# 2004 U.S. Commercial Space Transportation Developments and Concepts: Vehicles, Technologies, and Spaceports

Associate Administrator for Commercial Space Transportation
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## About the Associate Administrator for Commercial Space Transportation

The Federal Aviation Administration's Associate Administrator for 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.

## *About the Cover*

Clockwise from top: Scaled Composites' SpaceShipOne viewed from below during a glide test on December 4, 2003; a Lockheed Martin Atlas 5 521 carries Cablevision's Rainbow 1 to geosynchronous orbit (GEO) from Cape Canaveral Air Force Station (CCAFS), Florida, on July 17, 2003; an aerial view of Space Launch Complex 37 at CCAFS with the first flight of Boeing's Delta 4 poised to launch Eutelsat W5 in November 2002; a Falcon launch vehicle designed, built, and operated by Space Exploration Technologies Corporation (SpaceX), is unveiled to the public in December 2003; and the Aerojet AJ10-118K second stage of a Delta 2 launch vehicle is being readied for the summer 2003 launch of Opportunity, one of the rovers destined for Mars.

# Introduction

## *The Publication*

This report, *2004 U.S. Commercial Space Transportation Developments and Concepts: Vehicles, Technologies, and Spaceports,* reviews the major events relating to U.S. commercial space transportation in the past year and showcases current and planned U.S. commercial and commercially-oriented activities.

The Federal Aviation Administration's Associate Administrator for Commercial Space Transportation (FAA/AST) first published the report in 1998 with an exclusive focus on reusable launch vehicles (RLV). The current edition addresses RLVs as well as expendable launch vehicles (ELV), propulsion technologies, and launch and reentry sites – commonly referred to as "spaceports"– to provide a complete picture of the U.S. commercial space transportation industry.

This report reviews space transportation programs and projects as well as launch and reentry sites that will impact and support the development of commercial space activities and applications. The private sector plays a prominent role in the management, development, and funding of these activities; the federal government and several state governments substantially contribute to or provide leadership for many of the technologies and facilities described herein. With the exception of a few X Prize vehicle concepts, all activities and developments described in this report are being led by U.S. entities.

## *Expendable Launch Vehicle Industry*

U.S. commercial launch activity improved slightly over recent past years. In 2003, FAA/AST licensed eight orbital launches out of 17 total commercial launches worldwide. Those eight launches were an increase from the total of seven orbital and suborbital launches in 2002 and six orbital and suborbital launches in 2001. Lockheed Martin Corporation's Atlas had four U.S. licensed launches in 2003. In addition, the multinational Sea Launch Corporation completed three successful U.S. licensed launches of the Zenit 3SL in 2003. Orbital Sciences Corporation launched one Pegasus XL in 2003 with an FAA license.

There are a number of commercial ELVs under development to serve smaller payloads. These ELVs are primarily being developed by small entrepreneurial companies focusing on specific market niches, such as small government payloads. These companies are exploring various technologies, including new propellants and pressure-fed engines, which have the potential to reduce the cost of their vehicles. Indeed, there should be a number of key developments for these types of ELVs during 2004 as they pursue private investment and construct and test components needed for future launches.

### *Reusable Launch Vehicle Industry*

The Space Shuttle remains the first and only currently operational, partially reusable launch vehicle.[1] Development of new RLVs nonetheless remains of great interest to many national governments and private companies. 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. Many also have considered RLV development attractive because the 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.

As government and commercial RLV developers alike have come to realize in recent years, RLV development is an extremely challenging endeavor, not only technologically and operationally but also in terms of performance requirements, market development and costs. Government RLV development programs, which often both depend on and guide private RLV development, have had no shortage of these difficulties. Throughout the 1980s and 1990s, National Aeronautics and Space Administration (NASA) and Department of Defense (DoD) efforts to develop experimental RLVs to improve reliability, reduce operating costs, and demonstrate routine operations were dashed due to cost overruns, technical setbacks, and requirement shifts. As a result, no fully operational vehicle emerged. In 1999, NASA sought to meet its challenges with the Integrated Space Transportation Plan (ISTP), an investment strategy for its space transportation needs comprising a program of Space Shuttle upgrades; the Space Launch Initiative (SLI), a $4.8-billion technology development program that would support NASA in making a decision on whether or not to build a new RLV to replace the Shuttle; and a program to develop the technologies for third- and fourth-generation RLVs.

Once again, limited funds and competing performance requirements forced NASA to reevaluate its RLV development efforts. In 2002, NASA proposed in an amendment to its fiscal year 2003 budget a new ISTP to better coordinate its space transportation efforts with its International Space Station (ISS) and science and research needs. The new ISTP continued to support the Space Shuttle but restructured SLI to accommodate the near-term development of an ISS crew transfer vehicle called the Orbital Space Plane and the continued support of future generations of launch technology.

On January 14, 2004, President George W. Bush announced a new vision for the United States space exploration program that commits the nation 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. The plan involves retiring the Space Shuttle in 2010 after completion of U.S. responsibilities on the ISS, in favor of developing a Crew Exploration Vehicle (CEV) that could be used to conduct manned missions to the Moon starting in 2015. Knowledge gained through extended visits to the Moon will be used to develop technology and new space vehicles for human missions beyond the Moon, beginning with Mars. The plans are expected to cost $12 billion over five years, with the majority of the funding derived from reallocations within NASA's existing budget.[2]

In addition, some military space requirements may be met by DARPA's Responsive Access, Small Cargo, and Affordable Launch (RASCAL) program, which is expected to yield a vehicle that can meet the demand for launch of small payloads on short notice. In March, the Defense Advanced Research Projects Agency (DARPA) awarded a Phase 2 contract to Space Launch Corporation for the design of the RASCAL small payload launch system.

Commercial RLV developers have met with similar technological, cost, market and performance requirements challenges many times in recent years. In the 1990s, several private RLV development companies emerged, determined to build RLVs to meet the high projected launch demand fueled primarily by non-geosynchronous orbit (NGSO) satellite telecommunications constellations, which were to deploy large numbers of satellites and require many replacements and follow-on satellites. Bankruptcies and the failure of many of the constellation concepts to materialize curbed the market RLV developers anticipated while also making it difficult for developers to obtain capital from private investors to turn their concepts into reality. Today's low launch demand, the abundance of launch vehicles on the world market, and the general state of the economy have also contributed to the difficulties RLV developers have experienced in finding financial backers and solid markets.

Despite the challenges, the commercial RLV industry remained resilient in 2003. Several commercial RLV companies remain committed to the goal of developing and operating their vehicles and are aggressively pursuing private investment. Many have abandoned NGSO payloads as their target market in favor of human space travel, which now seems to be a more promising enterprise. In addition, 27 organizations are vying for the X Prize, several of which entered contention in 2003. The X Prize offers a $10-million prize to the first team that launches a vehicle capable of carrying three people (or one person and ballast weight for two others) on a suborbital trajectory to a 100-kilometer (62-mile) altitude and repeats the flight within two weeks in the same vehicle. Multiple contenders, including Scaled Composites and Armadillo Aerospace, are testing their vehicle concepts and expect to meet the January 2005 deadline for winning the prize.

The ability to reduce launch costs and thus stimulate demand will be critical to the success of new military and commercial RLVs given the current size of the market for small payloads. One company, the Space Exploration Technologies Corporation, or SpaceX, intends to make the first launch of its Falcon, which is intended to be mostly reusable, in 2004.

### *Enabling Technologies*

There are a number of efforts underway to develop new propulsion technologies for launch vehicles, including ELVs and RLVs. These efforts include government-funded research projects as well as engines and motors being developed by companies for their own launch vehicles and for sale to other companies. NASA's Next Generation Launch Technology program is funding several companies to conduct propulsion work. There is a trend of development of new liquid-propellant engines that use room-temperature propellants instead of cryogens or pressure-fed systems instead of turbopumps. These engines are considerably less complex, and potentially less expensive, than engines that use turbopumps and cryogenic propellants. In 2003, NASA, the Air Force, and two prime aerospace contractors completed tests of two innovative engine systems - a liquid-hydrogen turbopump and a unique oxidizer preburner, part of the Integrated Powerhead Demonstrator (IPD).

### *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 prior to 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. One of the recent major developments at federal launch sites that will benefit both commercial and government payload customers was the construction of new launch infrastructure at the two major federal sites – Cape Canaveral Spaceport and Vandenberg Air Force Base (VAFB) – to support the Delta and Atlas Evolved Expendable Launch Vehicles (EELV). These facilities were developed with commercial, federal, and state government funds.

The commercial dimension of U.S. space activity is evident not only in the numbers 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 spaceports in four different U.S. states, and these sites are currently available to serve commercial as well as government payload owners. With the launch market rather low, however, these spaceport operators now are also seeking out new opportunities such as payload processing and space research facility development. Organizations in several states nonetheless see the potential of spaceports to accommodate future launch vehicles and are actively working to turn their spaceport visions into reality.

## Significant 2003 Events

**February 1:**
STS-107 Space Shuttle Columbia broke apart upon reentry over the west coast of the United States, killing all seven crew members and launching an investigation into the technical and organizational issues that led to the disaster.

**February 18:**
NASA released the top level requirements for the Orbital Space Plane – a next generation system of space vehicles designed to provide a crew rescue and crew transport capability to and from the International Space Station. These requirements set the foundation for the design of the vehicle and its associated systems.

**March 11:**
Boeing Delta 4 delivered its first military satellite to orbit as part of the Evolved Expendable Launch Vehicle program. It was the second Delta 4 launch, and the first in the Medium configuration. The Delta 4 carried the $200 million Defense Satellite Communications System (DSCS III A3) satellite designed to provide secure communications to defense officials and battlefield commanders.

**March 13:**
DARPA selected Space Launch Corporation to develop the RASCAL Phase II in which it will design, develop and reduce the risk of critical technology. Based on the results of phase two, DARPA will determine whether to continue on into phase three, fabrication, integration and flight-demonstration of two payloads in FY 2006.

**April 11:**
A Lockheed Martin Atlas 3B launched the AsiaSat4 Communication satellite from Cape Canaveral Air Force Station (CCAFS).

**April 18:**
Scaled Composites officially rolled out its suborbital launch vehicle SpaceShipOne and its carrier aircraft White Knight.

**May 13:**
A Lockheed Martin Atlas 5-401 launched the Hellas-Sat 2 communications satellite from Cape Canaveral Air Force Station.

**June 10:**
A Sea Launch Zenit 3SL launched the Thuraya 2 communications satellite from the Odyssey mobile launch platform on the equator in the Pacific Ocean

**June 25:**
Space Exploration Technologies Corporation (SpaceX) reached an agreement with the Florida Space Authority to use complex 46 for launching the Falcon rocket. Missions will be staged from the Cape Canaveral Air Force Station pad that Florida jointly operates with the U.S. Navy.

**June 26:**
An Orbital Sciences Pegasus XL launched the OrbView 3 remote sensing satellite from Vandenberg Air Force Base (VAFB).

**July 7:**
In the last of seven foam impact tests conducted by the Columbia Accident Investigation Board in Texas, a 500 mph foam bullet punched a 16-inch by 16-inch hole in the reinforced carbon-carbon (RCC) panel from the Atlantis orbiter, prompting board member Scott Hubbard to say they had the "smoking gun" evidence of the root cause of the Columbia tragedy.

**July 17:**
A Lockheed Martin Atlas 5-521 launched the Rainbow 1 communications satellite from Cape Canaveral Air Force Station.

**August 7:**
A Zenit 3SL rocket lofted the Echostar IX/Telstar 13 satellite into orbit for Space Systems/ Loral.

**August 11:**
SpaceX completed a successful test firing of the low-cost Falcon rocket's upper stage engine, called Kestrel – a liquid oxygen and rocket grade kerosene-powered engine. The upper-stage engine is being designed for multiple restarts in the space vacuum for placement of one or more spacecraft into orbit.

**August 26:**
The Columbia Accident Investigation Board officially released its findings on the cause of the loss of STS-107 and made recommendations to improve the safety of the space shuttle and organizational management at NASA.

**September 23:**
NASA completed the Orbital Space Plane Systems Design Review, evaluating the vehicles concept design for providing crew rescue and transfer for the International Space Station.

**September 30:**
A Sea Launch Zenit 3SL launched the Galaxy 13 Communications satellite from the Odyssey mobile launch platform on the equator in the Pacific Ocean.

**October 30:**
FAA/AST informed XCOR Aerospace that its application for an RLV mission launch license was deemed "sufficiently complete," starting a 180-day process for a license determination.

**December 17:**
A Lockheed Martin Atlas 3B launched the UHF F11 communications satellite from Cape Canaveral Air Force Station.

**December 17:**
Scaled Composites performed the first manned supersonic flight of SpaceShipOne, firing the hybrid rocket motor to reach Mach 1.2 (930 mph) and gliding to a landing at Mojave Airport Civilian Flight Test Center.

# Expendable Launch Vehicles

This survey of U.S. expendable launch vehicles (ELV) 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 that are manufactured and operated by U.S. companies today.

## *Current ELV Systems*

The ELV systems available in the United States today are summarized in Table 1.[3] Three ELVs – Minotaur, Titan 2, and Titan 4B – are restricted to government payloads.[4] The remaining six – Athena, the Atlas variants, the Delta variants, Pegasus, Taurus, and Zenit 3SL (the Sea Launch vehicle) – are available for commercial use; all but the Zenit 3SL can also carry U.S. government payloads. The two newest members of the U.S. launcher supply, the Atlas 5 and Delta 4 Evolved Expendable Launch Vehicles (EELV), made their debuts in 2002. As a result of a new national vision to return manned missions to the Moon and eventually Mars, NASA may require larger vehicles to launch Crew Exploration Vehicles (CEVs) and other missions.

### *Athena - Lockheed Martin Corporation*

The Athena family of launch vehicles was created by Lockheed Martin to serve the small satellite market. Lockheed started development of what was first known as the Lockheed Launch Vehicle in 1993. The vehicle became the Lockheed Martin Launch Vehicle after Lockheed's merger with Martin Marietta in 1995 and was renamed the Athena in 1997. The Athena vehicles use Castor 120 solid-propellant motors: the Athena 1 uses a single Castor 120 as its first stage, while the larger Athena 2 uses Castor 120 motors for its first and second stages for enhanced payload performance. Both vehicles also use one solid and one liquid propellant upper stage.[5]

Athena launches have taken place from Vandenberg Air Force Base (VAFB), California; Cape Canaveral Air Force Station (CCAFS), Florida; and the Kodiak Launch Complex in Alaska. The latest Athena launch took place on September 29, 2001, when an Athena 1 launched from Kodiak and placed the Starshine 3, Sapphire, PICOSat, and PCSat spacecraft into polar orbit. Although no future launches are currently planned, Athena launch capability continues to be available on the market.

### *Atlas Family - Lockheed Martin Corporation*

The Atlas launch vehicle family traces its roots to the development of the Atlas Intercontinental Ballistic Missile (ICBM) in the 1950s. The Atlas family is in a stage of transition as older versions of the vehicle, the Atlas 2A and Atlas 2AS, as well as the Atlas 3A and

Atlas 3B, gradually will be retired to make way for the Atlas 5 EELV. Lockheed Martin plans to retire its Atlas 2 and Atlas 3 launch vehicles within the next year.

### *Atlas 2*

The Atlas 2A and Atlas 2AS are direct descendants of the original Atlas, incorporating its unique stage-and-a-half design. This design uses two powerful "booster" engines and one less powerful, but longer-duration "sustainer" engine on the vehicle's first stage, as well as a Centaur upper stage. The Atlas 2A and 2AS are identical except for the four strap-on Castor 4A solid rocket motors attached to the first stage of the Atlas 2AS to improve its payload performance. The last Atlas 2A flight took place on December 4, 2002, with the launch of the NASA Tracking and Data Relay Satellite J. The Atlas 2AS launched once in 2003 and four launches are planned for 2004. The Atlas 2AS is scheduled to retire at the end of 2004.

### *Atlas 3*

The Atlas 3A and Atlas 3B represent a transition between the older Atlas vehicles and the Atlas 5 EELV. The Atlas 3 abandons the stage-and-a-half design of the older Atlases for a single RD-180 main engine developed by the Russian company NPO Energomash and marketed under a joint Russian-American partnership with Pratt & Whitney. The RD-180 is a derivative of the RD-170 used by the now-defunct Russian Energia heavy-lift launch vehicle. Because the RD-180 has 70-percent component commonality with the proven RD-170, it was less risky to develop than a totally new design while giving better performance than available U.S.-built engines. The Atlas 3A, introduced in 2000, uses a single-engine Centaur upper stage. The Atlas 3B, first launched on February 21, 2002, uses a stretched Centaur upper stage with one or two engines. There was one Atlas 3 launch of the 3B in 2003 and there are two launches slated for 2004. The Atlas 3 will be phased out in favor of the Atlas 5 by the end of 2004.

*Atlas 3 Courtesy of Lockheed Martin Space Systems*

### *Atlas 5*

The Atlas 5 family of launch vehicles, developed under the EELV program, is based on a common first stage design known as the Common Core Booster (tm) that uses the NPO Energomash RD-180 engine introduced on the Atlas 3. The initial flights of government payloads on Atlas 5 vehicles will use Russian-built engines. The stretched version of the Centaur upper stage introduced on the Atlas 3B is also used on the Atlas 5, in both single and dual-engine versions. The first Atlas 5 launch 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 also marks a significant departure in launch preparations compared to previous Atlas versions. The Atlas 5 program utilizes a "clean pad" concept at Launch

Complex 41 at Cape Canaveral Air Force Station in Florida. The launch vehicle is prepared for launch "off pad" vertically in the Vertical Integration Facility (VIF) near the pad. Hours before launch, it is moved out to the pad fully prepared for launch. The Atlas 5 will be operational from Space Launch Complex 3E at Vandenberg Air Force Base, California, in mid-2005, and will be standardized to the operating processes at LC-41 except for the utilization 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 will accommodate 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), while the Atlas 500 series can place payloads between 3,970 and 8,670 kilograms (8,750 and 19,120 pounds) into GTO.[6] Lockheed Martin is currently finalizing its design of the Atlas 5 Heavy Lift Vehicle with a target initial operational capability in late 2006.[7] The most recent Atlas 5 launch took place on July 17, 2003, and two Atlas 5 launches were conducted in 2003. At least one commercial Atlas 5 launch is scheduled for 2004.

## *Delta Family - The Boeing Company*

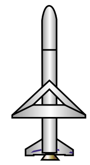
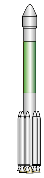
The Delta family of launch vehicles can trace its heritage to the Thor missile program of the 1950s. Like the Atlas program, the Delta family is undergoing a transition prompted by the introduction of the Delta 4 vehicles developed under the EELV program.

### *Delta 2*

The Delta 2 uses a liquid-oxygen (LOX)-kerosene first stage and a nitrogen tetroxide-aerozine second stage, along with an optional solid-propellant upper stage. The Delta 2 can also use between three and nine strap-on solid rocket motors, depending on the performance required.[8] A "heavy" version of the Delta 2, which uses the larger graphite epoxy motors 46 strap-on boosters developed for the Delta 3, entered service on August 25, 2003, with the launch of NASA's Space Infrared Telescope Facility spacecraft. Although the Delta 2's small payload capacity has limited usefulness for commercial GTO payloads, it is expected to remain in service through 2010, primarily launching military and civil government payloads. There were seven Delta 2 launches in 2003. Currently, there are 10 government Delta 2 launches scheduled for 2004.

Delta 2 Courtesy of The Boeing Company

TABLE 1: Currently Available Expendable Launch Vehicles

| | SMALL | | | | MEDIUM |
|---|---|---|---|---|---|
| |  |  |  |  |  |
| Vehicle | Athena | Minotaur | Pegasus | Taurus | Delta 2 |
| Company | Lockheed Martin | Orbittal Sciences | Orbital Sciences | Orbital Sciences | Boeing |
| First Launch | 1995 | 2000 | 1990 | 1994 | 1990 |
| Stages | 3(athena 1) 4(Athena 2) | 4 | 3 | 4 | 3 |
| Payload Performance (LEO) | 820 kg (1,805 lbs.) (Athena 1) 2,050 kg (4,520 lbs.) (Athena 2) | N/A | 440 kg (975 lbs.) | N/A | 5,125 kg (11,300 lbs.) |
| Payload Performance (LEO polar) | 545 kg (1,200 lbs.) (Athena 1) 1,575 kg (3,470 lbs.) (Athena 2) | 340 kg (750 lbs.) (SSO) | 330 kg (730 lbs.) | 1,070 kg (2,360 lbs.) | 3,895 kg (8,890 lbs.) |
| Payload Performance (GTO) | N/A | N/A | N/A | N/A | 1,870 kg (4,120 lbs.) |
| Launch Sites | CCAFS, VAFB, Kodiak | VAFB | CCAFS WFF** VAFB, EAFB, Kwajalein, Canary | VAFB | CCAFS, VAFB |

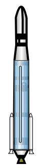
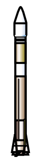
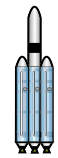
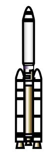
* First launch of refurbished Titan 2 ICBM. Titan 2 was also used for Gemini program launches, 1964-1966

** Wallops Flight Facility

## Delta 4

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), designed 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. It is, however, both larger and simpler than the SSME. Two to four solid-fuel, graphite-epoxy motors, two types of upper stages, and three payload fairings depending on customer needs can supplement the RS-68. It will be launched from both VAFB and CCAFS. The first Delta 4 launch took place on November 20, 2002, successfully lofting the Eutelsat W5 spacecraft from CCAFS.

TABLE 1

| | INTERMEDIATE | | | | HEAVY | | |
|---|---|---|---|---|---|---|---|
| |  |  |  |  |  |  |  |
| Vehicle | Delta 4 | Atlas 2 | Atlas 3 | Atlas 5 | Delta 4<br>Heavy | Titan 4B | Zenit 3SL |
| Comany | Boeing | Lockheed<br>Martin | Lockheed<br>Martin | Lockheed<br>Martin | Boeing | Lockheed<br>Martin | Sea Launch |
| First Launch | 2002 | 1990 | 2000 | 2002 | 2004 | 1997 | 1999 |
| Stages | 2 | 2 | 2 | 2 | 2 | 2 | 3 |
| Payload<br>Performance<br>(LEO) | 8,120 kg<br>(17,905 lbs.)<br>(Delta 4M)<br>11,475 kg<br>(25,300 lbs.)<br>(delta 4M+<br>(5,4)) | 7,315 kg<br>(16,130 lbs.)<br>(Atlas 2A)<br><br>8,620 kg<br>(19,000 lbs.)<br>(Atlas 2AS) | 8,640 kg<br>(19,050 lbs.)<br>(Atlas 3A)<br><br>10,720 kg<br>(23,630 lbs.)<br>(Atlas 3B) | 10,300 kg<br>(22,711 lbs.)<br>(Atlas 5 502)<br><br>20,711 lbs.)<br>(Atlas 5 552) | 23,040 kg<br>(50,800 lbs.) | 21,680 kg<br>(47,800<br>lbs.) | N/A |
| Payload<br>Performance<br>(LEO polar) | 6,870 kg<br>(15,150 lbs.)<br>(Delta 4 M)<br>10,400 kg<br>(22,930 lbs.)<br>(Delta 4M+<br>(5,4)) | 6,190 kg<br>(13,650 lbs.)<br>(Atlas 2A)<br><br>7,210 kg<br>(15,900 lbs.)<br>(Atlas 2AS) | N/A | N/A | 20,800 kg<br>(45,865 lbs.) | 17,600 kg<br>(38,800<br>lbs.) | N/A |
| Payload<br>Performance<br>(GTO)<br><br>Launch Sites | 4,210 kg<br>(9,285 lbs.)<br>(Delta 4 M)<br>6,565 kg<br>(14,480 lbs.)<br>(delta 4 M+<br>(5,4)) | 3,065 kg<br>(6,760 lbs.)<br>(Atlas 2A)<br><br>3,720 kg<br>(8,200 lbs)<br>(Atlas 2AS) | 4,035 kg<br>(8,900 lbs.)<br>(Atlas 3A)<br><br>4,475 kg<br>(9,870 lbs.)<br>(Atlas 3B) | 3,970 kg<br>(8,750 lbs.)<br>(Atlas 5 501)<br><br>8,670 kg<br>(19,10 lbs.)<br>(Atlas 5 551) | 13,130 kg<br>(28,950 lbs.) | 5,760 kg<br>(12,700<br>lbs.) (GEO) | 6,000 kg<br>(13,230 lbs.) |
| | CCAFS, VAFB | CCAFS, VAFB | CCAFS | CCAFS | CCAFS, VAFB | CCAFS, VAFB | Pacific<br>Ocean |

Boeing offers five different 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 will use three parallel common booster core stages. Three of these versions, the Delta 4 Medium-Plus vehicles, will be 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).[9] The Delta 4 has also replaced the Delta 3. The last Delta 4 launch took place on August 29, 2003. The Delta 4 had two launches in 2003 and three are planned for 2004 including the first launch of the heavy variant.

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

Delta 4 Courtesy of The Boeing Company

integration is complete, the vehicle is moved to the pad, raised, and launched in a relatively short period of time. In addition to making the launch vehicle easier to work on by keeping it closer to the ground, this integration method also 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. Since the availability of launch pads is one of the factors limiting launch rates, Boeing's integration process contributes to the economic advantages that are a major part of the EELV program's goals.

## ***Minotaur - Orbital Sciences Corporation***

The Orbital/Suborbital Program Space Launch Vehicle, also known as Minotaur, was developed by Orbital Sciences Corporation under contract to the U.S. Air Force to launch small government payloads. The 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, and the upper two stages are Orion 50 XL and Orion 38 motors from the Pegasus XL. All four stages use solid propellants.[10]

Minotaur Courtesy of Orbital Sciences Corporation

The Minotaur made its debut on January 26, 2000, when it successfully launched the FalconSat and JAWSAT satellites from VAFB. Minotaur's only other launch took place on July 19, 2000, when it launched the Air Force Research Laboratory's MightySat 2.1 spacecraft, also from VAFB. The Minotaur has one mission slated for 2004: XSS-11.[11]

## ***Pegasus - Orbital Sciences Corporation***

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

The booster is carried aloft under Orbital Sciences' "Stargazer" L-1011 carrier aircraft (early Pegasus launches used a B-52 leased from NASA) to an altitude of 11,900 meters (39,000 feet), where it is released. The booster drops for five seconds before igniting its first stage motor and beginning its 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 booster's payload capacity. 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.[12] Pegasus launches have been staged from seven sites to date: Edwards Air Force Base (AFB) and VAFB, California; CCAFS and Kennedy Space Center, Florida; NASA's Wallops Flight Facility, Virginia; Kwajalein Missile Range, Marshall Islands; and Gando AFB, Canary Islands. The last Pegasus XL was launched on August 12, 2003, carrying Scisat 1 for the Canadian Space Agency. Four Pegasus XLs were launched in 2003 and two government launches are scheduled for 2004.[13]


Pegasus Courtesy of Orbital Sciences Corporation

## Taurus - Orbital Sciences Corporation

The Taurus ELV is a ground-launched vehicle based on the air-launched Pegasus. Orbital Sciences Corporation developed the Taurus under the sponsorship of the Defense Advanced Research Projects Agency (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. The Taurus uses the three stages of a Pegasus, without wings or stabilizers, stacked atop a Castor 120 solid rocket motor that serves as the Taurus' first stage.[14][15]

The Taurus has successfully completed five of six launch attempts since entering service in 1994. A commercial Taurus is slated to launch Taiwan's ROCSAT-2 spacecraft in 2004.


Taurus Courtesy of Orbital Sciences Corporation

## Titan Family - Lockheed Martin Corporation

In 1986 Martin Marietta (now Lockheed Martin) won a contract from the U.S. Air Force to refurbish 14 decommissioned Titan 2 ICBMs into launch vehicles for government payloads. Thirteen of these boosters have been launched since 1988, with the Titan 2's final mission completed on October 18, 2003.[16] The two-stage Titan 2, which uses nitrogen tetroxide and Aerozine-50 as propellants, can place 1,905 kilograms (4,200 pounds) into polar LEO.

The Titan 4 program dates back to 1985, when the U.S. Air Force 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 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, is the most powerful ELV in the United States today.[17] It uses upgraded solid rocket motors that increase the payload

Titan 4 Courtesy of Lockheed Martin Corporation

capacity of the vehicle by 25 percent.[18] The Titan 4B is used solely for U.S. military payloads, with the exception of the October 1997 launch of NASA's Cassini mission. There were two Titan 4B launches in 2003 and two launches are planned for 2004. The final Titan 4 launch is scheduled for early 2005.[19] The Titan 4B is being phased out in favor of the heavy EELV variants.

### *Zenit 3SL - The Sea Launch Company, LLC*

The Zenit 3SL is a Ukrainian-Russian launch vehicle marketed by Sea Launch, a multinational joint venture led by The Boeing Company. The first two stages, each powered by a single engine using liquid oxygen and kerosene propellants, are provided by the Ukrainian firm SDO Yuzhnoye/PO Yuzhmash and are the same as those used on the Zenit 2 launch vehicle. The third stage is a Block DM-SL upper stage, which also uses liquid oxygen and kerosene propellants, provided by Russian firm RSC Energia. Boeing provides the payload fairing and interfaces for the vehicle.[20] The Zenit 3SL is launched from the Odyssey mobile launch platform, which travels from its homeport in Long Beach, California, to a position on the Equator in the Pacific Ocean for each launch. Launch operations are controlled from a separate vessel, the Sea Launch Commander. While Sea Launch conducts commercial launches with a license from the FAA, the multinational nature of the system prevents it from carrying U.S. government payloads at this time. There were three Zenit launches in 2003 and five launches are scheduled for 2004.

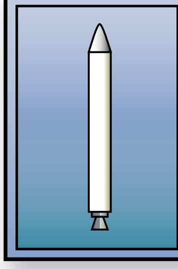
Sea Launch Zenit 3SL Courtesy of The Sea Launch Company

## *ELV Development Efforts*

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

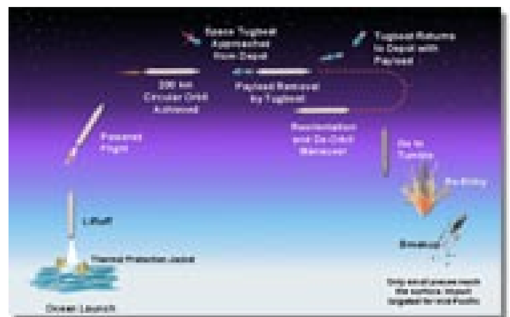
### *Aquarius - Space Systems/Loral*

Space Systems/Loral of Palo Alto, California, has proposed Aquarius, a low-cost launch vehicle designed to carry small, inexpensive payloads into LEO. Aquarius trades reliability for low launch costs. The vehicle will be primarily intended to launch into orbit bulk products, like water, fuel, and other consumables, that are inexpensive to replace in the event of a launch failure. The target launch cost is $1 million. 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



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

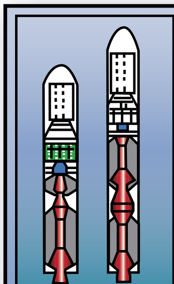
floated in the ocean prior to launch to minimize launch infrastructure and will be able to place a 1,000-kilogram (2,205-pound) payload into a 200-kilometer (125-mile), 52-degree orbit. The payload, located in the base of the vehicle, will be extracted by an orbiting space tug for transfer to its ultimate destination, after which the vehicle will de-orbit and be destroyed.[21]



Aquarius mission profile Courtesy of Space Systems/Loral

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 of El Segundo, California, and Wilson Composite Technologies of Folsom, California, for the study.[22] Funding of $1 million was provided in the FY 2004 Defense Appropriations Act to develop a prototype of the low-cost engine for the vehicle. The engine would provide 400,000 pounds of thrust using liquid oxygen and liquid hydrogen as propellants. For the engine development, Space Systems/Loral is partnered with Aerojet, a GenCorp Company based in Sacramento, California, and Microcosm. This program is expected to proceed under the auspices of the Air Force Research Laboratory. 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.[23]

## *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: Kennedy Space Center, Virginia Space Flight Center, Cape Canaveral, Kodiak Launch Complex

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, the vehicle will be ejected from a ground-based silo using a compressed-gas system. At a height 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, while a somewhat larger version, the Eagle, could put 1,360 kilograms (3,000 pounds) into LEO. Both will use solid propellant lower stages and liquid-propellant upper stages. E'Prime has also proposed larger vehicles, designated S-1 through S-7, that will be able to place considerably larger payloads into LEO and 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 Air Force to use Peacekeeper technology for commercial launch vehicles.[24]

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. The company plans to launch the Eaglet and Eagle boosters from facilities at NASA's Kennedy Space Center (KSC) that the company has yet to construct. E'Prime plans to launch from Virginia Space Flight Center or KSC for equatorial orbits and from the Kodiak Launch Complex for polar orbits.[25]

In July 2003, E'Prime Aerospace announced the Eagle Flier, to be developed by its affiliate SpacePlane Systems (described below) as an orbital space plane. The Eagle Flier is planned to be operational by 2005.[26]

## Eagle Flier - SpacePlane Systems

SpacePlane Systems of Titusville, Florida, is developing the next generation space plane vehicle based on the lifting body aircraft concept. The lifting body design with monocoque construction does not include heat resistant tile, which reduces failure points, and does not have wings. Its configuration will be modular, allowing it to be configured for multiple contingencies, respond quickly to new requirements, easily accommodate requirements for variations in crew and cargo size, minimize life cycle costs, prepare and execute missions in a reduced amount of time with increased launch probability, and support cargo delivery for the international space station.

The Eagle Flier spaceplane is being designed to satisfy customer requirements for unmanned air and space applications and manned air and space flight. The company is pursuing unmanned markets that include scientific research of weather events such as tornados or hurricanes; aerial photography; marine studies; university use of low-cost spaceplanes; NASA, NOAA, DoD space missions; de-orbiting spacecraft; on-orbit satellite

Vehicle: Eagle Flier
Dimensions: From 6 ft long/3 ft wide to 32 ft long/16 ft wide (manned and unmanned)
Developer: SpacePlane Systems
First Launch: 2005 for unmanned; 2006 for manned vehicle
Payload performance: Manned and unmanned
Launch sites: To be determined

maintenance and recovery; supply of the ISS; cargo transport; munitions delivery; and military reconnaissance. The manned configuration will serve the market for orbital and suborbital commercial space flights and rapid passenger transport worldwide.

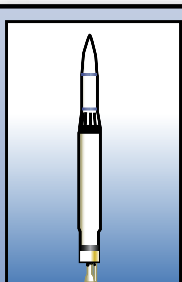
The SpacePlane Systems design allows the vehicle to be remotely piloted while manned, which will allow for the crew to focus on emergency operations while the ground crew controls vehicle operations. Operations would not be inhibited by crew incapacitation. The Eagle Flier will have the capability to be stored on the ground and readied for launch in less than 24 hours notice.[27] The company is conducting test flights of an unmanned scale model of the space plane.

### *Land Launch – The Sea Launch Company, LLC, and Space International Services*

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 will use a version of the Sea Launch Zenit-3SL rocket to lift commercial satellites in the 2,000-3,500 kg range to geosynchronous transfer orbit, and heavier payloads to inclined or lower orbits. A two-stage configuration of the same rocket will also be available for launching heavy payloads, or groups of payloads, to low Earth orbits. Payloads and vehicles will be processed and launched from existing Zenit facilities at the Baikonur launch site. Initial launch capability is slated for the fourth quarter 2005. Boeing Launch Services, Inc. will manage marketing and sales for the new offering, expanding on its Sea Launch marketing.[28]

### *LV-1 - Rocket Propulsion Engineering Company*

Rocket Propulsion Engineering Company of Mojave, California, has proposed developing the LV-1. The LV-1 is a two-stage ELV capable of launching 204 kilograms (450 pounds) into LEO. The vehicle uses hydrogen peroxide and kerosene pump-fed engines and graphite epoxy tanks. The company is working on two suborbital vehicles, the SV-1 and SV-2, that will test the engines and other technologies used in the LV-1 and anticipates beginning test launches of those suborbital vehicles no earlier than 2005.[29]



Vehicle: LV-1
Developer: Rocket Propulsion Engineering Company
First Launch: No sooner than 2005
Number of stages: 2
Payload performance: 204 kg (450 lbs.) to LEO
Launch sites: To be determined

## Scorpius Family - Microcosm, Inc.

Vehicle: Scorpius Sprite Mini-Lift
Developer: Microcosm
First Launch: Late 2006 or early 2007
Number of stages: 3
Payload performance: 315 kg (700 lbs.) to LEO, 150 kg (330 lbs.) to sun-synchronous orbit (SSO)
Launch sites: Vandenberg AFB, Wallops Flight Facility, and Cape Canaveral

Microcosm, Inc. of El Segundo, California, is developing the Scorpius family of ELVs. The boosters feature a modular design, using a number of identical propulsion pods, each with its own liquid propellant engines and graphite-composite propellant tanks. The Sprite Mini-Lift vehicle, the smallest orbital version of the Scorpius family, will use six booster pods, each with a 89,000-newton (20,000-pound-force) engine, clustered around a sustainer pod with a wider expansion ratio of the same engine. The Sprite Mini-Lift will be able to place 315 kilograms (700 pounds) into LEO and 150 kilograms (330 pounds) into sun-synchronous orbit (SSO). Three larger Scorpius vehicles are under study: the Sprite Heavy, capable of launching 640 kilograms (1,400 pounds) into LEO, the Liberty Light Lift capable of 1,280 kilograms (2,800 pounds), the Antares Intermediate-Lift, capable of launching 2,950 kilograms (6,500 pounds) into LEO, and the Exodus Medium-Lift, capable of placing 6,800 kilograms (15,000 pounds) into LEO.

In March 2001, Microcosm successfully launched its SR-XM-1 sounding rocket from the White Sands Missile Range, New Mexico. The Sprite Mini-Lift's sustainer pod has the same design but utilizes the larger 20,000-pound thrust engine as the SR-XM-2. The Sprite's booster pods will also use the same design as the SR-XM-2, but with sea level expansion ratio engines. Microcosm is currently developing the SR-XM-2 sounding rocket to test the larger engine. The company anticipates performing the first test launch of the Sprite Mini-Lift from Vandenberg by late 2006 or early 2007, with the vehicle entering commercial service nine months later at a cost per launch to Microcosm of $2.7 million.

Microcosm is also conducting preliminary studies under the DARPA Force Application and Launch from CONUS (FALCON) contract for the Sprite Heavy that will deliver twice the capability as the standard Sprite, but for less than twice the cost.[30] DARPA Falcon is intended to develop a Common Aero Vehicle capable of delivering up to 1,000 pounds of munitions to a target 3,000 nautical miles downrange and an Operational Responsive Spacelift (ORS) booster vehicle that will place CAV at the required altitude and velocity. The FALCON program will develop a low cost rocket booster to meet these requirements and demonstrate this capability in a series of flight tests culminating with the launch of an operable CAV-like payload.[31]

## SLC-1 - The Space Launch Corporation

Vehicle: SLC-1
Developer: The Space Launch Corporation
First Launch: Late 2006
Number of stages: Three (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 turbo-jet 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. The company is targeting microsatellites and other small payloads that would otherwise be launched as secondary payloads on larger vehicles.[32] The company anticipates the first launch of this system by the end of 2006.  The Space Launch Corporation was also selected as the sole prime contractor for DARPA's RASCAL program in March 2003.[33] RASCAL is a new tactical launch system that will provide the U.S. military with the capability 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/kg.

### Sounding Rockets

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

## Black Brant


Black Brant

Black Brant rockets have been manufactured since 1962, with over 800 vehicles having been launched during that time. The Black Brant motor and Nihka motors used on some Black Brant versions are manufactured in Canada by Bristol Aerospace while the Nike, Talos, and Taurus motors used on some Black Brant versions are built in the United States. The vehicles are integrated by the launch operator. In the United States, NASA has been a frequent user of Black Brant vehicles. Versions of the Black Brant can carry payloads ranging from 70 to 850 kilograms (154 to 1,874 pounds) to altitudes of 150 to 1,500 kilometers (93 to 932 miles). Black Brant vehicles can provide up to 20 minutes of microgravity time during a flight.[34]

The smallest version of the Black Brant family is the single-stage Black Brant 5 vehicle. The rocket is 533 centimeters (210 inches) long and 43.8 centimeters (17.26 inches) in diameter, and 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 model, the Black Brant 12, is a four-stage vehicle that uses the Black Brant 5 motor as its third stage. The Black Brant 12 can launch a 113-kilogram (250-pound) payload to an altitude of at least 1,400 kilometers (870 miles), or a 454-kilogram (1,000-pound) payload to an altitude of at least 400 kilometers (249 miles).[35]

## Oriole

Astrotech Space Operations developed the Oriole sounding rocket in the late 1990s to provide launch services for commercial and scientific payloads. The Oriole was the first new sounding rocket developed in the United States in 25 years and is the first privately-developed sounding rocket. The Oriole is a single-stage vehicle with a graphite epoxy motor 22 manufactured by Alliant Techsystems in Rocket Center, West Virginia. The vehicle can also be combined with other motors to create two-stage sounding rockets with the Oriole serving as the second stage. The Oriole is 396 centimeters (156 inches) long and 56 centimeters (22 inches) in diameter, and generates an average thrust of 92,100 newtons (20,700 pounds-force). The Oriole can provide payloads with six to nine minutes of microgravity during flight. The first flight of the Oriole took place on July 7, 2000, when the Oriole was launched from the NASA Wallops Flight Facility in Virginia. The launch took place in a two-stage configuration with the Oriole serving as the second stage and a Terrier Mk 12 motor as the first stage. The Oriole reached a peak altitude of 368.5 kilometers (229 miles) 315 seconds after launch during the test flight.[36] In July 2001, SPACEHAB sold the Oriole program to DTI Associates, who integrates the vehicle and offers it commercially.[37]

## Terrier-Orion

Terrier-Orion is a two-stage, spin-stabilized sounding rocket using a Terrier Mk 12 Mod 1 engine for the first stage and an Improved Orion motor for the second stage. The Terrier is a surplus U.S. Navy missile motor, while the Orion is a surplus U.S. Army missile motor. DTI Associates of Arlington, Virginia (formerly a part of Astrotech Space Operations, a SPACEHAB, Inc., subsidiary), is the general contractor for vehicle integration. 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 place payloads of up to 290 kilograms (639 pounds) to altitudes of up to 190 kilometers (118 miles).[38]

Terrier-Orion

A different version of the Terrier-Orion booster uses the more powerful TerrierMk 70 motor on the first stage. This version was used for two FAA/AST licensed suborbital launches carried out 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.[39]

# Reusable Launch Vehicles

This section describes active and emerging reusable launch vehicle (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 the precursor of what may become a long line of commercial and 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 more efficient RLV systems. Current government programs to develop follow-on RLVs (such as the restructured Space Launch Initiative [SLI]) may utilize some private sector innovation and may help to lay the foundation for future, privately developed RLVs for commercial and selected government applications. The first section addresses three RLV developments being pursued by the National Aeronautics and Space Administration (NASA) as a well as a project sponsored by the Defense Advanced Research Projects Agency (DARPA). Commercial RLV projects underway or under consideration, including those vying for the X Prize, comprise the balance of the section.

## *Government RLV Development Efforts*

Both NASA and the Department of Defense (DoD) have long been interested in the development of RLVs. During the late 1950s and 1960s, NASA and the Air Force developed the X-15 to study hypersonic flight. Following the successes of this program, NASA went on to great human space flight accomplishments with the Mercury, Gemini, Apollo, Skylab, Apollo Soyuz Test Project, Space Shuttle, and the International Space Station programs. Throughout the 1980s and 1990s, both NASA and DoD continued with several joint and independent experimental RLVs to improve reliability, minimize operating costs, and demonstrate “aircraft-like” operations. None of these concepts, however, resulted in a fully operational vehicle.

Today, both NASA and DoD still endeavor to develop new, reliable RLVs. Still the world’s only existing RLV, NASA’s Space Shuttle is aging and never achieved the launch rates and economies of scale the space agency originally anticipated for the vehicle. In 1999, NASA introduced its Integrated Space Transportation Plan (ISTP), an investment strategy for its space transportation needs. The ISTP included a program of Space Shuttle upgrades; SLI, originally a technology development program to support NASA in making a decision on a new RLV to replace the Shuttle; and a program to develop the technologies for third- and fourth-generation RLVs. The space agency also funded several RLV research vehicles. DoD studied an assortment of military space plane and related technology concepts.

In 2002, both NASA and the military reevaluated their RLV efforts. NASA implemented a revised ISTP to better coordinate its space transportation efforts with its International

Space Station (ISS) and science and research needs. The revised ISTP continued to support the Space Shuttle with a Service Life Extension Program (SLEP), and it restructured SLI to accommodate the development initially of an ISS crew rescue vehicle (CRV), and then the development of a crew transfer vehicle (CTV) 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. The Air Force and NASA also conducted a joint study to explore their respective RLV requirements and, after finding common requirements, agreed to cooperate as appropriate on RLV development, although in what form remains to be determined. In addition, some military space requirements may be met by DARPA's Responsive Access, Small Cargo, and Affordable Launch (RASCAL) program, which is expected to yield a vehicle that can meet the demand for launch of small payloads on short notice.

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 low Earth orbit. Initially, the United States will return the Space Shuttle to flight in accordance with the recommendations of the Columbia Accident Investigation Board to complete its work on the ISS by 2010, after which the Shuttle will be retired. The United States will also begin developing a new manned exploration vehicle, the Crew Exploration Vehicle (CEV), to be tested by 2008 and conduct its first manned mission in 2014. The CEV will transport astronauts and scientists to the ISS after the Shuttle is retired. Extended manned missions to the Moon could begin as early as 2015, following a series of robotic missions. 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 five years, with the majority of the funding derived from reallocations within NASA's existing budget. NASA, utilizing the advice of a new President's Commission on the Implementation of the U.S. Space Exploration Policy, will review all existing space flight and exploration programs and develop a plan for long-term implementation of the President's vision in 2004.[40]

## Space Shuttle

Consisting of an expendable external tank, two reusable solid rocket boosters, and a reusable Orbiter, NASA's Space Transportation System (STS), commonly referred to as the Space Shuttle, remains the world's only existing RLV. The Space Shuttle has conducted

Vehicles: Space Shuttles 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 low Earth orbit (LEO)
Launch site: Kennedy Space Center (KSC), Florida
Markets served: Non-commercial payloads and ISS access

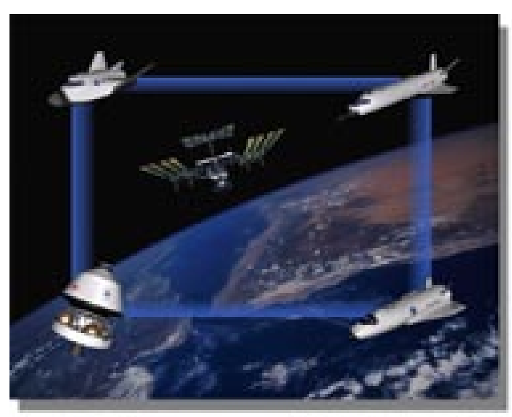
113 launches since its introduction in 1981. Unfortunately, on its first mission in 2003, the Space Shuttle Orbiter Columbia suffered a catastrophic failure on reentry that resulted in the loss of its seven astronauts and the vehicle. Fortunately, there were no casualties on the ground as the breakup of the vehicle and the resultant debris field covered a long swath of land primarily through sparsely inhabited Northeast Texas. The Columbia Accident Investigation Board (CAIB) has completed its report on the cause of the accident and its recommendations on actions required to be completed by NASA to return the STS safely to flight status.[41]

Space Shuttle

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 fly 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. In 2002, the space agency restructured its Shuttle upgrades program to better align investments with agency goals and the ISTP. Now called the Service Life Extension Program, the program's primary objective is to reduce risk and preserve Shuttle safety and viability through investments in Shuttle upgrades and infrastructure revitalization. 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, as well as others in the space community, has raised the possibility that even more responsibility for the Shuttle might be shifted from government to private sector control. A task force commissioned by NASA to examine this possibility suggested in 2002 a variety of options through which the space agency could further competitive outsourcing of Shuttle operations. NASA has not yet announced how it will proceed.[42]

## *Orbital Space Plane*

One of NASA's key requirements for space transportation is ensuring the ability to transport crews to and from the ISS, both under normal operations and emergency return situations. While the Space Shuttle, when it returns to flight status, and the Russian Soyuz vehicles currently serve these needs, these options may not exist for the duration of ISS operations, which will extend until at least 2016. In 2002, NASA cancelled the X-38, a full-scale prototype of a crew return vehicle that was intended to serve as a lifeboat for the ISS.



Orbital Space Plane concept Courtesy of NASA

The newest component of NASA's SLI, the Orbital Space Plane, is NASA's proposed vehicle architecture to meet the space agency's requirements for the ISS with minimal cost and risk. NASA anticipates the vehicle beginning as a crew return vehicle that will be launched to the ISS atop an Evolved Expendable Launch Vehicle (EELV). Crew rescue vehicle (CRV) operations will begin at least by 2010, and the initial capability may be accelerated to as early as 2008. By 2012, the Orbital Space Plane will be able to support the transfer of crew as well as limited cargo both to and from space. NASA envisions that the Orbital Space Plane will serve as a complement to the Space Shuttle for launching crews into space and could potentially fulfill ISS logistical needs.

NASA expects to approach the program aggressively and complete preliminary designs by 2005. The space agency awarded SLI contracts in November 2002 to Boeing and Lockheed Martin for flight demonstrator technologies to reduce the risks associated with the development of the Orbital Space Plane. Boeing will continue development of the X-37 experimental vehicle to demonstrate key flight technologies (described in greater detail in the "Enabling Technologies" section), while Lockheed Martin will develop a launch pad abort demonstrator to prove emergency crew escape technologies. Orbital Sciences Corporation was also awarded an SLI flight demonstration project for a Demonstrator for Autonomous Rendezvous Technologies (DART). It is a flight demonstrator vehicle to test technologies required to autonomously find and rendezvous with other spacecraft without having an astronaut on board. These plans are subject to change as NASA reevaluates its space flight programs as part of the new space exploration vision.

## Next Generation Launch Technology

Another component of NASA's restructured SLI, the Next Generation Launch Technology (NGLT) program combines elements of two previous research efforts: the original SLI program, which sought to reduce the risk associated with developing and flying a second-generation RLV around 2012, and NASA's former Advanced Space Transportation Program, which pursued propulsion, launch and flight technologies to produce options for third generation RLV concepts capable of flight in the 2025 timeframe. NGLT consists of investments for new research in propulsion, structures, vehicle systems and ground and flight operations. It is focusing on four significant technology research areas: 1) development of a reusable liquid-oxygen/liquid kerosene rocket booster engine; 2) development of hypersonic air-breathing propulsion and airframe systems; 3) development of cross-cutting launch vehicle system technologies; and 4) analysis activities to guide program investment and to ensure an appropriate fit with NASA's needs and the needs of NASA's civilian and government customers. In 2004, the program is slated to decide whether to proceed with a Next Generation Launch Vehicle risk-mitigation phase, which would include research and testing of large-scale tanks, structures and engines. NASA does not intend to make a decision on the development of a next-generation RLV any earlier than 2009. Also, a decision may be reached late in the next decade concerning future development of a hypersonic reusable launch vehicle, based on current air-breathing propulsion systems in development. NASA plans to work with DoD to assess common requirements and opportunities for cooperation on future RLV development efforts.[43] NASA's NGLT plans are subject to change pending its reevaluation of space flight programs.

## RASCAL

The Defense Advanced Research Projects Agency (DARPA) started work in 2002 on a project to create a low-cost partially reusable launch vehicle for small payloads. The Responsive Access, Small Cargo, and Affordable Launch (RASCAL) program seeks to develop a two-stage air launch system that can place payloads weighing up to 100 kilograms (220 pounds) into Low Earth Orbit (LEO). The RASCAL first stage will be a jet aircraft that flies to an altitude of at least 61 kilometers (200,000 feet). 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 one hour of a launch command and fly again within 24 hours at a cost of no more than $750,000 per flight.


RASCAL

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 injects a coolant, such as water or liquid oxygen, into the engine inlet. This process cools and compresses the airflow, extending the engine's limits and allowing it to operate at higher altitudes and greater speeds than otherwise possible. MIPCC will allow a vehicle powered by conventional turbofan engines to achieve a speed of Mach 4, an altitude over 61 kilometers (200,000 feet), and a dynamic pressure of less than 48 Pascals (1 pound per square foot). At that dynamic pressure, the rocket's upper stage can be released without a fairing to protect the payload. In 2003, DARPA selected Space Launch Corporation as the only RASCAL Phase II award winner. Phase II is an 18-month design phase that will advance the design of the RASCAL system and allow for risk reduction testing. Phase III will serve as the construction, test, and demonstration phase of the RASCAL program. Flight tests are scheduled to begin in FY 2005 with final system demonstrations - including the launch of at least two orbital payloads - in FY 2006.[44]

## Commercial RLV Development Efforts

## X Prize Contenders

In the spirit of the early 20th-century aviation prizes, such as the Orteig Prize that Charles Lindbergh won for crossing the Atlantic in 1927, the X Prize Foundation was established in 1995 as an educational, non-profit corporation dedicated to inspiring private, entrepreneurial advancements in space travel. The X Prize is being offered to help speed development of space vehicle concepts that will reduce the cost of access to space and allow human spaceflight to become routine. The St. Louis-based X Prize Foundation is offering a $10 million prize to the first team that launches a vehicle capable of carrying three people (or one person and ballast weight for two others) on a suborbital trajectory to a 100-kilometer (62-mile) altitude and repeats the flight within two weeks in the same vehicle. The X Prize is fully funded through January 1, 2005.

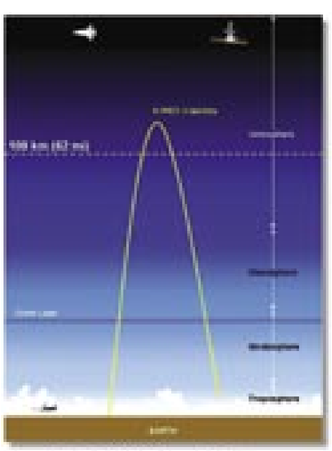
In June of 2003, the X Prize Foundation selected a former Space Shuttle Commander, Rick Searfoss, as the Chief Judge of the X Prize competition. His first job will be to finish forming the pool of aviation and space experts to judge the X Prize competition. The judges will ensure that the X Prize is awarded to the first team to meet the requirements of the X Prize.[45]

In 2003, eight new teams joined the X Prize competition, bringing the total to 27 entrants from seven countries proposing a variety of RLV concepts (see Table 2 for a complete listing of all of the X Prize competitors). Most of the commercial vehicles under development for the X Prize competition are uniquely designed for suborbital space tourism operations carrying three passengers. These vehicles use a variety of launch and landing design concepts.


X Prize Trophy

Dov Chartarifsky led the first new team to enter the X Prize in 2003, IL Aerospace Technologies (ILAT) of Israel, and became the seventh nation to compete for the X Prize on January 13, 2003. ILAT's vehicle, Negev, launches from a helium stratospheric balloon at 82,000 ft with a commercially available solid rocket motor. The ILAT team is dedicating its X Prize attempt in honor of the first Israeli astronaut, Col. Ilan Ramon who perished along with the rest of the Space Shuttle Columbia crew.

On January 14, 2003, Micro-Space Inc., of Denver, Colorado, registered its X Prize vehicle, Crusader X. The Crusader X vehicle uses a pressure-fed methyl alcohol and hydrogen peroxide engine. The cockpit core frame's seats and windshield are situated in a bobsled configuration. The propulsion modules are strapped onto the sides of the vehicle. The core also holds the attitude control jets, tiny flight controller, and parachute packages. Micro-Space plans to launch from Texas and recover the vehicle after a parachute water landing in the Gulf of Mexico.


Typical X Prize Trajectory

The third new team of 2003 was Interorbital Systems (IOS) of Mojave, California, with its SOLARIS X Vehicle on January 16, 2003. The IOS rocket team led by Roderick and Randa Milliron has been developing its launch vehicle since 1996. The Solaris X rocket is designed to carry four people to 152 km (52km higher than required to win the X Prize). White Fuming Nitric

Acid and Hydrocarbon X are used as propellants in the Solaris X's main engine. While the Solaris X can be launched vertically from either land or sea, IOS plans to launch from three possible sites: the Mojave Civilian Flight Test Center, South Texas Spaceport, or Spaceport Tonga. IOS also announced that the SOLARIS X will be piloted by a woman, Wally Funk, one of the original "Mercury 13" female astronaut trainees in the early 1960s. IOS is the first woman-owned team and female-piloted vehicle in the X Prize competition.[46]

The fourth new X Prize team was Bill Sprague's American Astronautics with The Spirit of Liberty vehicle on January 17, 2003. The booster uses one primary liquid oxygen/RP-1 liquid engine. After apogee, an aerobraking device reduces the velocity; then the main parafoil is deployed and unreefed in stages to control acceleration forces during deployment; and finally the vehicle touches down with deployed pressurized bags. The Spirit of Liberty also features an emergency escape system for the seven passengers.

The Spirit of Liberty Courtesy of the X Prize Foundation

On June 3, 2003, the fifth new team entered the X Prize competition, Vanguard Spacecraft Team with its vehicle, Eagle. The team is lead by Steve McGrath of Bridgewater, Massachusetts. The Eagle uses a three-stage combination of 12 liquid engines and four solid rocket motors to boost the vehicle up to 100 km. The Eagle has both drogue and main parachutes that deploy to slow the vehicle's speed for splashdown.[47]

Eagle Courtesy of the X Prize Foundation

The sixth team to register was the High Altitude Research Corporation, Inc. (HARC) team in November 2003 with its Liberator vehicle. HARC began as a spin-off of the High Altitude Lift-Off (HALO) program of the National Space Society's Huntsville chapter. The Liberator uses a single stage LOX-Kerosene pressure-fed engine that is launched from an ocean going vessel and reaches approximately 70 miles altitude before parachuting back for a water landing. The Liberator is designed with a crew escape system to allow the occupants to jettison the capsule from a malfunctioning booster and parachute downrange from the launch platform. The HARC team is based in Huntsville, Alabama.[48]

The Liberator Courtesy of the X Prize Foundation

Space Transport Corporation was the seventh team to enter the X Prize competition in November of 2003 with its Suborbital Tourism Vehicle (STV) the "Rubicon." Eric Meier and Phillip Storm established Space Transport Corporation in August of 2002 in Forks, Washington. The STV will have a gross lift-off weight of approximately 4000 lbs and stand 20 feet high. The STV has seven identical eight-foot long twelve-inch solid rocket engines; six of them are in a ring configuration around the seventh central engine. The outer engines are fired in opposing pairs and then the central engine is fired alone to make up four firing stages.[49]

The eighth and final team to register for the X Prize in 2003 was Blue Ridge Nebula Airlines. The Blue Ridge entrant is an asymmetric rotating lifting body, which is designed for vertical takeoff and landing.

## SpaceShipOne – Scaled Composites

| | |
|---|---|
|  | Vehicle: SpaceShipOne<br>Developer: Scaled Composites<br>First Launch: 2003<br>Number of Stages: 1<br>Possible Launch Sites: Mojave, California<br>Targeted Markets: Research and Development |

Scaled Composites, the first team to register for the X Prize, unveiled its vehicle on April 18, 2003. Led by Burt Rutan, Scaled Composites has started flight-testing its launch vehicle, SpaceShipOne. SpaceShipOne is a three-person vehicle designed to be air-launched at an altitude of 50,000 ft from a carrier aircraft, called White Knight. During 2003, Scaled conducted 11 flights, starting with three captive carry flights and seven drop tests. On December 17, 2003, the 100th anniversary of the Wright Brother's first powered flight, SpaceShipOne had its first powered flight. The hybrid propulsion system roared to life for 15 seconds pushing the vehicle past the speed of sound and reached an apogee of 68,000 feet. At apogee the pilot configured the vehicle into its feathered high-drag configuration for about one minute, and then reconfigured the vehicle for a glide back to the Mojave Civilian Flight Test Center.[50]

## Black Armadillo - Armadillo Aerospace

| | |
|---|---|
|  | Vehicle: Black Armadillo<br>Developer: Armadillo Aerospace<br>First Launch: expected 2004<br>Number of Stages: 1<br>Possible Launch Sites: White Sands, New Mexico<br>Targeted Markets: Public space transportation and other emerging markets |

For Armadillo Aerospace, succeeding in the development of an X Prize vehicle is the first step to considering future suborbital and potentially orbital launch services. The company's specific objective beyond winning the X Prize is to adapt its X Prize vehicle for space tourism and provide a suborbital platform for small microgravity research payloads. The X Prize vehicle, Black Armadillo, will consist of an autonomously guided single stage powered by four canted motors fueled by a bi-modal monopropellant hydrogen peroxide/methanol mixture. The vehicle is about six feet in diameter and 30 feet in height and about 1,700 lbs.[51] Armadillo has been making significant progress in the development of test articles and components. In 2003, Armadillo Aerospace tested the parachutes and crushable nose cone landing system by drop testing their vehicle from a helicopter. Armadillo Aerospace also spent considerable time fine-tuning its propellant mixture. They switched from 90 percent hydrogen peroxide to a mixture of 50 percent hydrogen peroxide with water and methanol that is cheaper and more readily available. In 2004, Armadillo plans to start its flight test program with some captive hover tests at its 100-acre test facility in Texas, followed by low altitude amateur launches before making its attempt at the X Prize.

### *Rocketplane XP - Rocketplane Limited, Inc.*

Vehicle: Rocketplane XP
Developer: Rocketplane Limited, Inc.
First launch: September 2006
Number of stages: 1
Possible launch sites: Oklahoma Spaceport
Targeted markets: Suborbital space tourism

Pioneer Rocketplane's Rocketplane Limited, Inc. is concurrently developing a scaled-down version of its Pathfinder vehicle, called the Rocketplane XP, to provide passenger service along suborbital trajectories. The Rocketplane XP is a four-seat fighter-sized vehicle powered by two jet engines and two rocket engines, enabling it to reach altitudes of 350,000 feet. Rocketplane has an agreement with the U.S.-based company Space Adventures to offer suborbital flights to customers paying between $98,000 and $100,000 per seat. The company recently contracted with a cost analysis team to conduct a technical appraisal on Pathfinder and its infrastructure as a requirement to receive financial support from the state of Oklahoma, where it plans to operate. Rocketplane's first suborbital spaceplane to be developed is a half-scale version of the Pathfinder without the payload bay. This spaceplane is intended to service the suborbital adventure travel market, and is also Rocketplane's X Prize vehicle. The spaceplane will carry a minimum of two passengers, plus a pilot and co-pilot. The half-scale vehicle takes off fully fueled and does not require the tanker operations that the larger spaceplane needs for LEO satellite launch operations.[52]

The Oklahoma Department of Commerce, the Oklahoma Space Development Authority and the Oklahoma Tax Commission certified Rocketplane in early 2004 as a qualified space transportation vehicle. Certification means investors in Rocketplane Limited will be eligible to receive state tax credits of up to 59.9 percent of the value of their investment.

## TABLE 2: X Prize RLV Concepts

| X Prize Team<br>Leader<br>Location | Vehicle and Website | Launch System and<br>Mission Description |
|---|---|---|
| Acceleration Engineering<br>Mickey Badgero<br>Bath, Michigan | Lucky Seven | Cone-shaped vehicle powered by rocket engines. The vehicle will launch vertically and land using a parafoil. |
| Advent Launch Services<br>Jim Akkerman<br>Houston, Texas | Mayflower<br>www.ghg.net/jimakkerman | Cyclinder-shaped glider powered by LOX/methane rocket engines. The vehicle will launch vertically from water and land horizontally at the launch site. Hardware has been built and tested. |
| Aeronautics and Cosmonautics Romanian Association (ARCA)<br>Dimitru Popescu Romania | Orizont<br>www.arcaspace.ro | Cylinder-shaped vehicle of standard rocket design with vertical launch plan. Hardware has been built and tested. |
| American Astronautics Corporation<br>Bill Sprague<br>Oceanside, California | The Spirit of Liberty<br>www.americanastronautics.com | Cylinder-shaped vehicle of standard rocket design with single stage LOX/RP-1 engine. This vehicle will launch vertically and glide to a landing with a parafoil and airbags. |
| Armadillo Aerospace<br>John Carmack<br>Dallas, Texas | Black Armadillo<br>www.armadilloaerospace.com | Development work has focused on mono- and bi-propellant hydrogen peroxide engines. Hardware has been built and tested. |
| Blue Ridge Nebula Airlines<br>Douglas Haynes | El Jimmile<br>www.blueridgeairlines.com | Asymmetric rotating lifting body, saucer shaped, designed for vertical take off and landing with ramjet/rocket hybrid engines. |
| Bristol Spaceplanes<br>David Ashford –England | Ascender<br>www.bristolspaceplanes.com | RLV powered by two conventional jet engines and a liquid-fueled rocket engine. The vehicle will take off horizontally and land horizontally. Hardware has been built and tested. |
| Canadian Arrow<br>Geoff Sheerin<br>Canada | Canadian Arrow<br>www.canadianarrow.com | Stretched, two-stage version of the V-2 rocket. It launches vertically and performs a parachute, water landing of the booster and passenger stages. Hardware has been built and tested. |
| The da Vinci Project<br>Brian Feeney<br>Canada | Wild Fire<br>www.davinciproject.com | Air-launched, LOX/kerosene rocket deployed from a large helium balloon. Recovery system features a high-drag reentry ballute and a Global Positioning System-guided parafoil. Hardware has been built and tested. |
| Pablo de León and Associates<br>Pablo de León<br>Argentina | Gauchito<br>(Little Cowboy)<br>www.pablodeleon.com | Single-stage vehicle that will launch vertically. The first stage booster and the passenger capsule return to Earth using parachutes. Hardware has been built and tested. |
| Discraft Corporation<br>John Bloomer<br>Portland, Oregon | The Space Tourist | Disc-shaped vehicle powered by air-breathing "blastwave-pulse jets." The vehicle will take off and land horizontally. |
| Flight Exploration<br>Graham Dorington<br>England | The Green Arrow | Cylinder-shaped rocket using liquid-fueled rocket engines. The vehicle will launch vertically and land vertically using parachutes and air bags. |
| Fundamental Technology Systems<br>Ray Nielsen<br>Orlando, Florida | Aurora<br>www.funtechsystems.com | Horizontal takeoff and landing double-delta-winged RLV powered by a single kerosene and hydrogen peroxide engine capable of being throttled. |

**TABLE 2: X Prize RLV Concepts (Cont'd)**

| | | |
|---|---|---|
| High Altitude Research Corporation (HARC)<br>Tim Pickens<br>Huntsville, AL | The Liberator<br>www.harcspace.com | Cylinder-shaped rocket with single stage LOX-Kerosene pressure-fed engine launched from an ocean going vessel and parachute landing. |
| IL Aerospace Technologies (ILAT)<br>Dov Chartarifsky<br>Israel | Negev<br>www.ilat.co.il | Solid rocket engine ignition at 30km via Helium Balloon ascent. Unpowered descent via three parachutes to a land or water landing. |
| Interorbital Systems (IOS)<br>Roderick and Randa Milliron<br>Mojave, California | Solaris X<br>www.interorbital.com | Cylinder-shaped rocket using liquid-fueled rocket engines. The vehicle will launch vertically and land vertically. |
| Kelly Space & Technology<br>Michael Gallo<br>San Bernardino, California | LB-X<br>www.kellyspace.com | Air-launched, lifting body vehicle that is taken to altitude by a tow aircraft. The vehicle will perform an unpowered horizontal landing. Hardware has been built and tested. |
| Lone Star Space Access<br>Norman LaFave<br>Houston, Texas | Cosmos Mariner<br>www.lonestarspace.com | RLV powered by two air-breathing engines and one rocket engine. The vehicle will launch and land horizontally. |
| Micro-Space, Inc.<br>Richard Speck<br>Denver, Colorado | Crusader X<br>www.micro-space.com | Multiple cylinder-shaped rockets using liquid-fueled rocket engines with a bobsled type capsule configuration. The vehicle will launch vertically and land under parachutes. |
| PanAero<br>Len Cormier<br>Fairfax, Virginia | SabreRocket<br>www.tour2space.com | Modified Sabre Jet with seven small LOX/Kerosene engines. The vehicle will perform a horizontal takeoff and powered, horizontal landing. |
| Pioneer Rocketplane<br>Mitchell Clapp<br>Solvang, California | Pioneer XP<br>www.rocketplane.com | Powered by both air-breathing jet engines and LOX/kerosene rocket engines. XP will takeoff horizontally and perform a powered, horizontal landing. |
| Scaled Composites<br>Burt Rutan<br>Mojave, California | White Knight and SpaceShipOne<br>www.scaled.com | Two-stage vehicle consisting of a turbo-fan-powered carrier aircraft and a rocket-powered second stage. Hardware has been built and tested. |
| Space Transport Corporation<br>Eric Meier and Phillip Storm<br>Forks, Washington | Suborbital Tourism Vehicle “Rubicon”<br>www.space-transport.com | Cylindrical-shaped rocket using seven solid rocket engines. Some hardware is built. |
| Starchaser Industries<br>Steve Bennet<br>England | Thunderbird<br>www.starchaser.co.uk | Traditional, multi-stage rocket using solid booster and liquid-fueled rocket engines. The vehicle will launch vertically and make a ballistic, guided--parachute landing. Hardware has been built and tested. |
| Suborbital Corporation<br>Sergey Kostenko<br>Russia | Cosmopolis-21 | Space plane carried to take-off altitude on the back of an M55-X carrier aircraft. The vehicle ejects the solid rocket motor after burn-out and glides to a horizontal landing. Hardware has been built and tested. |
| TGV Rockets<br>Kent Ewing<br>Bethesda, Maryland | M.I.C.H.E.L.L.E.-B<br>www.tgv-rockets.com | MICHELLE-B will launch vertically, perform a straight-up, straight-down flight trajectory, and perform a powered, vertical landing. |
| Vanguard Spacecraft<br>Steve McGrath<br>Bridgewater, Massachusetts | Eagle | Cylinder-shaped rocket using both solid and liquid-fueled rocket engines. The vehicle will launch vertically and land using parachutes. |

## Other Commercial RLV Efforts

### Falcon 1 - Space Exploration Technologies Corporation

Vehicle: Falcon 1
Developer: Space Exploration Technologies Corporation
First launch: May 2004
Number of stages: 2
Payload performance: 454 kg (1,000 lbs.) to LEO
Launch sites: Vandenberg Air Force Base, Cape Canaveral Air Force Station, Kwajalein Atoll

Elon Musk, an Internet entrepreneur, founded Space Exploration Technologies Corporation (SpaceX) of El Segundo, California, in June 2002. The company is developing the Falcon 1 launch vehicle, which is a mostly reusable rocket capable of placing either 1,250 pounds in the standard configuration or 4,000 pounds in the heavy configuration into low Earth orbit. The Falcon's first launch is scheduled for May 2004, to loft the TacSat-1 data communications satellite into orbit for the Office of the Secretary of Defense's Office of Force Transformation from Vandenberg Air Force Base in California.[53]

SpaceX is privately developing the entire two-stage vehicle from the ground up, including first and second stage LOX/kerosene engines, the turbo-pump, the cryogenic tank structure and the guidance system.[54] SpaceX initially plans to launch the Falcon two to three times a year from Space Launch Complex (SLC)-3W at VAFB, Launch Complex (LC)-46 at CCAFS, and the Kwajalein Atoll in the western Pacific Ocean, eventually ramping up to five to six flights a year at a price of $6 million per launch.

Vehicle: Falcon 5
Developer: Space Exploration Technologies Corporation
First launch: mid-2005
Number of stages: 2
Payload performance: 4,173 kg (9200 lbs.) to LEO
Launch sites: Vandenberg Air Force Base, Cape Canaveral Air Force Station, Kwajalein Atoll

### Falcon 5 - Space Exploration Technologies Corporation

Drawing from its experience with the single engine Falcon 1, due to launch in mid-2004, Space Exploration Technologies Corporation (SpaceX) is developing a five engine version that will be the first U.S. rocket capable of losing any three of the five engines and still complete its mission. Like Falcon 1, Falcon 5 is a two stage, liquid oxygen and rocket grade kerosene (RP-1) powered launch vehicle. It also makes use of the same engines, structural architecture (with a wider diameter), avionics and launch system.

The Falcon 5 also will increase the capability of the Falcon launch vehicle family with a capacity of over 4,000 kg (9,200 lbs.) to low Earth orbit and up to a 4 meter (13.1 foot) diameter payload fairing. The vehicle also will be capable of launching missions to geostationary orbit and the inner solar system as well as carrying supplies to the International Space Station with the addition of a lightweight automated transfer vehicle. Contract pricing will be set at a firm $12 million per flight plus range costs, resulting in an unprecedented cost of $1,300 per pound to orbit.[55]

## K-1 - Kistler Aerospace Corporation

Vehicle: K-1
Developer: Kistler Aerospace Corporation
First launch: To be determined
Number of stages: 2
Payload performance: 4,535 kg (10,000 lbs.) to LEO; 1,570 kg (3,460 lbs.) to geosynchronous transfer orbit (GTO)
Possible launch sites: Woomera, Australia; Nevada Test Site
Targeted markets: Deployment of LEO payloads GTO payloads (with Active Dispenser), ISS re-supply and cargo return missions.

Kistler has been developing the K-1 for commercial launches of LEO payloads. The K-1 design was developed in the mid-1990s as a two-stage-to-orbit (TSTO) vehicle with a payload capacity of approximately 4,535 kilograms (10,000 pounds) to LEO and a then-expected market price of $17 million per launch. Kistler has completed a conceptual design for an Active Dispenser that will deploy payloads to medium Earth orbits (MEO), geosynchronous transfer orbits (GTO), and interplanetary trajectories. The Active Dispenser will expand the K-1's capability beyond LEO (approximately 1,570 kilograms [3,460 pounds] to GTO) at a launch price of $25 million. The K-1 also will be capable of providing cargo re-supply and return services for the ISS. The K-1 will be able to launch multiple small payloads on dedicated missions or as secondary payloads. Kistler is working with Astrium, Ltd., in the United Kingdom to develop reusable payload dispensers for multiple small payloads. The K-1 will launch vertically like a conventional expendable launch vehicle (ELV) but will use a unique combination of parachutes and air bags to recover its two stages. The vehicle, designed to operate with a small complement of ground personnel, will be transported to the launch site and erected with a mobile transporter. The K-1 will measure about 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, is powered by three liquid oxygen (LOX)/kerosene GenCorp Aerojet AJ26 engines. These engines include elements of the NK-33 engines originally built by the Soviet Union in the 1960s. After launch, the Launch Assist Platform separates from the second stage and restarts its center engine to fly a return trajectory to a landing area near the launch site. The Launch Assist Platform 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. The Orbital Vehicle is powered by a single Aerojet AJ26-60 engine (derived from the Russian NK-43 engine).

Following payload separation, the Orbital Vehicle continues on orbit for about 24 hours, after which a LOX/ethanol orbital maneuvering system performs a deorbit burn. The Orbital Vehicle ends its ballistic re-entry profile by deploying parachutes and air bags in a manner similar to the Launch Assist Platform. Kistler expects to operate the K-1 from two launch sites: Woomera, Australia, and the Nevada Test 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's 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 2003, Kistler filed to reorganize under Chapter 11 of the U.S. Bankruptcy Code. However, the company expects to emerge with a reorganization plan once it has secured long term financing and continue vehicle development.[56]

## *Pathfinder - Pioneer Rocketplane*

Vehicle: Pathfinder
Developer: Pioneer Rocketplane
First Launch: To be determined
Number of stages: 2 (Second "stage" is an air refueling aircraft)
Payload performance: 1,818 kg (4,000 lbs.) to LEO
Possible launch sites: Oklahoma Spaceport
Targeted markets: Launch of small- and medium class payloads to LEO

The Pathfinder traces its heritage to a military space plane concept called "Black Horse," which was promoted within the Air Force in the early 1990s. Pioneer Rocketplane developed a derivative design that it called Pathfinder and proposed a precursor to it as a potential design for NASA's now cancelled X-34 vehicle. Pioneer Rocketplane continued Pathfinder development, and in June 1997 it was awarded one of four, $2-million NASA Low Cost Boost Technology Program contracts to develop detailed preliminary designs and to conduct wind tunnel tests for concepts to launch small satellites.

The vehicle will be operated by a crew of two pilots with experience in high performance aircraft and will have accommodations to carry two passengers. Both air-breathing jet engines and LOX/kerosene rocket engines will power the vehicle. The 23-meter- (75-foot-) long vehicle will take off horizontally using conventional turbofan jet engines. When it reaches an altitude of 6,000 meters (19,685 feet), Pathfinder will receive 59,000 kilograms (130,000 pounds) of LOX from a tanker aircraft. After disconnecting from the tanker, Pathfinder will ignite its RD-120 rocket engine and climb to an altitude of 112 kilometers (70 miles) at a speed of about Mach 12. Once out of the atmosphere, Pathfinder will be able to open its cargo bay doors and release its payload with a conventional rocket upper stage. The payload will proceed to its orbit while the Pathfinder re-enters the atmosphere. After deceleration to subsonic speeds, Pathfinder will re-start its turbofan engines and land horizontally. Pathfinder's maximum payload capacity to LEO will be 1,818 kilograms (4,000 pounds). The first air-breathing test flights are planned for three to four years after the acquisition of funding and will be followed two to three months later by rocket-powered test flights. Pioneer Rocketplane is designing Pathfinder as a low-cost alternative for small- to medium-class payloads to LEO.

## Xerus - XCOR Aerospace

Vehicle: Xerus
Developer: XCOR Aerospace
First launch: To be determined
Number of stages: 1
Payload performance: To be determined
Possible launch sites: Mojave Civilian Flight Test Center
Targeted market: Suborbital space tourism

Since XCOR's founding in 1999, the company has been focusing on the development of reusable engines with high reliability, efficient turnaround and maintenance, and safe operations. XCOR has developed an airborne platform called the EZ-Rocket to test the most successful of its engine designs (see the "Liquid Engines - XCOR Aerospace" entry in the "Enabled Technologies" section). The EZ-Rocket is powered by two engines, each capable of 1,779 newtons (400 pounds force) of thrust, and is piloted by veteran test pilot Dick Rutan. By demonstrating the reusability, efficiency, and safety of its engines, XCOR expects to gather enough data and experience to pursue its follow-on suborbital vehicle project. The vehicle, called Xerus, will be designed to carry one commercial pilot and one passenger. XCOR's philosophy is to take one step at a time toward suborbital, and perhaps later orbital, launch operations. XCOR hopes to provide suborbital flights on Xerus for about $10,000 per passenger and may develop a "stretched" version capable of taking two passengers at a time. XCOR expects to build Xerus within 18 months of securing $3 million and expects to offer commercial flights three years later. In 2003, XCOR Aerospace submitted a launch license application to FAA/AST for an intermediate technology demonstration vehicle.

**TABLE 3: Other Commerical RLV Concepts**

| Program | Developer | Vehicle Type |
|---|---|---|
| Bladerunner | Air Force Research Laboratory (AFRL) | Horizontally-launched orbital vehicle |
| Hyperion | Applied Astronautics | Horizontally-launched suborbital/orbital vehicle |
| Millennium Express | Third Millennium Aerospace | Horizontally-launched orbital TSTO vehicle |
| Neptune | Interorbital Systems Corporation | Sea-launched orbital vehicle |
| Pogo | Olson | Horizontally-launched orbital vehicle |
| SC-1 | Space Clipper International | Vertically-launched suborbital vehicle developed by spin-off from Universal Space Lines |
| SC-2 | Space Clipper International | Vertically-launched orbital vehicle developed by spin-off from Universal Space Lines |
| Space Cruiser | Vela Technology Development | Horizontally-launched suborbital vehicle specifically designed to ferry passengers |
| SpaceCub | Burkhead | Vertically-launched suborbital vehicle |
| Starlifter and Aquila | Starcraft Boosters, Inc. | Vertically-launched suborbital vehicle |
| Star-Raker | Star-Raker Associates | Horizontally-launched orbital vehicle |
| Swiftlaunch | University of California at Davis | Horizontally-launched orbital vehicle |
| The ET Scenario | Formation | Vertically-launched orbital vehicle |
| XPV | Canyon Space Team | Horizontally-launched suborbital vehicle |
| (unnamed) | SpaceDev | Suborbital |

# Enabling Technologies

There are a number of efforts underway to develop new propulsion technologies for launch vehicles, including expendable launch vehicles (ELV) and reusable launch vehicles (RLV). These efforts include government research projects as well as engines and motors being developed by companies for their own launch vehicles and for sale to other companies. Many companies are attempting to build considerably less complex and potentially less expensive rocket engines. Some of these designs use room-temperature propellants instead of cryogenics, while others use pressure-fed engines instead of turbopumps. The gains achieved in simplifying the engines, however, may be offset by reduced performance. NASA is working to advance new space vehicle and flight technologies in its Next Generation Launch Technology Program. This program incorporates elements of the original Space Launch Initiative and NASA's former Advanced Space Transportation Program. The Next Generation Launch Technology program seeks to develop and mature innovative technologies in the areas of propulsion, structures, vehicle systems, and ground and flight operations.[57]

## *Hypersonics - NASA*

NASA's hypersonics research and development is intended to develop enabling technologies to support the creation of third-generation RLVs. With this program, NASA hopes to:

- Dramatically reduce the cost of access to space
- Dramatically reduce the trip time between destinations
- Cut turnaround time between flights from weeks to hours
- Maintain aircraft-like levels of safety and reliability

## *Combined Cycle Air-Breathing Engines*

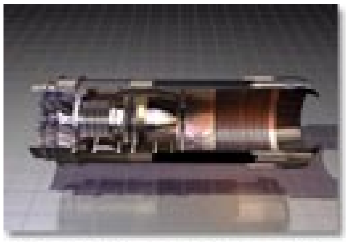
"Combined cycle" engines use multiple engine technologies within a single engine. Two combined cycle engine concepts are rocket-based combined cycle (RBCC) and turbine-based combined cycle (TBCC). For take-off, an RBCC engine uses a rocket and a TBCC engine uses turbomachinery (like a turbojet engine). Both transition to using a ramjet at about Mach 3 and then transition to a scramjet, a supersonic combustion ramjet, between Mach 5 and Mach 7 to accelerate up to about Mach 12. An on-board rocket (integral to the RBCC configuration, but separate in the TBCC configuration) would then be used to reach orbit.[58]

### *ISTAR*

The Integrated System Test of an Air-breathing Rocket (ISTAR) is the first RBCC developed by NASA. The ISTAR industry development team includes the Rocketdyne Propulsion & Power business unit of The Boeing Co., the Pratt & Whitney Space Propulsion business unit of United Technologies Corp., and the Aerojet Missile and Space Propulsion business unit of GenCorp, Inc.

The ISTAR program is currently developing a ground test engine to demonstrate the technologies of a rocket-based combined cycle engine. The ISTAR prototype engine is named ARGO. Testing of a flight-weight, fuel-cooled engine flowpath is scheduled to begin in 2008.[59]

### *Revolutionary Turbine Accelerator*



Revolutionary Turbine Accelerator TBCC engine Courtesy of NASA

The Revolutionary Turbine Accelerator (RTA) represents NASA's proposed TBCC system. The RTA is being developed by NASA Glenn Research Center with General Electric Aircraft Engines. The RTA is intended to show the feasibility of using an ultra-high-speed turbine engine to accelerate a hypersonic vehicle to speeds well above Mach 4. This project is expected to be ready for ground testing in 2006.

## ***Hyper-X Series Vehicles***

NASA's Hyper-X program is designed to study and improve air-breathing hypersonic engine technologies. Three different vehicle designs, designated X-43A, B, and C, are planned to conduct a variety of tests of hypersonic vehicle design. In an X-43A flight, 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 and is then separated from the booster for independent flight at high speed. The X-43A program involves three flights in an effort to understand intake and combustion chamber airflow patterns. The first X-43A flight, on June 2, 2001, had to be aborted due to an in-flight incident. Following the investigation of this failure, there will be several changes for the second flight. The NASA B-52 will release the vehicle at 40,000 ft altitude, instead of 23,000 ft as in the first attempt, in order to reduce the aerodynamic loads on the booster's control surfaces. The second X-43A was built at NASA Dryden Flight Research Center in 2002 and is being prepared for flight-testing in 2003.[60]

X-43A Courtesy of NASA

X-43C Courtesy of NASA

The X-43A will be followed by the X-43C, a 4.9-meter- (16-foot-) long vehicle that will test a different scramjet engine design. The X-43C will use three Ground Demonstrator Engine-1 engines developed by Pratt & Whitney for the U.S. Air Force's HyTech project, reaching speeds of Mach 5 to 7 for up to ten minutes. Like the X-43A, the vehicle will use a rocket booster stage to accelerate to speeds where the scramjet can function.

In October 2003, NASA selected Micro Craft, which was acquired by ATK Alliant Techsystems in November 2003, to provide three flight-ready demonstrator vehicles that

X-43B Courtesy of NASA

will fly about 5,000 miles per hour under a contract estimated at $150 million. Other team members include Pratt & Whitney, Boeing Phantom Works, and RJK Technologies.[61] The first X-43C flight is scheduled for 2008. The last Hyper-X vehicle, the X-43B, will test a rocket- or turbine-based combined-cycle engine to accelerate to hypersonic speeds. The first flight of the 12.2-meter (40-foot) long X-43B is planned for between 2010 and 2012.

## *Hybrid Rocket Motors - SpaceDev, Inc.*

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 hydroxyl-terminated polybutadiene (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 geosynchronous transfer orbit (GTO) to low Earth orbit (LEO) or geosynchronous orbit (GEO). In May 2002, the Air Force Research Lab awarded SpaceDev a contract to develop a hybrid propulsion module to deploy small payloads from the Space Shuttle.[62] In September 2003, Scaled Composites announced that it had selected SpaceDev for propulsion support for Scaled's SpaceShipOne project.[63]

## *Hybrid Propulsion Systems - Lockheed Martin-Michoud*

Michoud Operations is leading an industry/government team studying hybrid propulsion technology to decrease the cost, and increase the reliability and safety of launch vehicles. The hybrid system under study is powered by a combination of solid, non-explosive fuel and a liquid oxidizer. Unlike solid rockets currently in use, the hybrid system can be throttled, shut off and restarted during flight.

Launch of a 57-foot-long sounding rocket from NASA Wallops Flight Facility as part of the Hybrid Propulsion Demonstration Program Courtesy of Lockheed Martin-Michoud

The industry team working on the Hybrid Propulsion Demonstration Program (HPDP) includes: United Space Technologies Chemical Systems Division of San Jose, CA., Rocketdyne of Canoga Park, CA., Allied Signal of Torrance, CA., Environmental Aerosciences Company of Miami, FL., Thiokol of Brigham City, Utah, Lockheed Martin Astronautics of Denver, CO., and Michoud Operations, Lockheed Martin Space Systems Company of New Orleans, LA. NASA's Marshall Space Flight Center will provide the test facilities and various technical support.

HPDP consists of the development and testing of 11-inch and 24-inch diameter hybrid motors, four flight demonstrations by hybrid-powered sounding rockets and development and static firing of several 250,000 foot-pound thrust (lbf) motors.

Hybrid motors of the 250,000 lbf thrust class are being studied for possible use on current and future launch vehicles. Hybrid boosters would increase Atlas' payload-carrying capabilities to about 11,000 pounds. Funding for the hybrid team comes from the Department of Defense Technology Reinvestment Program, from NASA monetary and in-kind support, and from the contributions of industry team members.[64] In late 2002, Lockheed Martin launched a 57-foot-long sounding rocket at NASA Wallops Flight Facility on Wallops Island, VA, using liquid oxygen and solid fuel. The rocket generated 60,000 pounds of thrust during a burn time of 31 seconds while reaching an altitude of about 43 miles.[65]

## *Liquid Engines - Rocketdyne Propulsion & Power*

XRS-2200 linear aerospike engine

Rocketdyne Propulsion & Power, a division of The Boeing Company in Canoga Park, California, is developing a series of new engines for launch vehicles. Rocketdyne is developing two main engines as part of NASA's Next Generation Launch Technology program. The RS-83 is a reusable liquid hydrogen/ liquid oxygen engine designed to produce 664,000 lbs of thrust at sea level. The engine is being designed to run 50 times between major overhauls, and a total lifetime of 100 missions. The RS-84 is the first reusable hydrocarbon staged-combustion rocket engine. This engine is designed to produce 1,064,000 lbs of thrust at sea level with a design life of 100 missions.[66] In 2003, Rocketdyne successfully tested a key component of the RS-84 engine. In the test, a subscale preburner, which produces high-pressure, oxidizer-rich combustion gases to spin the engine's oxidizer and fuel turbopumps, achieved a chamber pressure in excess of 6,800 pounds per square inch, well beyond the levels seen in current domestic oxygen/kerosene rocket engines. Hot-fire tests of the preburner will conclude in 2004, paving the way for development of the full-scale version by 2007.[67]

Rocketdyne developed the XRS-2200 linear aerospike engine for the X-33 program. Aerospike engines offer significant efficiency advantages over fixed-nozzle-geometry engine designs. The engine provides up to a 909,305-newton (204,420-pound) thrust at sea level, using liquid hydrogen and liquid oxygen as propellants.[68]

## *Liquid Engines - Microcosm, Inc.*

Microcosm is developing liquid-propellant rocket engines for its Scorpius series of ELVs (see the ELV section for a description of Scorpius). The company has built a pressure-fed, ablatively-cooled, 22,250-newton (5,000-pound) thrust engine using liquid oxygen and jet fuel as propellants. This engine was successfully tested on the company's SR-S and SR-XM-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. A larger version, an 89,000-newton (20,000-pound) engine is in development.[69] This engine will be used on the booster pods and sustainer stage of the Sprite Mini-Lift.[70]

## Liquid Engines - Space Exploration Technologies Corporation

Space Exploration Technologies Corporation (SpaceX) of El Segundo, California, is developing two new liquid-propellant engines for use on its Falcon launch vehicle. The first stage engine, the Merlin, is a 267,000-newton (60,000-pound) engine that operates on a gas generator cycle.[71] The second stage engine, the Kestrel, is a pressure-fed engine that produces 33,300 newtons (7,500 pounds) vacuum thrust.[72] Both engines will use liquid oxygen and kerosene propellants. SpaceX began testing the Merlin in March 2003 and began testing the Kestrel in August 2003.

SpaceX Kestrel engine
Courtesy of
Space Exploration Technologies Corporation

## Liquid Engines - XCOR Aerospace

XCOR Aerospace, located in Mojave, California, specializes in the development of engines for use on launch vehicles and spacecraft. The company has developed and extensively tested three different liquid-propellant engines. XCOR's largest engine, designated XR4AE, is a 1,780-newton (400-pound), pressure-fed, regeneratively-cooled, liquid-oxygen and alcohol engine. Four such engines have been built and, combined, have been fired 558 times for over 6,434 seconds. The engines have also been flown on EZ-Rocket, a modified Long-EZ aircraft fitted with two of the engines. 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 two smaller engines. A 67-newton (15-pound) engine, designated XR2P1, using nitrous oxide and ethane as propellants, was initially built to test the design of proposed larger engines. This engine has made more than 950 firings, with a cumulative burn time of 94.8 minutes. XCOR's XR3B4 regeneratively-cooled engine is capable of a 220-newton (50-pound) thrust using nitrous oxide and isopropyl alcohol as propellants. This engine has completed 216 firings with a cumulative burn time of more than 812 seconds. XCOR designed this engine for use as a maneuvering thruster on spacecraft.

In April 2002, XCOR acquired selected intellectual property assets of the former Rotary Rocket Company, including a 22,250-newton (5,000-pound) liquid oxygen and kerosene engine developed and tested by the company as well as hydrogen peroxide engine technology. XCOR has completed development of their third generation igniter and is now testing a 1,800 lb thrust engine, which uses LOX and kerosene as propellant. This engine is of the same class of engine as will be used to power its Xerus suborbital vehicle.[73]

XCOR XR4K5 1,800 lb thrust engine
Courtesy of XCOR

## Propellant Production - Andrews Space & Technology, Inc.

Andrews Space & Technology, Inc., of Seattle, Washington, has proposed a propulsion system that will generate liquid oxygen propellant from the atmosphere. The "Alchemist" Air Collection and Enrichment System (ACES) will take high-pressure air from a turbofan jet engine flying at subsonic speeds and liquefy it by passing it through a series of heat exchangers cooled by liquid nitrogen and/or liquid hydrogen. Liquid oxygen will then be separated out and stored in propellant tanks for use by liquid hydrogen-liquid oxygen rocket engines. This will allow a horizontal-takeoff launch vehicle to leave the ground without any oxidizer, reducing its takeoff weight. The company has proposed ACES in conjunction with its own two-stage to-orbit (TSTO) RLV design as well as for use in other horizontal-takeoff launch vehicles. Andrews Space & Technology carried out initial studies of the ACES concept, in cooperation with Pratt & Whitney, using internal funds and a NASA SBIR contract. A detailed feasibility and risk analysis study has been carried out under a NASA SLI contract. Andrews now supports the NASA NGLT technology and architecture evaluation efforts, which includes Alchemist configuration studies.[74]

## RLV Technologies - The Boeing Company

### X-37

Boeing is currently developing the X-37 reusable aerospace vehicle under a cooperative agreement with NASA signed in July 1999. Based on the design of a proposed Air Force Space Maneuver Vehicle, the X-37 will serve as a test bed for multiple airframe, propulsion, and operations technologies intended to reduce the cost of space transportation operations. X-37 flights will permit the testing of a wide variety of experiments and technologies, including thermal protection systems, high-temperature structures, and advanced guidance, navigation, and control systems. In addition, the X-37 has a 2.1-by-1.2-meter (7-by-4-foot) experiment bay, which will allow the testing of additional technologies in the future. In November 2002, NASA awarded Boeing Phantom Works of Seal Beach, California, a $301-million contract to complete work on the X-37. As part of the X-37 program, two vehicles will be produced. The first is the Approach and Landing Test Vehicle (ALTV), which will validate system performance of the approach, landing, and turnaround operations needed for flight. This vehicle will be released from a B-52 at altitudes up to 42,000 ft.[75] A series of drop tests of the ALTV are scheduled to begin in late 2004. The second vehicle, the Orbital Vehicle (OV), is planned to test key embedded technologies and flight experiments in relevant environments of ascent, on-orbit, reentry and landing phases of flight. NASA temporarily halted work on the OV in late 2003 due to funding constraints.

X-37

### X-40A

The X-40A is a concurrent test program designed to explore the low-speed atmospheric flight dynamics of the X-37 design. Originally developed as a prototype of the Air Force's

X-40A

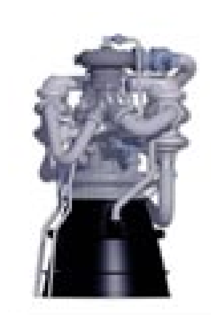
proposed Space Maneuver Vehicle, the X-40A is an 80-percent scale atmospheric precursor to the X-37. It uses the X-37's guidance, navigation, and control software and simulates its aerodynamic performance. It also uses the X-37's flight operations control center. The X-40A completed a program of seven successful flights at NASA's Dryden Flight Research Center in May 2001. During these flights, the uncrewed X-40A was released from a CH-47 Chinook helicopter at 4,570 meters (15,000 feet) and autonomously guided itself to the target runway and landed in a fashion similar to a conventional aircraft.[76]

## *Liquid Engines and Thrusters - NASA Next Generation Launch Technology*

As part of the Next Generation Launch Technology Program and Space Launch Initiative, NASA has supported development of several new engine designs that will reduce the cost and increase the reliability, efficiency and safety of launch vehicles. One area of research includes studies of engines that use liquid oxygen and kerosene propellants that can generate approximately 4.5 million newtons (1 million pounds) of thrust. A second area of research has focused on liquid oxygen and liquid hydrogen engines than can generate at least 2.67 million newtons (600,000 pounds) of thrust. Both engine designs will be reusable and designed for the first and second stages, respectively, of an RLV. In addition, SLI has funded development of reaction control thruster systems that use liquid oxygen and liquid hydrogen propellants; these thrusters will be used to maneuver spacecraft in orbit.

### *Booster Engine Prototype*

Under the Booster Engine Prototype (BEP) Project, the TR107 engine technologies activity is developing innovative components that could be integrated into a new liquid-oxygen/kerosene-propelled engine system. Led by Northrop Grumman Space Technology Group, formerly TRW Inc., of Redondo Beach, CA, the TR107 is one of several technology developments competing for BEP. TR107 development was initiated in 2001 via a $15.5 million contract awarded to TRW. In April 2003, under the second cycle of the research project, NASA awarded an additional $21 million to Northrop Grumman to refocus the TR107 project. Concentrating on key booster engine technologies, the NASA/Northrop Grumman team is developing two critical engine components: a single-pintle injector for the engine's oxygen-rich preburner, and a duct-cooled combustion chamber intended to eliminate conventional engine cooling channels. In 2004, NASA will select a single booster engine system, which could make use of the component technologies delivered by the TR107. The design of the final flight engine is expected to begin in 2007.[77]



Boeing-Rocketdyne RS-84 Courtesy of NASA

Boeing-Rocketdyne is also competing for BEP with its RS-84 engine, which met testing milestones in 2004 (above).

### *Integrated Powerhead Demonstrator*

The Integrated Powerhead Demonstrator (IPD) is a joint venture between NASA's Next Generation Launch Technology program, and the Integrated High Payoff Rocket Propulsion Technologies program, managed for the Department of Defense by the U.S. Air Force Research Laboratory at Edwards Air Force Base, California. The 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 250,000-pound thrust class. The IPD will employ dual preburners that provide both oxygen-rich and hydrogen-rich staged combustion, which is expected to keep engines cooler during flight, achieve higher system efficiency and reduce exhaust emissions. Boeing's Rocketdyne Propulsion and Power is developing the liquid-hydrogen fuel turbopump and the demonstrator's oxygen pump, main injector and main combustion chamber. Aerojet Corporation of Sacramento, CA, 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 is complete.[78] In 2003, tests of the liquid-hydrogen turbopump and the oxidizer preburner were successfully completed. Integrated system testing is scheduled for late 2004 at NASA's Stennis Space Center.[79]

Integrated Powerhead Demonstrator engine rendering
Courtesy of NASA

# Spaceports

Launch and reentry sites – often referred to as "spaceports" – are the nation's gateways to and from space. Although their 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 prior to 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 four non-federal launch sites. These spaceports have served both commercial and government payload owners. This section describes both the federal and non-federal spaceports capable of supporting launch and landing activities that currently exist in the United States. A sub-section detailing state and private proposals for future spaceports with launch and landing capabilities is also included. Table 4 shows which states have non-federal, federal, and proposed spaceports. Tables 5, 6, and 7, located at the end of this section, summarize each spaceport's major characteristics.

**TABLE 4: Spaceport Summary By State**

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

## *National Coalition of Spaceport States*[80]

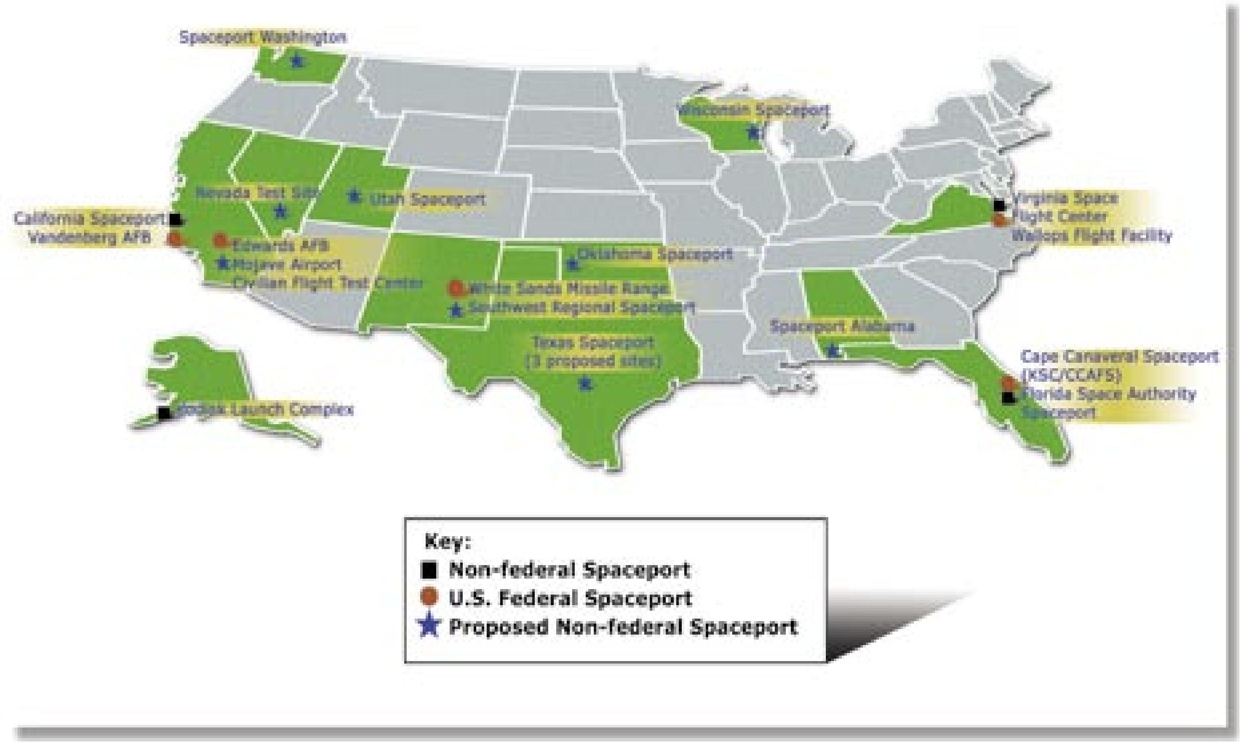
Throughout 2003 the National Coalition of Spaceport States (NCSS) continued the aggressive pursuit of its Vision Statement: "The National Coalition of Spaceport States envisions a future where space serves as an extension of the nation's industrial and economic base; and space transportation becomes and integral part of the nation's space transportation system."

The year 2003 has seen a number of critical developments in the commercial space sector and NCSS member states have been involved in nearly every one of them. As an organization, NCSS has been actively encouraging the commercialization of space and highlighting the critical role that non-federal launch facilities play in facilitating this process. Also, NCSS has maintained constant support for the still nascent, but promising, suborbital space sector. The development of small, private, reusable suborbital spacecraft marks the beginning of what could be a major change for the entire industry. Additionally, many of these vehicles currently under development would be well suited for operations from some NCSS members that have yet to commence actual flight activity such as the Oklahoma Spaceport.

Recognizing the continuing critical nature of federal launch sites, NCSS has continued its involvement in a number of projects that have the potential to reshape how space access operations are conducted. NCSS continues to be a regular contributor to both the Advanced Range Technology Working Group (ARTWG) and the Advanced Spaceport Technology Working Group (ASTWG), two NASA and Air Force-led initiatives aimed at creating roadmaps for the development of the nation's space transportation infrastructure in the years to come. Additionally, NCSS member states have continued working with Congress to ensure that the interests of non-federal space launch facilities are represented at the national level. As a representative of the interests of the various operational and emerging space access facilities throughout the country, NCSS will continue to be actively involved in all of the issues that have the potential to affect its membership.

## *Federal Spaceports*

Since the first licensed commercial orbital launch in 1989, the federal ranges have continually supported commercial launch activity. The importance of commercial launch 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 Evolved Expendable Launch Vehicles (EELV). Cape Canaveral Spaceport (consisting of Cape Canaveral Air Force Station [CCAFS] and the National Aeronautics and Space Administration's [NASA] Kennedy Space Center [KSC])[81] hosts pads for Delta 4 and Atlas 5. Vandenberg Air Force Base currently accommodates the Delta 4 and a pad is under construction to accommodate the Atlas 5.




U.S. Spaceport Locations

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 Air Force, the Department of Commerce, and the 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 Air Force, and considering them in the existing Air Force requirements process.

## ***Cape Canaveral Spaceport***

Cape Canaveral Spaceport (CCAFS and KSC) is located on the "Florida Space Coast" at Cape Canaveral and also encompasses the launch complex owned by the Florida Space Authority (FSA) (see the FSA description below). The Cape Canaveral area has endured several name changes and an expanding list of tenants. In 1948, the Banana River Naval Air Station was transferred to the Air Force for use as a joint service missile range. NASA's Launch Operations Center was renamed for President Kennedy in 1963. Air Force Space Command redesignated Cape Canaveral Air Station as CCAFS in February 2000. The Cape developed rapidly during the space race of the 1950s and 1960s supporting Mercury, Gemini, and Apollo programs, as well as ballistic missile testing.

Cape Canaveral Spaceport

Today, CCAFS encompasses six active launch pads for Delta, Atlas, Titan and Athena launch vehicles, while the Space Shuttle operates from two pads at KSC. NASA oversees launch operations for the Space Shuttle and checkout of its payloads, while 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's 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 Atlantic Ocean as far north as Canada and as far southeast as Africa. There is currently one active launch complex (LC), LC-40, for remaining Titan 4 vehicles launching from the East Coast. In 1999, Lockheed Martin began to work on new facilities for Atlas 5 at LC-41. FSA has entered into an arrangement for ownership of LC-41 and support integration facilities and is leasing them to Lockheed Martin. Refurbishment and construction of the launch pad, gantry, and support facilities was completed in 2001. The first Atlas 5 launch from LC-41 occurred on August 21, 2002.

Boeing has a similar agreement with FSA for lease of the Delta 4 Horizontal Integration Facility. LC-37 has been inactive since the 1960s when it served as the site for eight Saturn 1 and Saturn 1B launches. The launch tower and launch pad at LC-37 were completed in 2001. The first Delta 4 launch occurred on November 20, 2002.

KSC maintains its own launch complex, LC-39. LC-39's pads A and B were originally built to support the Apollo program. After the end of the lunar landing program in 1972, they served to launch Skylab, Apollo-Soyuz, and now the Space Shuttle. LC-39 launch and processing facilities are all located on Merritt Island, between the Florida mainland and Cape Canaveral. LC-39 support facilities include the Vehicle Assembly Building, the Launch Control Center, the Mobile Launcher Platform, the Crawler Transporter, the Orbiter Processing Facilities, the Payload Processing Facility, and the Shuttle Landing Facility. KSC also provides five hangars for non-hazardous payload processing, the Shuttle Payload Integration Facility, the Satellite Assembly Building, and an explosive safe area.

In 2001, KSC began construction of a new office building near the Vertical Assembly Building. The building was completed in 2003. Also in 2001, KSC broke ground for the new Space Life Sciences Laboratory that will replace CCAFS's Hangar L for International Space Station (ISS) experiment processing and constructed a road leading into a 1.6-square-kilometer (400-acre) area that will be developed as an international space research park. The state of Florida provided $26 million for the development of the Space Life Sciences Laboratory and another $4 million for road construction in the facility's vicinity.[82]

## Edwards Air Force Base


Edwards Air Force Base

Located in California, Edwards Air Force Base (AFB) 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 Edwards AFB as a back-up site.

Before its cancellation, X-33 was to use Edwards AFB as a test site. In December 1998, NASA completed construction of a launch site at Edwards AFB. The site consisted of an X-33-specific 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. A water tower with a height of 76 meters (250 feet) could supply nearly 1 million liters (265,000 gallons) of water to the concrete flame trench during launch. X-33 telemetry and tracking functions would have been performed using existing Air Force and NASA facilities at Edwards AFB and Wallops Flight Facility, Virginia. With X-33's cancellation, the government and associated contractors redistributed the components of the X-33 infrastructure for SLI projects.

The federal government is investing several million dollars to refurbish and modernize two large-scale rocket test stands at the Air Force Research Laboratory'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.

Edwards AFB, 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 and a second test flight of this hypersonic vehicle is scheduled early in 2004. NASA used a helicopter to conduct seven successful X-40A flight tests during 2001. NASA will fund X-37 atmospheric approach and landing testing at Edwards AFB in 2004 and 2005.[83]

## Vandenberg Air Force Base

In 1941, the Army activated this site in Lompoc, California, as Camp Cook. In 1957, Camp Cook was transferred to the Air Force, and in 1958 it was renamed Vandenberg AFB (VAFB) in honor of General Hoyt S. Vandenberg, the Air Force's second Chief of Staff.

Vandenberg Air Force Base

VAFB is currently the headquarters of the 30th Space Wing, which conducts space and missile launches and operates the Western Range. Range tracking capabilities extend into the Pacific Ocean as far west as the island of Kwajalein, with boundaries to the north as far as Alaska and to the south near 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 (see the California Spaceport description below).

VAFB partnered with Boeing to develop launch infrastructure for the Delta 4 EELV. Space Launch Complex (SLC)-6 has been converted from a Space Shuttle launch pad into an operational facility for the Delta 4. The SLC-6 refurbishment has been completed. The new launch table, which arrived at VAFB in October 2001, weighs 650,000 kilograms (1.4 million pounds) and stands 7 meters (23 feet) high, 14 meters (46 feet) wide, and 26 meters (85 feet) long. Other construction at SLC-6 included enlarging the existing mobile service tower and completing the construction of the West Coast Horizontal Integration Facility, where the Delta 4 is assembled.

In preparation for five Atlas 5 EELV launches from Vandenberg, Lockheed Martin will upgrade the Space Launch Complex (SLC)-3 East launch pad in time for the first launch in late 2005. Lockheed Martin anticipates spending $200 million to upgrade the pad, which was previously used to launch the Atlas 2AS. The upgrades starting in January 2004 will include adding 30 feet to the mobile service tower to accommodate the larger rocket, and replacing the crane capable of lifting 20 tons with a crane that can lift 60 tons. The concrete exhaust tunnel will be enlarged and crews will install a stationary launch platform and retrofit the existing umbilical tower to fit the Atlas 5.[84]

VAFB is also upgrading its range instrumentation and control centers to support the space launch industry. These upgrades are scheduled to be completed by 2010. In addition, the state of California is looking into developing an alternate range operations control center to demonstrate Unmanned Aerial Vehicle wideband communication downlink technology.

In 2001, VAFB opened a customer support office to provide a centralized interface for customers of launch and base services.

Current launch vehicles using VAFB include Atlas 2, 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 and then flown to various worldwide launch areas. A new commercial launch vehicle, Falcon, being developed by Space Exploration Technologies Corporation, plans to launch from VAFB in March 2004.

The final Titan 2 launch from Vandenberg took place in October 2003. Under a $3 million Air Force contract, Lockheed Martin will "safe" and deactivate Space Launch Complex-4 West, which served as the launch pad for Titan 2 since 1988. Space Launch Complex-4 East, which hosts the Titan 4, will see its final launch in February 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 2007.[85]

At this time, VAFB has active partnerships with nine private organizations in which VAFB provides launch property and launch services and the private companies use the government facilities to do their own 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 Astrotech's Payload Processing 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 NASA's Goddard Space Flight Center.[86] 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, including six Pegasus launches, the most recent in 1999. The retired Scout made its last orbital launch from Wallops in 1985.

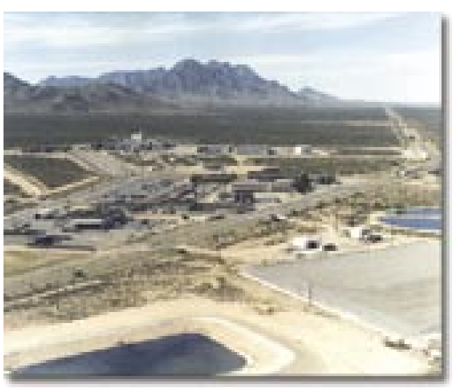

Wallops Flight Facility

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), so possible future vehicle users include the Minotaur and other vehicles developed under that program.

Although Wallops has not attempted any orbital flights (beyond support of the air-launched Pegasus) since the Conestoga failure in 1995, NASA is committed to maintaining the existing infrastructure that will be used by both orbital and suborbital missions for government and commercial users. Three blockhouses and numerous payload and vehicle preparation facilities are operational. Wallops launches about 10 to 20 suborbital vehicles per year. The facility also supports northerly launches from KSC and CCAFS as well as worldwide orbital and suborbital launches with transportable range instrumentation and safety equipment. Wallops equipment was used to support the first orbital launch from Kodiak, Alaska. The Virginia Space Flight Center (VSFC) is co-located with Wallops. Wallops also contains several research facilities, a research airport, machine shops, and a center that consolidates the control of launch range and research airport operations. Wallops assets also support aeronautical testing and U.S. Navy testing.

In March 2002, $6.8 million in launch range modernization projects were initiated, including upgrades in range clearance radars, vehicle-tracking systems, launch data acquisition and management systems, and range control center interfaces. Along with the launch range modernization projects, $3.2 million in support facilities improvement projects were started, including a new, 1,115-square-meter (12,000-square-foot) payload processing and integration facility; a high-security area in the range control center; upgrades to the existing hazardous vehicle processing facility; and a cryogenic fueling capability for small- to mid-sized vehicles. All of these projects were completed in 2003.

## *White Sands Missile Range*



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 Missile Defense Agency 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.[87]

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

## 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. In order 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 four non-federal launch sites, all of which are described in this subsection. Three of these are co-located with federal launch sites, including the California Spaceport at VAFB, the spaceport facilities operated by Florida Space Authority (FSA) at Cape Canaveral, and Virginia Space Flight Center (VSFC) at Wallops Flight Facility. The fourth licensed, non-federal spaceport is Kodiak Launch Complex in 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 lifted off from FSA's LC-46.

### *California Spaceport*


California Spaceport

On September 19, 1996, the California Spaceport became the first launch site licensed by FAA/AST. In June 2001, FAA/AST renewed the spaceport's license for another five years. The California Spaceport offers commercial launch services and is operated and managed by Spaceport Systems International (SSI), a limited partnership between ITT Federal Service Corporation and California Commercial Spaceport, Inc. Co-located with VAFB on the central California coast, SSI signed a 25-year lease in 1995 for 0.44 square kilometers (0.17 square miles) of land. Located at 34° North latitude, the California Spaceport can support a variety of mission profiles to low polar orbit inclinations, with possible launch azimuths ranging from 220° to 150°.

Initial construction at California Spaceport's 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 is routed underground to provide a "flat pad" with the flexibility to accommodate a variety of different launch systems. Although the facility currently is configured to support solid propellant vehicles, plans are in place to equip it with commodities required by liquid fueled boosters. The current configuration consists of the following infrastructure: pad deck, support equipment building, launch equipment vault, launch duct and stand, communications equipment, and launch control room. Final configuration awaits customer requirements. When fully developed, the Commercial Launch Facility will be able to accommodate a wide variety of launch vehicles including the Minuteman-based Minotaur and Castor 120-based vehicles.

Originally, the focus of the California Spaceport's payload processing services was on the refurbishment of the Payload Preparation Room. This room, located near SLC-6, is a clean room facility designed to process three Space Shuttle payloads simultaneously. It is now leased and operated by the California Spaceport as the Integrated Processing Facility. Today, payload-processing activities occur on a regular basis. The facility supports booster processing and administrative activities. It is capable of handling all customer payload-processing needs. This includes Delta 2- and Delta 4-class payloads as well as smaller payloads as required. The spaceport receives limited financial support from the state in the form of grants. In 2000, it received about $180,000 to upgrade the breech load doors in the Integrated Processing Facility transfer tower. The modification was completed in March 2001, and the new transfer tower is now capable of accommodating 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. There are plans to upgrade the launch site infrastructure for liquid vehicles and to build a new launch control center in the future, as well as a mobile access tower.

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.

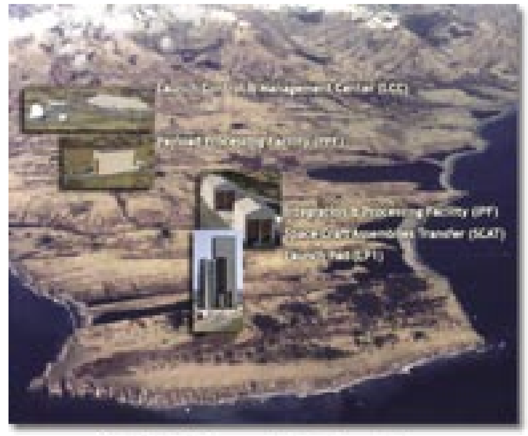
The California Spaceport provides payload processing and orbital launch support services for both commercial and government users. The California Spaceport provided payload-processing services for three NASA satellites: Landsat 7, 1995; TIMED/Jason, December 2001; and Aqua, May 2002. The California Spaceport's first orbital launch was that of JAWSAT, a joint project of the Air Force Academy and Weber State University, on a Minotaur launch vehicle in July 2000. To date, the site has launched two Minotaur launch vehicles. In 2002, SSI won a ten-year Air Force satellite-processing contract for Delta 4-class four- and five-meter payloads. This contract complements an existing 10-year NASA payload-processing contract for Delta 2-class three-meter 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-class payload processing support for multiple missions to be launched from VAFB. NASA and commercial Delta-class payloads are also processed for launch on the Delta 2, launched from SLC-2W on VAFB. In 2003, California Spaceport continued improvements to the IPF and supported Air Force Pathfinders including the EELV 5 M Pathfinder.[88]

## *Kodiak Launch Complex*

In 2000, the Alaska Aerospace Development Corporation (AADC) completed the $40-million, two-year construction of the Kodiak Launch Complex at Narrow Cape on Kodiak

Island, Alaska. This launch complex is the first new U.S. launch site since the 1960s and is the only non-federal spaceport not co-located with a federal launch site. In 1991, the Alaska state legislature created the AADC as a public company to develop aerospace related economic, technical, and educational opportunities for the state of Alaska. Owned by the state of Alaska and operated by the AADC, the Kodiak Launch Complex has received funding from the Air Force, Army, NASA, the State of Alaska, and private firms. The commercial spaceport on Kodiak Island 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) arch around Launch Pad 1.



Kodiak Launch Complex

Kodiak facilities currently include the Launch Control Center; the Payload Processing Facility, which includes a class-100,000 cleanroom, an airlock, and a processing bay; the Integration and Processing Facility/Spacecraft Assemblies Transfer Facility; and the Launch Pad and Service Structure. These facilities are designed such that they allow the transfer of vehicles and payloads from processing to launch without exposure to the outside environment. This protects both the vehicles and those working on them from exterior conditions, allowing 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 dishes with 8 telemetry links with command destruct. The KLC RSTS #1 system will be located on a newly constructed multi-elevation antenna field that also supports customer unique instrumentation.[89]

The AADC is also supporting the 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. NASA's Wallops Flight Facility currently provides mobile tracking equipment.

Located at 57° North latitude, Kodiak provides a wide launch azimuth and unobstructed downrange flight path. Kodiak's markets are military launches and government and commercial telecommunications, remote sensing, and space science payloads weighing up to 990 kilograms (2,200 pounds). These can be delivered into low Earth orbit (LEO), polar, and Molniya 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 a total of six launches to date. The first launch from Kodiak was that of a suborbital vehicle, Ait-1, built by Orbital Sciences for the Air Force in November 1998. A second Ait launch followed in September 1999. A joint NASA-Lockheed Martin Astronautics mission on an Athena 1 became the first orbital launch from Kodiak on September 29, 2001. In April 2002, Orbital Sciences launched a suborbital rocket, the Quick Reaction Launch Vehicle (QRLV-2), for the U.S. Air Force. The mission of the launch was missile defense flight testing.

The Missile Defense Agency has awarded a five-year contract to AADC launch services and support for target launches in support of the MDA flight test program.

## *Spaceport Operated by Florida Space Authority*

Established by the state of Florida as the Spaceport Florida Authority in 1989, the Florida Space Authority (FSA), renamed as such in 2001, is empowered like an airport authority to serve the launch industry and is responsible for statewide space-related economic and academic development. FSA owns and operates space transportation-related facilities on about 0.29 square kilometers (0.11 square miles) of land at CCAFS owned by the Air Force. FAA/AST first issued the state organization a license for spaceport operations on May 22, 1997, and renewed the license in 2002 for another five years.

Launch Complex-46
at the Cape Canaveral Spaceport

Under an arrangement between the federal government and FSA, underutilized facilities at CCAFS have been conveyed to FSA for improvement and use by commercial entities on a dual-use, non-interference basis with Air Force programs. FSA's efforts have concentrated on CCAFS's LC-46, an old Trident missile launch site. LC-46 has been modified to accommodate small commercial launch vehicles as well as the Navy's Trident. The philosophy guiding the development of LC-46 was to build a public transportation infrastructure for several competing launch systems rather than to tailor a facility for a single launch system. As a result, LC-46 can currently 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. Its 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 NASA's 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. It 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. It has also financed $292 million for Atlas 5 launch facilities at CCAFS Launch Complex-41, financed and constructed the $24 million Delta 4 Horizontal Integration Facility for Boeing at Launch Complex-37, and provided financing for a Titan 4 storage and processing facility. SpaceX plans to use FSA's Launch Complex-46 for operations on the east coast.

As part of an overall effort to expand the utilization of the Cape for research and development and educational activities, FSA obtained a five-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 current status of all intermodal transportation-related functions and assets on and near the Cape Canaveral Spaceport. Based on the Master Plan, FSA is now developing a Five-Year Work Program in cooperation with NASA/KSC and the U.S. Air Force 45th Space Wing to identify transportation-related improvements needed at the spaceport and its intermodal connections to the surrounding community. The plan will be submitted in 2004 to the Brevard Metropolitan Planning Organization for inclusion in the county's Transportation Improvement Program.

In collaboration with NASA and the state, FSA is helping develop the International Space Research Park on about 400 acres at NASA/KSC. Contracts for development of the research park are anticipated in 2004, with implementation planned for 2005. The recently completed Space Life Sciences Laboratory, which FSA helped finance, serves as a magnet facility for the commerce park.

The state of Florida is competing for the X PRIZE Cup, an exhibition intended to spark the suborbital space tourism market by bringing together space vehicle developers every year for two weeks at a selected spaceport to race and set new records. A site selection for the event is expected in 2004.[90]

### ***Virginia Space Flight Center***

The Virginia Space Flight Center (VSFC) 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 NASA's Wallops Flight Facility on Wallops Island, Virginia, 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.

Virginia Space Flight Center

On December 19, 1997, FAA/AST issued VCSFA a launch site operator's license for the VSFC. This license was renewed in December 2002 for another five years. The VSFC is designed to provide "one-stop shopping" for space launch facilities and services for commercial, government and 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. Both NASA and VSFC 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 VSFC for the VCSFA. The state maintains ownership of the spaceport's assets. VSFC is located at NASA Wallops Flight Facility under a long-term use agreement for real estate on which the 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-sized expendable launch vehicles (ELV) 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, VSFC 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. An Air Force Orbital Space Plane (OSP) Minotaur mission is currently scheduled for this site.

In March 2000, VSFC acquired a second pad at Wallops, 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 in orbit. VSFC 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, VSFC can accommodate a wide range of orbital inclinations and launch azimuths. Optimal orbital inclinations accessible from the site are between 38 and 60 degrees; other inclinations, including sun synchronous orbits (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. VSFC also has an interest in supporting future RLVs, possibly using its launch pads or three runways at Wallops Flight Facility.

VSFC 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. VSFC is in the process of constructing a $4-million logistics and processing facility at NASA Wallops, capable of handling payloads of up to 5,700 kilograms (12,600 pounds). The facility, which includes high bay and clean room environments now in construction, is scheduled for completion in early 2004. In conjunction with NASA Wallops, VSFC 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 currently in final integration and test phase.[91]

## *Proposed Non-federal Spaceports*

Several states are planning to develop spaceports offering a range 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 present-day U.S. spaceports – as well as interest in hosting RLV operations. Descriptions of specific efforts to establish spaceports, which are in various stages of development, are presented below.

### *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 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 development plan will determine what infrastructure is necessary.[92] The Amateur Spaceflight Association launched a 12-foot long amateur rocket from this site on May 3, 2003. The website for the spaceport is www.gulfcoastspaceport.org.

### *Mojave Airport Civilian Flight Test Center*

The East Kern County, California, government established the Mojave Airport in 1935 in Mojave, California. The original facility was equipped with taxiways and basic support


Mojave Airport Civilian Flight Test Center

infrastructure for general aviation. A short time after its inception, the Mojave Airport became a marine auxiliary air station. Mojave is currently the largest general aviation airport in Kern County. The airport is owned and operated by the East Kern Airport District (EKAD), which is a special district with an elected Board of Directors and a General Manager. The airport serves as a Civilian Flight Test Center, the location of the National Test Pilot School (NTPS), and as a base for modifications of major military jets and civilian aircraft. The NTPS operates various aircraft types including high performance jet aircraft, single-and twin-engine propeller aircraft and helicopters. Numerous large air carrier jet aircraft are currently being stored and maintained at the Mojave Airport.

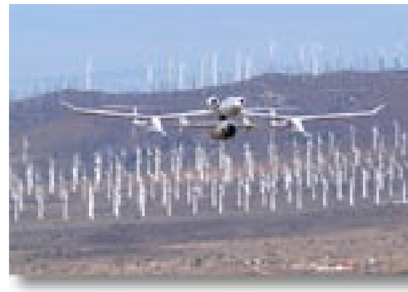
The Mojave Airport consists of three runways with associated taxiways and other support facilities, Runway 12-30, Runway 8-26, and Runway 4-22. Runway 12-30 is 2,896 meters (9,502 feet) long and is the primary runway for large air carrier jet and high performance civilian and military jet aircraft. Runway 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, Interorbital Systems, and General Electric. The Civilian Flight Test Center consists of several test stands, an air control tower, a rocket test stand, engineering facilities, and a high bay building.

In the last two years, XCOR Aerospace has been performing flight tests at this facility and recently had 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) of thrust were tested at the site in 2002 and 2003.

On the 100th anniversary of the Wright Brother's first powered flight, December 17, 2003, Scaled Composites flew its SpaceShipOne from Mojave, breaking the speed of sound in the first manned supersonic flight by an aircraft developed by a small company's private, non-governmental effort.

Mojave's application for a launch site license is currently under review by FAA/AST. A public meeting was held in December 2003 regarding the airport's environmental assessment, as required by the National Environmental Policy Act and the California Environmental Quality Act.



Scaled Composites flight testing at Mojave Airport

## *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.[93] Kistler Aerospace Corporation selected it as a spaceport for the K-1 RLV in addition to its Woomera, Australia, facility in order to increase scheduling flexibility and to widen the range of launch azimuths available to customers.[94] Kistler filed for reorganization under Chapter 11 of the bankruptcy laws in July 2003. 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*

The state of Oklahoma is interested in developing a broader space industrial base and a spaceport. In 1999 the Oklahoma state legislature created the Oklahoma Space Industry Development Authority (OSIDA). Consisting of five full-time employees and directed by seven governor-appointed board members, OSIDA promotes the development of spaceport facilities, space exploration, space education, and space-related industries in Oklahoma. Currently, the state of Oklahoma provides operating costs for OSIDA, but the organization expects to be financially independent in five years.

Burns Flat, Proposed Oklahoma Spaceport

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 awarded a contract to SRS Technologies to conduct an environmental impact study. The study, expected to continue through September of 2004, is a critical step toward receiving a launch site operator license from FAA/AST. In the fall of 2003, OSIDA took another step toward receiving its license by awarding a contract to The Aerospace Corporation to conduct a safety study of the proposed site and operations.

Clinton-Sherman Industrial Airpark, located at Burns Flat, is the preferred site for a future spaceport in Oklahoma. Existing infrastructure includes a 4,100-meter (13,500-foot) runway, a large maintenance and repair hangar, utilities, a rail spur, and 12.4 square kilometers (4.8 square miles) of open land. The city of Clinton conveyed ownership of the spaceport site to OSIDA in 2003, and has requested that the FAA's Southwest Region approve the transfer. The launch activities proposed will not greatly impact the continued use of the CSIA as an active airport for general aviation and for USAF training.

The Oklahoma Spaceport will provide launch and support services for RLVs and may become operational in late 2006 or early 2007, becoming one of the first inland launch sites in the United States. The state of Oklahoma offers several incentives, valued at over $128 million over 10 years, to attract space companies to the state. 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. Also, the state will provide a $15-million tax credit to the first corporation that meets specific qualifying criteria, including equity capitalization of $10 million and the creation of at least 100 Oklahoma jobs. Some organizations also may qualify for other state tax credits, tax refunds, tax exemptions and training incentives. 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 the 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. Due to its extreme southern location, the site would become the U.S. site capable of supporting the largest payload launches to geosynchronous Earth orbit (GEO).

In 2003, a 150-pound sounding rocket and an 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.[95] [96]

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.[97]

## Southwest Regional Spaceport

The State of New Mexico continues to make progress in the development of the Southwest Regional Spaceport (SRS). 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 m (4,700 ft) 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 be able to accommodate both vertical and horizontal launches and landings, and will include two launch complexes, a runway, an aviation complex, a payload assembly complex, other support facilities, and 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 in funds for fiscal years 2002 through 2004 for spaceport development, including environmental studies and land acquisition; this funding, however, is contingent on the state receiving a written commitment from a private company or government organization to host an RLV program.

The state has 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. The agreement enables the spaceport to share resources and integrate launch scheduling and operations with the Army test range. In 2003, New Mexico updated environmental studies for the SRS, and performed a comprehensive analysis of the advantages of launching from high altitude for vertical launch vehicles.[98]

In December 2003, New Mexico submitted its proposal to host the X Prize Cup competition.[99]

## Spaceport Alabama

Proposed as a next-generation spaceport, Spaceport Alabama will be a full-service departure and return facility supporting both orbital and suborbital space access vehicles. Spaceport Alabama is currently in the planning phase under direction of the Aerospace Development Center of Alabama. Upon completion of the Spaceport Alabama plan, a proposal will be presented to the Alabama Commission on Aerospace Science and Industry and the Alabama Legislature for formal adoption. Under the current plan, the Alabama Legislature would establish the Spaceport Alabama Authority, which would oversee the 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 both government and commercial customers operating next-generation reusable flight vehicles that are designed for access to LEO, medium Earth orbit (MEO), and GEO.

Under the current spaceport development plan, a spaceport facility could become operational within 10 years depending on market demand. The current plan calls for the establishment of a "total spaceport enterprise" concept, consisting of a departure and return facility, processing and support facilities, full support infrastructure, a research and development 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, research and development, national security, science and related services. Given that the site currently under consideration is adjacent to the Gulf of Mexico, Spaceport Alabama would service primarily RLVs, although some suborbital ELVs in support of scientific and academic missions could be supported.[100]

## *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 takeoffs and horizontal landings of all classes of RLVs. The 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. Spaceport Washington has received $350,000 and staff support from the state of Washington.[101]

## *Utah Spaceport*

In 2001, the state of Utah passed the Utah Spaceport Authority Act, creating a Utah Spaceport Authority with the power to develop and regulate spaceport facilities in the state. The Act also created a seven-member advisory board appointed by the governor to advise the Authority on spaceport issues. Since the Act was signed into law, the advisory board has been created but no other actions have been taken. The Wah Wah Valley Interlocal Cooperation Entity proposed to construct and operate a commercial launch site utilizing approximately 280 square kilometers (108 square miles) of Utah state trust lands located 50 kilometers (31 miles) southwest of Milford, Utah. The proposed spaceport's mission is to provide a cost-effective launch and recovery facility for RLVs.

There is no existing or planned infrastructure at this time. The state of Utah appropriated $300,000 to conduct a spaceport feasibility study and appointed a Spaceport Advisory Board to research the economic development opportunities of the X-33 and other RLVs. The study was put on hold after the cancellation of the X-33 and VentureStar programs. The state did not provide funding for the Spaceport Authority in 2002 and 2003, and no funding was approved for 2004.[102]

## 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.

In February 2002, the Texas Aerospace Commission awarded a $500,000 contract to the West Texas Spaceport. In June 2002, the Air Force approved the site for various test-launch projects. JP Aerospace began launching small suborbital rockets from the site in October 2002.[103]

## Wisconsin Spaceport

On August 29, 2000, the Wisconsin Department of Transportation officially approved the 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 currently 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 from which launches take place was widened and strengthened during 2002. Additionally, some existing structures were removed from the property 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. Draft legislation for the creation of a spaceport authority is under review by the Wisconsin Senate and is anticipated to be passed in 2004.[104]

**TABLE 5: Federal Spaceports: Infrastructure and Status**

| Spaceport | Location | Owner/ Operator | Launch Infrastructure | Current Development Status |
|---|---|---|---|---|
| Cape Canaveral Spaceport (CCAFS/KSC) | Cape Canaveral, Florida | U.S. Air Force, NASA, Florida Space Authority | 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 | California, near Mojave | U.S. Air Force | 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. |
| Vandenberg AFB | Lompoc, California | U.S. Air Force | Launch pads, vehicle assembly and processing buildings, payload processing facilities, telemetry and tracking facilities, control center engineering 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. |

**Table 6: Licensed Non-federal Spaceports: Infrastructure and Status**

| Spaceport | Location | Owner/ Operator | Launch Infrastructure | Current Development Status |
|---|---|---|---|---|
| California Spaceport | Lompoc, California | Spaceport Systems International | Existing launch pads, runways, payload processing facilities, telemetry and tracking equipment. | The Integrated Processing Facility has an upgraded power system, digital control systems, secure communication, HVAC systems, fuel and oxidized pads and fairing encapsulation in Cell 1. A new 30-ton crane has been added to the Transfer Tower as well as a new interior blast door. The IPF is now fully configured to support Delta 2- and Delta 4-class payloads. Concrete flame ducts communication, electrical and water infrastructure are in place. |
| 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. |
| Virginia Space Flight Center | 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. VSFC is adding a new mobile Liquid Fueling Facility capable of supporting a wide range of liquid-fueled and hybrid rockets. |

**Table 7: Proposed Non-federal Spaceports: Infrastructure and Status**

| Spaceport | Location | Owner/ Operator | Launch Infrastructure at Site | Current Development Status |
|---|---|---|---|---|
| Gulf Coast Regional Spaceport | Brazoria County, Texas | To be determined | No infrastructure at this time. | The final Texas Spaceport site(s) has not been selected yet. Three sites are being considered at this time. Grant money was provided to conduct a safety analysis and the site has supported an amateur launch. |
| Mojave Airport Civilian Flight Test Center | Mojave, California | East Kern Airport | Air control tower, runway, rotor test stand, engineering facilities, high bay building. | FAA/AST is currently reviewing site s application for a launch site license. Site has supported testing by XCOR Aerospace and Scaled Composites. |
| 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 by NTS. Nevada Test Site Development Corporation is actively promoting the site as a spaceport for both RLVs and conventional launchers. |
| Oklahoma Spacport | 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(s) has not been selected yet. 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 of 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. 4,100-meter (13,452-foot) main runway and a 3,200-meter (10,500-foot) crosswind runway. | Open field space with basic power, water, and utilities. Development plan calls for departure and return facility, processing and support facilities, full support infrastructure, a research and development park, a commerce park, supporting community infrastructure, intermodal connectivity, and other services and infrastructure. |
| Spaceport Washington | Grant County International Airport, Washington | Port of Moses Lake | | The site is certified as an emergency-landing site for the Space Shuttle. No additional infrastructure has been planned for this site. |

**Table 7: Proposed Non-federal Spaceports: Infrastructure and Status (Cont'd)**

| Spaceport | Location | Owner/ Operator | Launch Infrastructure at Site | Current Development Status |
|---|---|---|---|---|
| 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 facility 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 final Texas Spaceport site(s) has not been selected yet. Three sites are being considered at this time. Site has supported suborbital launches. Plans for development 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. |

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