shuttle. No additional infrastructure has been planned for the site.[45]

### West Texas Spaceport

The Pecos County/West Texas Spaceport Development Corporation, established in mid-2001, has proposed the development of a spaceport 29 kilometers (18 miles) southwest of Fort Stockton, Texas. Spaceport infrastructure will include a launch site with a 4,570-meter (15,000-foot) safety radius, an adjacent recovery zone 4,570 meters (15,000 feet) in diameter, and payload integration and launch control facilities.

A joint project with the school district has made a state-of-the-art technology center available for Pecos County Aerospace Development Center users. The Technology Center has multiple monitors, high-speed Internet service, and full multiplexing capability. Video can be streamed from the Greasewood or Hudgins sites to the Technology Center to accommodate dignitaries and other officials in air-conditioned comfort. The Pecos County/West Texas Spaceport Development Corporation has access to optical tracking video capability that can record the vehicle's flight up to tens of thousands of feet (depending upon the vehicle's size) regardless of its speed.[46]

In February 2002, the Texas Aerospace Commission awarded a $500,000 contract to the West Texas Spaceport. In June 2002, the USAF approved the site for various test launch projects. JP Aerospace began launching small suborbital rockets from the site in October 2002. The University of Houston Division of Research Agency awarded the Pecos County/West Texas Spaceport Development Corporation $80,000 for 2003.

In 2005 members of the USAF Space Battlelab will conduct a Phase 1 demonstration flight of the V-Airship, a Near Space Maneuvering Vehicle, at the new Pecos County/West Texas Spaceport in Fort Stockton, Texas.[47]

Other projects are being pursued by the Pecos County/West Texas Spaceport Development Corporation. These projects include the Blacksky DART program, intended to characterize the performance of an innovative aerospike nozzle on a solid rocket motor. Texas A&M University's senior level student aerospace engineering program gives students the opportunity to build and fly an advanced design rocket. In addition, the Texas Partnership for Aerospace Education project supports middle and high school students to send experiments fitted inside ping pong balls on balloons to the edge of space.[48]

### Wisconsin Spaceport

On August 29, 2000, the Wisconsin Department of Transportation officially approved creation of the Wisconsin Spaceport, 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.

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. Rockets for Schools is a firmly established, high-quality program of the Great Lakes Spaceport Education Foundation.

The spaceport's existing infrastructure includes a vertical pad for suborbital launches in addition to portable launch facilities, such as mission control, which are erected and disassembled as needed. The pier, which the city leased from the U.S. Army Corps of Engineers for spaceport launches and citizens' enjoyment (i.e. walking and fishing), was widened and strengthened in 2004. Additionally, some structures were removed to clear space for the construction of a proposed mission control and education center.

Plans for developing additional launch infrastructure are ongoing. Future projects include adding orbital launch capabilities for RLVs. Spaceport developers are in the process of creating a development plan. Although no action was taken in 2004, draft legislation for the creation of a spaceport authority is under review by the Wisconsin Senate.

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