2002 U.S. Commercial Space Transportation Developments and Concepts: Vehicles, Technologies, and Spaceports

January 2002
Associate Administrator for Commercial Space Transportation
Federal Aviation Administration

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List of Acronyms

AADC - Alaska Aerospace Development Corporation

AFB - Air Force Base

AST - Associate Administrator for Commercial Space Transportation

ASTP - Advanced Space Transportation Program

CBC - Common Booster Core

CCAFS - Cape Canaveral Air Force Station

CCB - Common Core Booster™

CCSI - Center for Commercial Space Infrastructure

CLF - Commercial Launch Facility

CRV - Crew Return Vehicle

DoD - U.S. Department of Defense

EELV - Evolved Expendable Launch Vehicle

ELI - Elliptical Orbit

ELV - Expendable Launch Vehicle

ESA - European Space Agency

EXT - External Orbit

FAA - Federal Aviation Administration

GEO - Geosynchronous Earth Orbit

GTO - Geosynchronous Transfer Orbit

ICBM - Inter-Continental Ballistic Missile

IPF - Integrated Processing Facility

ISS - International Space Station

ISTP - Integrated Space Transportation Plan

KSC - Kennedy Space Center

LC - Launch Complex

LEO - Low-Earth Orbit

LOX - Liquid Oxygen

LP - Launch Pad

MEO - Medium-Earth Orbit

NASA - National Aeronautics and Space Administration

NCSS - National Coalition of Spaceport States

NGSO - Non-Geosynchronous Orbit

OSIDA - Oklahoma Space Industry Development Authority

OV - Orbital Vehicle

RLV - Reusable Launch Vehicle

SBIR - Small Business Innovative Research

SLC - Space Launch Complex

SLI - Space Launch Initiative

SSI - Spaceport Systems International

SSME - Space Shuttle Main Engine

SSO - Sun-Synchronous Orbit

SSTO - Single Stage to Orbit

TSTO - Two Stage to Orbit

VAFB - Vandenberg Air Force Base

VCSFA - Virginia Commercial Space Flight Authority

VSFC - Virginia Space Flight Center

Introduction

The Publication

This report, *2002 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 (FAA)/ Associate Administrator for Commercial Space Transportation (AST) first published the report in 1998 with an exclusive focus on reusable launch vehicles (RLV). The current edition addresses not only RLVs but also expendable launch vehicles (ELV), propulsion technologies, and spaceports to provide a more complete picture of the U.S. commercial space transportation industry.

This report focuses on commercial and commercially oriented activities; it includes industry-led and -funded projects, private-public cooperative projects, as well as government-led and -funded projects that will impact and support the development of commercial activities. 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

The coming year is shaping up to be key for the ELV industry. While virtually all of the U.S.-built ELVs that were available in 2001 will continue to be available in 2002, some of the variants will be phased out in the upcoming years as the Evolved Expendable Launch Vehicle (EELV) boosters enter use. The two EELVs, The Boeing Company's Delta 4 and Lockheed Martin Corporation's Atlas 5, are slated to make their inaugural flights in 2002. These boosters represent the next generation of medium- and heavy-lift launchers for both commercial and government payloads. Although any new launch vehicle initially carries a high degree of risk, the fact that these boosters represent evolutionary improvements over previous Atlas and Delta versions should improve the likelihood for a successful debut.

While the EELV program supports the larger end of the launch market, 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 satellites that currently fly as secondary payloads on larger boosters. These companies are exploring various technologies, including new propellants and pressure-fed engines, which have the potential to reduce the cost of their vehicles. The ability to reduce launch costs and thus stimulate demand will be critical to the success of these ELVs given the current size of the market for small payloads. While none of these new ELVs are expected to launch in 2002, there should be a number of key developments for these efforts during the year as they pursue private investment and construct and test components needed for launches planned for 2003 and beyond.

Reusable Launch Vehicle Industry

RLVs may become attractive alternatives for access to space for several reasons. With the exception of the United States' Space Shuttle, world access to space is made possible only by ELVs. As a new vehicle is needed for each launch, the customer who purchases an ELV launch must pay the cost to build an entire vehicle. In contrast, an RLV has the capacity not only to launch but also to return to Earth for reuse. Because the construction cost of an RLV could be amortized over multiple launches, RLVs may potentially reduce the cost of access to space for government and commercial users. In addition, the return nature of RLVs would facilitate human trips to and from space. Although many national governments and companies have explored the development of RLVs, the Space Shuttle remains the first and only currently operational, partially reusable launch vehicle (the orbiter, main engines, and solid rocket boosters are refurbished and reused, but the external tank is irrecoverable).

Starting in the 1990s, however, both the public and private sectors intensified RLV design and development efforts. On the commercial side, RLV design and development activity increased in response to strong growth in projected launch demand during the 1990s fueled primarily by nongeosynchronous orbit (NGSO) satellite telecommunications constellations. These NGSO constellations required large numbers of satellites for initial deployment as well as many replacements and follow-on satellites. In 1998, FAA/AST projected that 1,063 NGSO satellites would be deployed between 2000 and 2010.[1]

Unfortunately, the operators and proponents of NGSO systems have suffered substantial setbacks. In particular, the pioneering Iridium NGSO mobile telephony system, which deployed 88 spacecraft on 20 launches, failed to attract enough subscribers to service its debt and was compelled to file for bankruptcy protection. The ICO system, which had not yet been deployed, soon followed suit. As a result, future NGSO satellite constellations, as well as the replacements and follow-ons of existing NGSO constellations, face increased market skepticism and appear less likely than once believed to be funded and launched. FAA/AST's 2001 forecast reflected these reduced expectations and estimated only 151 NGSO satellite deployments between 2001 and 2010.[2]

The bankruptcies, along with the associated reduced launch projections, have made it increasingly difficult for commercial RLV companies to obtain capital from private investors to complete their vehicle development. U.S. RLV companies continued to have a difficult time in 2001, as many vehicle development programs were stalled or delayed due to lack of funds.

The government also increased RLV design and development activity in the mid-1990s. For many reasons, the Space Shuttle had proven extremely expensive to operate, and the Shuttle's aging orbiters required expensive upgrades. In accordance with the 1996 National Space Policy's mandate that the National Aeronautics and Space Administration (NASA) lead the development of a next-generation RLV, the space agency embarked on an ambitious series of experimental vehicle, or X-vehicle, programs.

The centerpiece of these programs was NASA's X-33, a sub-orbital vehicle that would demonstrate technology for a reusable, single-stage-to-orbit (SSTO) launch vehicle. Lockheed Martin, the prime contractor for X-33, planned to develop a commercial RLV called VentureStar™ using X-33 technology. Escalating costs and technical setbacks, however, prompted NASA to cancel the X-33 in 2001 along with the X-34, an operations demonstrator and test bed being developed by NASA and Orbital Sciences Corporation to test RLV technologies, including structures, components, and thermal protection systems. A joint NASA-Orbital Sciences review of the X-34 in 2000 concluded that the project's approach, scope, budget, and schedule needed to be redefined.[3]

The space agency is incorporating lessons learned from the X-33 program into its Second Generation Reusable Launch Vehicle Systems Engineering Risk Reduction program. NASA's second generation RLV program received support from Congress and the President when the Space Launch Initiative (SLI) was passed into law in the fall of 2000. SLI is an initiative that commits $4.8 billion over five years for NASA and industry to pursue second-generation RLV technologies. Rather than focusing on a specific vehicle concept, the program is designed to substantially reduce the technical, programmatic, and business risks associated with developing a safe, reliable, and affordable second generation RLV. NASA intends to sustain commercial competition through 2005 and to invest in high-priority risk reduction work. The desired payoff of these investments is to enable NASA to make a decision on the full-scale development of at least one commercially competitive, privately owned and operated RLV by 2005. Operations would commence by 2010.

Finally, while 2001 was another challenging year for the RLV industry, the industry has remained resilient. Several commercial RLV companies remain committed to the goal of developing and operating their vehicles. These companies are aggressively pursuing private investment, and many have revised their business plans to include a much higher percentage of government payloads. Several are pursuing NASA SLI contracts to support their development efforts. Some RLV companies are focusing on providing alternative access to the International Space Station (ISS); NASA, however, has not yet selected any contractors for ISS re-supply.

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 research projects as well as engines and motors developed by companies for their own launch vehicles and for sale to other companies. There is a trend of development of new liquid-propellant engines that use room-temperature propellants and either pressure-fed or pump-fed systems. Such engines are considerably less complex, and potentially less expensive, than engines that use turbopumps and cryogenic propellants.

Spaceports

Spaceports characteristically 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 spaceports in the United States emerged in the 1950s, 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 of these facilities, commercial payload customers have become frequent users of federal spaceports as well.

The commercial dimension of U.S. space activity is evident not only in the growing numbers of commercially-procured launches but also in an expanding list of commercial launch sites supplementing federally operated sites. Today, four licensed commercial launch sites exist. These spaceports serve commercial payload customers as well as government payload owners that have commercially procured launch services. The recently formed National Coalition of Spaceport States (NCSS) is working to advance the development of additional state and commercially owned and operated spaceports through a variety of grant and legislative activities.

2001 Highlights

January 22: Boeing combined the management of its Delta 2, Delta 3, and Delta 4 launch vehicles into a single organization.

February 5: Representatives of 14 states established the National Coalition of Spaceport States (NCSS) in Washington, D.C.

February 26: Boeing Expendable Launch Services and the Sea Launch Company signed a memorandum of agreement to provide mutual backup of each other's launches.

March 1: NASA announced that it would provide no funding through the Space Launch Initiative (SLI) program for the X-33 and X-34 reusable launch vehicle (RLV) technology demonstration programs, effectively shutting down both programs.

March 16: New Mexico governor Gary Johnson signed into law an appropriations bill that included a total of $1.5 million in fiscal years 2002 through 2004 for development of a commercial spaceport in the state.

March 18: A Sea Launch Zenit 3SL launched the XM Rock digital radio broadcasting satellite from a mobile platform on the Equator in the Pacific Ocean.

April 10: Pratt & Whitney Space Propulsion announced plans to develop the RL-60, a new upper-stage engine capable of 289,000 newtons (65,000 pounds-force) of thrust. The company plans to have the engine ready for service by the end of 2005.

April 19: Utah governor Mike Leavitt signed into law the Utah Spaceport Authority Act. The act created a Utah Spaceport Authority to develop and regulate spaceport facilities in the state and also established a seven-person advisory board.

May 8: A Sea Launch Zenit 3SL launched the XM Roll digital radio broadcasting satellite from a mobile platform on the Equator in the Pacific Ocean, thereby completing the XM Radio satellite duo.

May 9: Boeing completed a series of hot-fire tests of the Common Booster Core (CBC) for its Delta 4 launch vehicle at NASA's Stennis Space Center, Mississippi.

May 17: NASA announced $767 million in SLI awards to 22 contractors. Kistler Aerospace Corporation received $135 million, including a $125 million option for a flight of Kistler Aerospace Corporation's K-1 RLV. A Pratt & Whitney/ Aerojet joint venture received $125 million for advanced rocket booster and upper stage research.

May 23: NASA conducted the seventh and final drop test of the X-40A, an 85-percent scale model of the X-37 RLV technology demonstrator, at Edwards Air Force Base (AFB), California. The success of the tests paves the way for future X-37 flight tests.

June 2: A modified Pegasus booster carrying the X-43A, an experimental vehicle designed to test scramjet technologies for potential use in future RLVs, lost attitude control five seconds after ignition and was destroyed. The cause of the failure has yet to be identified.

June 17: Texas governor Rick Perry signed into law an appropriations bill that includes $1.5 million for the Texas Aerospace Commission to support the development of proposed spaceports in the state.

June 19: An Atlas 2AS launched the ICO F-1 communications satellite from Cape Canaveral Air Force Station (CCAFS).

July 24: XCOR Aerospace began flight testing of EZ-Rocket, a modified Long-EZ airplane powered by two 1,780-newton (400-pound-force) rocket engines. The aircraft is designed to test rocket technologies planned for future sub-orbital RLVs.

August 6: NASA completed a series of test firings of twin XRS-2200 linear aerospike engines at the Stennis Space Center, Mississippi, as part of the SLI.

August 30: NASA's Marshall Space Flight Center and Lockheed Martin Corporation completed tests of the first subscale liquid oxygen tank made of composite materials. Such tanks could be used to reduce the weight of future RLVs.

September 7: The U.S. Air Force announced that it would neither assume project responsibility nor provide funding for the X-33 program. The Air Force also announced that it would not fund the X-37 program after September 2002.

September 19: FAA/AST renewed the commercial launch license for the California Spaceport at Vandenberg AFB (VAFB), California, for five years.

September 21: A Taurus launch vehicle failed to deliver Orbital Imaging Corporation's OrbView-4 and NASA's QuikTOMS satellites to their intended orbits due to an anomaly with the vehicle's second stage.

September 24: Boeing established Boeing Launch Services, Incorporated, to market and sell both Sea Launch and Delta commercial launch services.

September 26: Boeing shipped the CBC for its first production Delta 4 launch vehicle from its factory in Decatur, Alabama to CCAFS.

September 29: An Athena 1 launched NASA's Starshine-3 spacecraft and three satellites for the Department of Defense Space Test Program from the Kodiak Launch Complex, Alaska. It was the first orbital launch from the Kodiak Launch Complex.

October 9: Boeing dedicated its new Space Launch Complex (SLC) 37 at CCAFS. The facility will be used to launch its Delta 4 boosters.

October 9: Boeing announced that its first Delta 4 launch, scheduled for mid-2002, will carry a satellite for Eutelsat.

October 18: A Delta 2 launched the QuickBird 2 commercial remote sensing satellite from VAFB.

October 19: The first Atlas 5 booster was stacked vertically in the Vehicle integration Facility of LC-41 at CCAFS.

November 22: Starchaser Industries launched the Nova booster from Morecambe Sands, United Kingdom. The vehicle is designed to test technologies for Thunderbird, the company's RLV and X-PRIZE® entrant.

December 10: Disassembly of the flight-ready X-33 hardware began. Hardware components will be distributed to NASA centers and companies involved with SLI.

December 10: The Willacy County (Texas) Commissioners Court established the Willacy County Development Corporation for Spaceport Facilities to investigate the feasibility of creating a spaceport in the county.

December 12: Aerojet successfully tested a reaction control engine it is developing under an SLI contract. The test was the first hot-fire test of any propulsion system whose development began under SLI.

December 17: NASA awarded an additional $94.6 million in SLI contracts for systems engineering, crew survivability, and advanced propulsion studies. Rocketdyne won a $64 million option to an existing contract for advanced propulsion systems.

December 19: Lockheed Martin completed a series of tests of the RD-180 engine, qualifying its use on all Atlas 5 launches.

Expendable Launch Vehicles

This survey of expendable launch vehicles (ELV) in the United States 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 discusses the Atlas 5 and Delta 4 Evolved Expendable Launch Vehicle (EELV) boosters, which promise to provide more reliable, less expensive access to space for commercial and government payloads. The final section reviews a number of proposed commercial ELVs under study or development. These vehicles would primarily serve small commercial payloads at prices that are potentially much lower than available today.

Existing ELV Systems

There are nine ELV systems available in the U.S. today, a summary of which is provided in Table 1.[4] Three ELVs–Minotaur, Titan 2, and Titan 4B–are restricted to government payloads. The remaining six–Athena, Atlas, Delta, Pegasus, Taurus, and Zenit 3SL (Sea Launch)–are available for commercial use, and all but the Zenit 3SL can also carry U.S. government payloads. The Athena system was mothballed in late 2001 because of a lack of customers, while the existing Atlas and Delta boosters will be gradually phased out in favor of their EELV variants, Atlas 5 and Delta 4.

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 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 either one solid and one liquid or two solid and two liquid propellant upper stages.[5]

Athena launches have taken place from Vandenberg Air Force Base (VAFB), California; Cape Canaveral Air Force Station (CCAFS), Florida; and, most recently, from the Kodiak Launch Complex in Alaska. The latest Athena launch took place on September 29, 2001, when an Athena 1 launched from Kodiak placed the Starshine 3, Sapphire, PICOSat, and PCSat spacecraft into polar orbit. With no launches manifested and a limited market for small spacecraft payloads, Lockheed Martin decided in late 2001 to suspend the Athena program.

Atlas Family – Lockheed Martin Corporation

The Atlas launch vehicle family traces its roots to the development of the Atlas ICBM in the 1950s. 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.

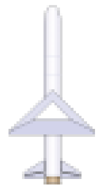
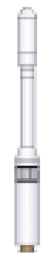
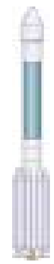
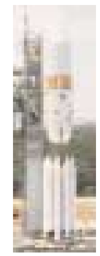
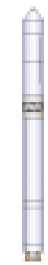
The Atlas 3A and Atlas 3B represent a transition between the older Atlas vehicles and the Atlas 5 EELV under development by Lockheed Martin. The Atlas 3 abandons the stage-and-a-half design of the older Atlases for a single RD-180 main engine developed by the Russian company NPO Energomash and marketed under a joint Russian-American partnership. The Atlas 3A, which first launched in 2000, uses a single-engine Centaur upper stage, while the Atlas 3B, whose inaugural launch is planned for 2002, uses a stretched Centaur upper stage with two engines.[6]

Delta Family – The Boeing Company

The Delta 2 and Delta 3 boosters are the latest versions of a launch vehicle family that dates back to the Thor missile program in the 1950s. The Delta 2 uses a 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.[7]

The Delta 3 was developed both to serve larger payloads and to be a transition towards the Delta 4 EELV boosters. The Delta 3 uses the same first-stage engine as the Delta 2 but incorporates nine more powerful strap-on solid rocket motors as well as a new cryogenic upper stage with an engine similar to the one used on the Centaur upper stage. After two unsuccessful initial launch attempts in 1998 and 1999, the Delta 3 successfully launched a test payload in August 2000. Boeing plans to phase out the Delta 3 as the Delta 4 becomes operational.[8]

Table 1: Currently Available Expendable Launch Vehicles

	Small				Medium		Intermediate			Heavy	
											
Vehicle Company	Athena	Minotaur	Pegasus	Taurus	Delta 2	Titan 2	Delta 3	Atlas 2	Atlas 3	Titan 4B	Zenit 3SL
Company	Lockheed-Martin	Orbital Sciences	Orbital Sciences	Orbital Sciences	Boeing	Lockheed-Martin	Boeing	Lockheed-Martin	Lockheed-Martin	Lockheed-Martin	Sea Launch
First Launch	1995	2000	1990	1994	1990	1988*	1998	1990	2000	1997	1999
Stages	3 (Athena 1) 4 (Athena 2)	4	3	4	3	2	2	2	2	2	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.)	N/A	8,290 kg (18,280 lbs.)	7,315 kg (16,130 lbs.) (Atlas 2A) 8,620 kg (19,000 lbs.) (Atlas 2AS)	8,640 kg (19,050 lbs.) (Atlas 3A) 10,720 kg (23,630 lbs.) (Atlas 3B)	21,680 kg (47,800 lbs.)	N/A
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 (8,590 lbs.)	1,905 kg (4,200 lbs.)	N/A	6,190 kg (13,650 lbs.) (Atlas 2A) 7,210 kg (15,900 lbs.) (Atlas 2AS)	N/A	17,600 kg (38,800 lbs.)	N/A
Payload Performance (GTO)	N/A	N/A	N/A	N/A	1,870 kg (4,120 lbs.)	N/A	3,810 kg (8,400 lbs.)	3,065 kg (6,760 lbs.) (Atlas 2A) 3,720 kg (8,200 lbs.) (Atlas 2AS)	4,035 kg (8,900 lbs.) (Atlas 3A) 4,475 kg (9,870 lbs.) (Atlas 3B)	5,760 kg (12,700 lbs.) (GEO)	5,700 kg (12,566 lbs.)
Launch Sites	CCAFS, VAFB, Kodiak	VAFB	CCAFS, WFF, VAFB, EAFB,	VAFB	CCAFS, VAFB	VAFB	CCAFS	CCAFS, VAFB	CCAFS	CCAFS, VAFB	Pacific Ocean

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

Minotaur – Orbital Sciences Corporation

The Orbital/Sub-orbital 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.[9]

The Minotaur made its debut on January 26, 2000, when it successfully launched the FalconSat and JAWSAT satellites from VAFB. FalconSat was a spacecraft developed by the Air Force Academy, while JAWSAT carried three university-built microsatellites. 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.

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 in 1996. The original, or standard, version of the Pegasus was retired in 2000, and only the Pegasus XL is used today. The air-launched nature of the Pegasus permits launches from a number of different facilities, depending on the orbital requirements of the payload. Pegasus launches have been staged from six sites to date: Edwards AFB and VAFB, California; CCAFS; Wallops Flight Facility, Virginia; Kwajalein Missile Range, Marshall Islands; and Gando AFB, Canary Islands.[10] Five Pegasus XL launches are planned in 2002, carrying four NASA and one commercial payloads.

Taurus – Orbital Sciences Corporation

The Taurus ELV is a ground-launched vehicle based on the air-launched Pegasus. The Taurus was developed by Orbital Sciences Corporation under the sponsorship of the Defense Advanced Research Projects Agency to develop a standard small launch vehicle 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 (the first stage of a Peacekeeper ICBM was used as the Taurus first stage for the first Taurus launch).[11]

The Taurus has successfully completed five of six launch attempts since entering service in 1994. During the latest Taurus launch, on September 21, 2001, an anomaly during the first stage separation caused the booster to fly off course for several seconds. While the booster resumed its intended trajectory, the deviation prevented the booster's payload from reaching orbital velocity.[12]

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. Ten of these boosters have been launched since 1988, most recently on September 21, 2000. 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. With the addition of eight Graphite Epoxy Motor 40 solid-propellant strap-on boosters, the payload capacity can be increased to 3,540 kilograms (7,800 pounds) to the same orbit. Three Titan 2 launches are scheduled for 2002.[13]

The Titan 4B is the most powerful ELV in the United States today. The Titan 4B is used solely for U.S. military payloads, with the exception of the October 1998 launch of NASA's Cassini mission. 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, uses upgraded solid rocket motors that increase the payload capacity of the vehicle by 25 percent.[14] Four Titan 4B launches are planned for 2002, including the successful launch of a Milstar communications satellite from CCAFS on January 15. The Titan 4B will be phased out by 2004 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.[15] The Zenit 3SL is launched from the Odyssey mobile launch platform, which travels from its home port in Long Beach, California, to a position on the Equator in the Pacific Ocean for each 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.

EELV Development

The National Space Transportation Policy, signed by President Clinton on August 5, 1994, gave NASA responsibility for RLV development while tasking the Department of Defense (DoD) with developing EELVs and improving the nation's existing launch infrastructure. The goal of the EELV program was to partner with industry to develop a national launch capability that satisfies both government and commercial payload requirements and reduces the cost of space access by at least 25 percent.[16] Four companies initially competed for DoD contracts to develop heavy-lift launch capability for the United States. Ultimately, Lockheed Martin and Boeing were awarded EELV production and service contracts for their respective Atlas 5 and Delta 4 vehicles. The Air Force provided each company with $500 million for technology development and initial launch contracts worth $650 million for the Atlas 5 and $1.38 billion for the Delta 4.

Atlas 5 – Lockheed Martin Corporation

Vehicle: Atlas 5

Developer: Lockheed Martin

First launch: 2002

Number of stages: 2

Payload performance: between 3,970 and 8,670 kg (8,750 and 19,100 lbs.) to GTO

Launch sites: CCAFS

The Atlas 5 family of launch vehicles will be able to carry twice the payload mass of previous Atlas vehicles and will dispense with the pressure-stabilized fuel tanks used on previous Atlas vehicles. Unlike earlier Atlas first stages, Lockheed Martin's newly developed Common Core Booster™ (CCB) will be able to stand under the weight of its payload without being fully fueled. All Atlas 5 launch vehicles will use the CCB as well as the NPO Energomash RD-180 engine that was introduced on the Atlas 3.

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. In order to meet national security requirements, Pratt & Whitney will build this engine in the United States for government versions of the Atlas 5. Domestic production has not begun, however, and the initial flights of government payloads on Atlas 5 vehicles will use Russian-built engines under a waiver.

Atlas 5 Vehicles

Lockheed Martin has approached the problem of pad dwell time in a different way than Boeing. The Atlas 5 will be prepared for launch in a vertical configuration in an assembly building near the pad. Hours before launch, it will be moved out to the pad fully prepared for launch. Through the use of multiple assembly buildings, multiple vehicles could be accommodated simultaneously; thus very high launch rate may be possible with this system.

The Atlas 5 is available in the 400 and 500 series and will have three available fairings and a variety of 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 19,110 pounds) into GTO.[17] Lockheed Martin has chosen not to develop a heavy version of the Atlas 5 at this time. Unlike the Delta 4, the Atlas 5 will only be launched from CCAFS.

Delta 4 – The Boeing Company

Vehicle: Delta 4

Developer: Boeing

First launch: 2002

Number of stages: 2

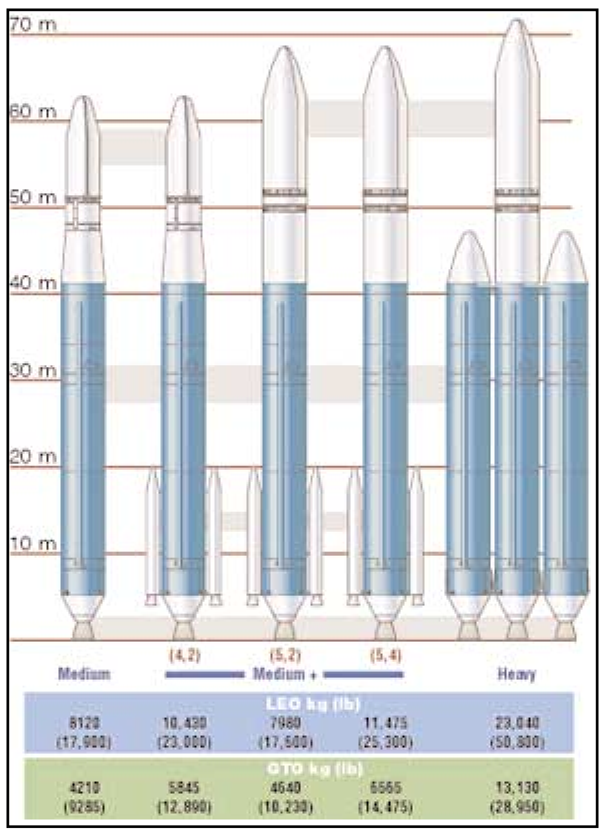
Payload performance: between 3,685 and 10,450 kg (8,120 and 23,040 lbs.) to LEO, between 4,210 and 13,130 kg (9,285 and 28,950 lbs.) to GTO

Launch sites: CCAFS, VAFB

The Delta 4 family of launch vehicles utilizes a common booster core (CBC) first stage that uses the first new liquid rocket engine developed in the United States since the Space Shuttle Main Engine (SSME), which was designed in the 1970s. This engine, the Rocketdyne RS-68, was developed from the J-2 engine used on the second stage of the Saturn 5 launch vehicle with the addition of technology from the SSME. It is, however, both larger and simpler than the SSME. This engine is one of the key technologies required to make the Delta 4 a success. The RS-68 is supplemented by two to four solid-fuel, graphite-epoxy motors, two types of upper stages, and three payload fairings, depending on customer needs. It will be launched from both VAFB and CCAFS.

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 CBC, and one heavy-lift version that will use three parallel CBC 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 LEO range from 3,685 kilograms (8,120 pounds) for the Medium to 10,450 kilograms (23,040 pounds) for the Heavy; GTO capacities range from 4,210 to 13,130 kilograms (9,285 to 28,950 pounds).[18] Boeing plans to replace the Delta 3 with the Delta 4 once it is introduced into service over the next few years; subsequently, Boeing expects to phase out Delta 2.

A distinctive design feature of the Delta 4 is its use of horizontal integration. The vehicle will be assembled, tested, and prepared for launch horizontally, away from the launch pad. When integration is complete, the vehicle will be moved to the pad, raised, and launched in a relatively short amount of time. In addition to making the launch vehicle easier to work on by keeping it closer to the ground, horizontal integration 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, horizontal integration contributes to the economic advantages that are a major part of the EELV program's goals.



Delta 4 Vehicles

More ELV Development Efforts

A number of efforts by both large corporations and small 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, placing payloads as small as a few hundred kilograms 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.

AirLaunch – The Boeing Company/ Thiokol Propulsion

Vehicle: Air Launch
Developer: Boeing/Thiokol
First launch: To be determined
Number of stages: 3
Payload performance: 3,400 kg (7,500 lbs.) to LEO
Launch sites: TBD

The Boeing Company and Thiokol Propulsion are currently studying a launch vehicle system called AirLaunch that features a solid-propellant ELV launched from an aircraft. The AirLaunch booster would use Castor 120 solid rocket motors for its first and second stages with a custom-designed third stage provided by Thiokol. The launch vehicle would be carried aloft atop a modified Boeing 747-400F aircraft; at an altitude of 7,300 meters (24,000 feet) it would separate from the aircraft and continue toward LEO propelled by its rocket engines. Wing and tail assemblies attached to the launch vehicle would provide lift and stability during this initial phase of the flight; the assemblies would later be jettisoned as the booster accelerated toward orbit.

AirLaunch

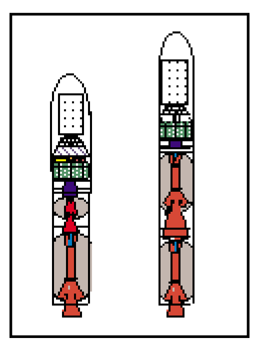
AirLaunch was initially designed to launch the Air Force's proposed Space Maneuver Vehicle, a small reusable spacecraft. AirLaunch could also be used to place payloads of up to 3,400 kilograms (7,500 pounds) into LEO.[19] AirLaunch could operate out of any airport with a runway longer than 3,650 meters (12,000 feet); only downrange ground tracking is required because launch and range control would be managed onboard the aircraft. Since announcing the AirLaunch project in 2000, Boeing has conducted extensive wind tunnel and structural tests. Future development of AirLaunch will depend on the requirements of the military and any commercial customers.[20]

Eagle S-Series - E'Prime Aerospace Corporation

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

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 would be ejected from a ground-based silo using a compressed-gas system, thereby not requiring extensive launch infrastructure. At a height of 61 meters (200 feet), the vehicle's engines would ignite. The smallest vehicle, the Eaglet, would launch 580 kilograms (1,280 pounds) into LEO, while a somewhat larger version, the Eagle, would put 1,360 kilograms (3,000 pounds) into LEO. Both would use solid-propellant lower stages and a liquid-propellant upper stage. E'Prime has also proposed larger vehicles, designated S-1 through S-7, that would be able to place considerably larger payloads into LEO and add a geosynchronous Earth orbit (GEO) capability.[21]

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. Provisions of the Strategic Arms Reduction Treaty I severely restricted development of the first-stage motor for much of the 1990s.

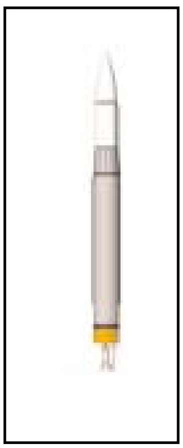


Eaglet and Eagle

The company has since updated the design of the first stage to avoid the arms control restrictions. The Air Force approved user manuals for the Eaglet and Eagle vehicles in April 2001. E'Prime signed an agreement with NASA in February 2001 that gives the company non-interference use of available property and services. 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.

LV-1 - Rocket Propulsion Engineering Company

Vehicle: LV-1
Developer: Rocket Propulsion Engineering Company
First launch: No sooner than 2004
Number of stages: 2
Payload performance: 204 kg (450 lbs.) to LEO
Launch sites: To be determined


LV-1

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.[22] The company is working on two sub-orbital 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 sub-orbital vehicles in 2004.[23]

Scorpius - Microcosm, Inc.

Vehicle: Sprite Mini-Lift
Developer: Microcosm
First launch: Late 2003
Number of stages: 2
Payload performance: 315 kg (700 lbs.) to LEO, 150 kg (330 lbs.) to SSO
Launch sites: California Spaceport

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, would use six booster pods, each with a 89,000-newton (20,000-pound-force) engine, clustered around a sustainer pod with a 22,250-newton (5,000-pound-force) engine. The Sprite Mini-Lift would be able to place 315 kilograms (700 pounds) into LEO and 150 kilograms (330 pounds) into sun-synchronous orbit (SSO). Two larger Scorpius vehicles are under study: 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.[24]


Scorpius Sprite Mini-Lift LEO Vehicle

In March 2001, Microcosm successfully launched its SR-XM sounding rocket from the White Sands Missile Range, New Mexico.[25] The Sprite Mini-Lift's sustainer pod has the same design and engine as the SR-XM. The Sprite's booster pods will also use the same design as the SR-XM, but with larger 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 the California Spaceport by the fourth quarter of 2003, with the vehicle entering commercial service one year later.

SLC-1 - Space Launch Corporation

Vehicle: SLC-1
Developer: Space Launch Corporation
First launch: Mid-2003
Number of stages: To be determined
Payload performance: 50-60 kg (110-132 lbs.) to SSO
Launch sites: To be determined

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, solid rocket motors based on existing technology. The booster will be deployed from an existing jet aircraft and be able to put payloads of up to 50 to 60 kilograms (110 to 132 pounds) into a 800-kilometer (500-mile) SSO. The company is targeting microsatellites and other small payloads that would otherwise be launched as secondary payloads on larger vehicles. The company anticipates the first launch of its system in mid-2003.[26]

Reusable Launch Vehicles

This section describes active reusable launch vehicle (RLV) programs in the United States. While emphasis is placed on commercial programs, government-funded programs are also presented as they are enablers of a robust commercial space transportation infrastructure. The Space Shuttle, for example, is considered a first generation RLV and the foundation of what may become a long line of commercial and government next-generation systems to follow. Because of the enormous expenditures of time and money needed to develop a launch system capable of reducing launch costs as well as risk to human life, the government's role as a partner and supporter of commercial RLV efforts is becoming clearer. Experiences gained by operating the Space Shuttle for over 20 years have helped solve crucial problems related to the design of more efficient RLV systems. This section first addresses government RLV development efforts and then describes the commercial RLV projects underway or under consideration.

Government RLV Development Efforts

The National Aeronautics and Space Administration's (NASA) launch vehicle plans are governed by its Integrated Space Transportation Plan (ISTP), which was introduced in the fall of 1999. Developed from joint NASA-industry space transportation architecture studies and national space policies, the ISTP is a long-range plan to reduce the cost of access to space and improve launch safety. The plan delineates the schedule and priorities of NASA's various space launch development efforts, from current operations to the development of fourth-generation RLV technology for the 2040s, and is composed of three parts:[27]

- Space Shuttle safety upgrades;
- The Space Launch Initiative (SLI); and
- Third- and fourth-generation RLV technologies and in-space transportation systems.

In addition to NASA's efforts, the Air Force is exploring the possibilities for improved military access to space. In the short run, this effort has resulted in the Evolved Expendable Launch Vehicle (EELV) program. In the longer term, various efforts are ongoing in support of the Space Maneuver Vehicle concept, military space planes, and other areas of technology development.

Space Shuttle

Vehicles: Space Shuttles Columbia, Discovery, Atlantis, and Endeavour

Developer: Rockwell International (Now Boeing). Fleet is managed, operated, and maintained on the ground by United Space Alliance (USA) a joint venture between Boeing and Lockheed Martin

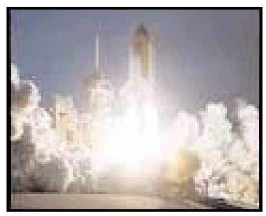
First launch: April 12, 1981

Number of stages: 1.5

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

Launch site: KSC, FL

Markets served: Non-commercial payloads and ISS access


Space Shuttle

Currently, NASA operates the world's only operational RLV system, the Space Shuttle. Consisting of an expendable external tank, two reusable solid rocket boosters, and one of four reusable orbiters, the Shuttle has conducted more than 100 launches since its introduction in 1981. The orbiters Atlantis, Discovery, and Endeavour collectively performed six successful missions in support of the International Space Station (ISS) in 2001. In February 2001, the fourth orbiter, Columbia, returned to service after undergoing over a year of maintenance, inspections, and upgrades.

Under the ISTP, NASA is preparing to upgrade the Space Shuttle fleet to improve safety and extend its service life until a commercially developed and operated second-generation RLV system can replace it. The Space Shuttle safety upgrade goals are to achieve the following:

- Major reduction in catastrophic failure risk when ascending to orbit;
- Significant reduction in catastrophic failure risk when in orbit and during reentry; and
- Improved crew cockpit-situational awareness for managing critical operations.

Space Shuttles Columbia and Atlantis have both received Honeywell's new glass cockpit system, known as the Multifunction Electronic Display System. While not part of the ISTP, the system has been installed to improve crew training and to assist in contingency planning. It will be fully employed when new cockpit avionics are installed by 2005.[28]

Other planned improvements include Phase 1 of the Advanced Health Management System for the Space Shuttle's main engines, improved manufacturing techniques for the Shuttle's external tank, and upgrades to its landing gear assemblies. Improvements under consideration include cockpit avionics upgrades, the addition of electric auxiliary power units, solid rocket booster thrust-vector system improvements, and Advanced Health Management System Phase II. Both these planned and projected safety upgrades are scheduled for completion by 2007. These upgrades are projected to improve ascent safety and reliability to approximately one loss in 1,000 missions.

In addition to vehicle upgrades, NASA is also considering an early departure from the launch vehicle operations arena. Under the concept of Space Shuttle privatization, NASA would turn over full responsibility for the Space Shuttle fleet to a private entity that would operate and maintain the fleet for profit. This would foreshadow the transfer of responsibility for launch operations that is anticipated when commercial second-generation RLVs provide launch services for all NASA payloads.

Space Launch Initiative

SLI is the main component of ISTP. While the goal of SLI is to produce a follow-on system to the Space Shuttle, it will do so after a series of incremental steps have been completed successfully. These steps involve the methodical selection of technologies, architectures, and addressable markets required for a commercially operated, second-generation RLV. SLI represents a partnership between government and industry within the context of a larger, national transportation infrastructure development framework, a relationship that differs significantly from the independent RLV program partnerships of the past. The goals of SLI are to produce an RLV system ten times safer than the Space Shuttle, with crew survivability 100 times greater and launch costs one-tenth of current prices, or approximately $450 per kilogram ($1000 per pound) to LEO.[29] With a planned budget of $4.8 billion through fiscal year 2006, SLI is managed by NASA's Marshall Space Flight Center in cooperation with other agencies and industry partners.

SLI consists of two basic phases. Phase I, Architecture Definition and Risk-Reduction, is planned to continue through the second half of 2003, and is intended to develop and maintain system-level requirements to meet safety, cost, and performance goals through integrated systems engineering.[30] Following the development of system requirements under Phase I, Phase II will involve systems engineering and requirements definition objectives to develop the detailed technical and programmatic requirements necessary to link technology and business risk reduction efforts to competing architectures.[31] Phase I ends and Phase II begins with the selection of at least two competing commercial RLV architectures, which are intended to lead to full-scale development decisions in 2006 for operations beginning early in the next decade.

SLI Phase I was announced in October 2000 as NASA Research Announcement (NRA) 8-30. On May 17, 2001, 22 contracts covering 37 different task awards were awarded under NRA 8-30.[32] These contracts, valued at $767 million, initiated the development of alternative technologies for a new generation of launch systems and associated space transportation operations. These developing technologies include crew survival systems, advanced tanks and vehicle structures, reusable rocket engines, and robust thermal protection systems. On December 17, 2001, NASA announced an additional $94.6 million in contract awards as part of SLI Phase I in areas such as systems integration and architecture design, crew escape systems, and advanced propulsion concepts.[33] SLI contract awards are for ten-month base periods and include options for one or more additional years. These options allow NASA to measure contractor performance on an annual basis and to monitor progress towards the program's ambitious goals. This schedule also allows for continued competition in key technology areas and allows NASA to capitalize on emerging technologies. In December 2001, Aerojet became the first contractor to hot-fire engine tests in the SLI program, initial evidence that this technology development process has begun.

In October 2001, NASA's Johnson Space Center opened a new office in support of the SLI program to focus on human-specific research and development associated with a follow-on RLV. Johnson's Space Launch Initiative Office is expected to receive hundreds of millions of dollars over the next four years.[34]

Third- and Fourth-Generation RLV Technologies and In-space Transportation Systems

NASA's Advanced Space Transportation Program (ASTP) was established, in part, to build upon the successes that emerge from the SLI program. The objectives of ASTP are to further increase the crew survivability and safety of future space transportation systems and lower launch costs using technology that is expected to emerge from SLI and other areas of research and development. In addition, the ASTP will explore infrastructure and vehicle concepts for exclusive use in space, such as travel between Earth orbit and the Moon.[35]

Third- and fourth-generation RLV technologies being researched include air-breathing rocket engines, electromagnetic propulsion systems, and solar-powered space sails, among others. ASTP aims to mature existing technologies that, when integrated with newer technologies, will enable safe and routine Earth-to-orbit transportation, rapid transportation to other celestial bodies, and eventual interstellar travel. Alternative propulsion technologies are currently being researched at NASA's Marshall Space Flight Center in conjunction with university participants.

RLV Research Vehicles

The NASA/Lockheed Martin X-33 and Orbital Sciences' X-34 program were cancelled when NASA allowed the agreement governing the jointly funded endeavor to expire on March 31, 2001. Both companies had hoped that NASA would add funds to the programs through SLI's NRA 8-30, but NASA determined that further funding of the X-33 and X-34 was not an efficient use of funds when compared to other SLI projects. The only NASA RLV research vehicle currently under development, the X-38, is discussed here; the X-40A/X-37 and the X-43A, which are technology test beds, are discussed in a later section.

The X-38 is a full-scale prototype of the emergency Crew Return Vehicle (CRV), the proposed lifeboat for the ISS. As an independent review group concluded in 2001, the CRV is essential to the ISS program if the station is to safely house up to seven occupants. [36] Without the CRV, the ISS is limited to three crewmembers due to the Soyuz lifeboat's capacity.

The X-38 program, which is being managed by NASA's Johnson Space Center and tested by the Dryden Flight Research Center, began in 1995. Although not expected to launch payloads into orbit, the X-38's development supplements a growing body of knowledge related to lifting body designs, which allow a vehicle to maintain an efficient reentry profile while still permitting controlled but unpowered flight through the atmosphere. Unlike previous lifting body designs, the X-38 uses a parafoil to augment the vehicle's aerodynamic control surfaces in order to achieve a safe landing profile.

The X-38 has been successfully flight tested eight times, the last test incorporating remote piloting software provided by the European Space Agency (ESA). The ESA, which does not have the capability to return payloads from space, has worked with NASA on the development of the CRV concept as well as their own Crew Transport Vehicle. The U.S. Congress has agreed to continue funding the X-38 program with $40 million slated during fiscal year 2002. ESA has agreed to fund half of the X-38 program in order to ensure that its astronauts have continued access to ISS.

Commercial RLV Development Efforts

Astroliner – Kelly Space and Technology, Inc.

Vehicle: Astroliner

Developer: Kelly Space and Technology

First launch: 2005

Number of stages: 3-4 (including towing aircraft)

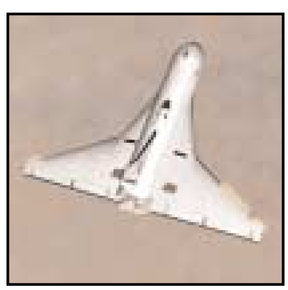
Payload performance: 4,690 kg (10,340 lbs.) to LEO

Possible launch sites: To be determined

Markets served: Public space transportation and other emerging markets

Kelly Space and Technology, Inc. is developing an RLV to address the needs of various sub-orbital markets, ISS customers, and small payloads to destinations higher than low-Earth orbit (LEO).

Kelly's piloted Astroliner will be based on its patented horizontal takeoff and landing tow-launch technique and is designed to carry humans and cargo to and from sub-orbital and orbital destinations. The two-stage-to-orbit (TSTO) system will be towed to altitudes of 6,096 meters (20,000 feet) using a modified Boeing 747 aircraft. Astroliner's onboard turbine engines will supplement the thrust of the tow aircraft during the initial ascent. The RLV system will be released at altitude and, using its rocket engines, will ascend to


Kelly Astroliner

stage separation. The second-stage system for the specific mission will proceed to orbit. The first stage will return to its planned landing site and use conventional turbofan engines for powered landing.

Astroliner includes a number of different upper-stage vehicles and intends to serve current and future customers anticipated through 2030, including both government and private citizen space travelers. Kelly expects the system design to readily accommodate the use of customer-supplied, orbit-transfer stages in conjunction with their satellites or other payloads.

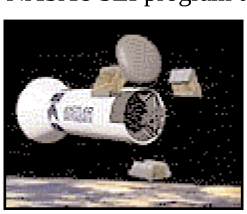
Kelly claims its tow-launch technique will facilitate significant reductions in expensive ground facilities, achieve system operating safety and reliability that approaches commercial airline operations, and enable delivery of heavier payloads than can be achieved by competing air-dropped system concepts.

Under a cooperative program with NASA's Dryden Flight Research Center and the Air Force Flight Test Center at Edwards AFB, California, Kelly's tow-to-launch concept has been successfully flight demonstrated. Using a modified QF-106 (called Eclipse) and a C-141A tow aircraft, Kelly successfully conducted six flight tests to demonstrate the RLV tow-launch technique in late 1997 and early 1998. Kelly expects tow tests and atmospheric powered flight-testing of Astroliner to begin in the latter half of 2003 and to last until early 2004. This series of tests will be followed by sub-orbital flights later in 2004. The first orbital flight is planned for mid-2005, with operations planned for early 2006.[37]

Kelly teamed with Vought Aircraft Industries in January 2001 to submit a joint proposal for the development of an RLV under NASA's SLI program. NASA, however, did not award the companies a contract when the first cycle of the SLI Phase I contract awards was announced in May 2001.

K-1 – Kistler Aerospace Corporation

On May 17, 2001, Kistler Aerospace Corporation was awarded a contract worth up to $135 million under NASA's SLI program to use the K-1 as a flight demonstrator under NRA 8-30.[38] Kistler will provide flight results of 13 embedded technologies flown on the first four K-1 flights. These technologies include propellant densification, novel parachute and airbag landing systems, and avionics. NASA also has options to use the K-1 as a test bed for advanced technology experiments in advanced materials, thermal protection systems, avionics, and other technology areas. This major award followed less than a year after Kistler was awarded a three-month study contract from NASA Marshall Space Flight Center to assess the K-1 as a potential vehicle to provide alternate access to ISS. The K-1 is 75 percent complete.[39]



K-1

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 GTO

Possible launch sites: Woomera, Australia; Nevada Test Site

Markets served: 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 TSTO vehicle with a payload capacity of approximately 4,535 kilograms (10,000 pounds) to LEO and an 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, or 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. Astrium designed a similar payload dispenser for small satellites for Arianespace's Ariane launch vehicles.

The K-1 will launch vertically like a conventional 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 (OV), continues into LEO, where it releases its payload. The OV is powered by a single Aerojet AJ26-60 engine (derived from the Russian NK-43 engine). Following payload separation, the OV continues on orbit for about 24 hours, after which a LOX/ethanol orbital maneuvering system performs a deorbit burn. The OV 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 pads 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 environmental review process is nearing completion for the Kistler project.

Pathfinder – Pioneer Rocketplane


Pathfinder

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.

Vehicle: Pathfinder

Developer: Pioneer Rocketplane

First launch: 2003

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

Markets served: Launch of small- and medium-class payloads

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.

Construction of Pathfinder is expected to begin in 2002. 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 kilometers (3.6 miles), 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 4 kilometers (2.5 miles) per second. 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 Pathfinder re-enters the atmosphere. After deceleration to subsonic speeds, Pathfinder will re-start its turbofan engines and land horizontally.[40] Pathfinder's maximum payload capacity to LEO will be 1,818 kilograms (4,000 pounds). The first air-breathing test flights are planned for 2003 and will be followed two to three months later by rocket-powered test flights.[41]

Pioneer Rocketplane is designing Pathfinder as a low-cost alternative for small- to medium-class payloads to LEO. The company is concurrently developing a scaled-down version of the Pathfinder vehicle, called the Pathfinder XP, to provide passenger service along sub-orbital trajectories. Pioneer Rocketplane has an agreement with the U.S.-based company Space Adventures to offer sub-orbital flights to customers paying between $98,000 and $100,000 per seat.[42]

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. On September 13, 2000, Pioneer signed a memorandum of understanding with the Oklahoma Space Industry Development Authority (OSIDA). Under the terms of the memorandum of understanding, OSIDA agreed to provide up to $300 million in revenue bond financing to help finance the development of the Pathfinder launch vehicle. Pioneer Rocketplane expects to receive the financing package during 2002.[43] In exchange for this financial assistance, Pioneer agreed to conduct launch operations from the proposed Oklahoma Spaceport at the former Clinton-Sherman AFB in Washita County, Oklahoma. Until such time as FAA/AST authorizes over-land launch corridors, Pioneer plans to base its vehicles at the Oklahoma Spaceport and ferry-fly to approved launch sites on the East or West Coasts.[44]

Pioneer'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 sub-orbital adventure travel market, and is also Pioneer'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.

SA-1 – SPACE ACCESS®, LLC

SPACE ACCESS®, LLC, is developing the SA-1, an uncrewed RLV that uses a hybrid propulsion system and one or two rocket-powered upper stages to deliver a range of payloads to LEO or GTO.

The propulsion system for the system's first stage, the "aerospacecraft," is based on a proprietary modification by SPACE ACCESS® to a ramjet engine

SA-1

Vehicle: SA-1

Developer: SPACE ACCESS®, LLC

First launch: 2007

Number of stages: 2-3 (depending on payload requirements)

Payload performance: 15,000 kg (33,000 lbs.) to LEO, 5,200 kg (11,500 lbs.) to GTO

Possible launch sites: Texas Spaceport; Homestead Air Reserve Base, FL; and KSC/CCAFS, FL

Markets served: Launch of LEO and GTO payloads

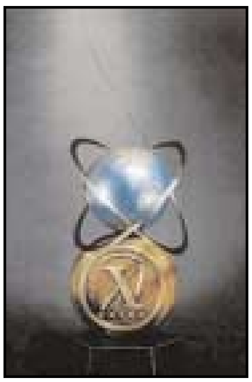
design that was tested in early 1960s. The modification to the engines allows the ramjets to operate at both subsonic and supersonic speeds (ramjets normally only operate above Mach 2).[45] One of the company's subcontractors, Kaiser Marquardt, has tested elements of the propulsion system,[46] and SPACE ACCESS® worked with the Air Force Research Laboratory in September 1995 under a Cooperative Research and Development Agreement to review the SA-1 aeromechanics and the "ejector" ramjet propulsion system. As of March 1998, SPACE ACCESS® had wind tunnel tested the ejector ramjet engine at all of the altitudes and speeds of the SA-1's planned flight profile.[47]

The SA-1 vehicle will take off horizontally from a conventional runway, using a mixture of air and liquid hydrogen to power its ejector ramjet engines. As the aerospacecraft climbs and accelerates and reaches the limits of the atmosphere, it will gradually transition from ramjets to liquid rocket propulsion in order to reach its final altitude of over 100 kilometers (62 miles) and speed of Mach 9. The aerospacecraft will then deploy an upper stage with its satellite payload and return to land on a conventional runway. The SA-1 will carry a single, rocket-powered upper stage for LEO missions and two upper stages for GTO. After deploying the satellite payload, the upper stage will deorbit and return to land horizontally on the same runway.[48]

The SA-1 vehicle will be able to launch payloads of over 5,200 kilograms (11,500 pounds) to GTO. Although SPACE ACCESS® intends to pursue deployment of commercial geosynchronous orbit (GEO) satellites as its primary market, the SA-1 will also have a capability of deploying well over 15,000 kilograms (33,000 pounds) to LEO. The SA-1's significant payload capability and reliability will also make the SA-1 well suited for conducting re-supply missions to the ISS.[49]

In 1999, SPACE ACCESS®, LLC was the recipient of a California Space Authority grant in the amount of $50,000 for a Reusable Launch Vehicle Structural Concept Evaluation. Research helped determine a second stage orbital vehicle design. A NASA Space Transportation Architecture Study program contract was signed in 1998 to further refine designs of the orbital vehicle, which would give the SA-1 the capability to provide human access to space. In cooperation with the state of California, SPACE ACCESS® is now conducting tests of its proprietary integral hot structure and ramjet designs. SPACE ACCESS® currently plans to expand its test program over the next several years to include avionics and full-scale propulsion hardware.[50]

X PRIZE® Contenders



X PRIZE® Trophy

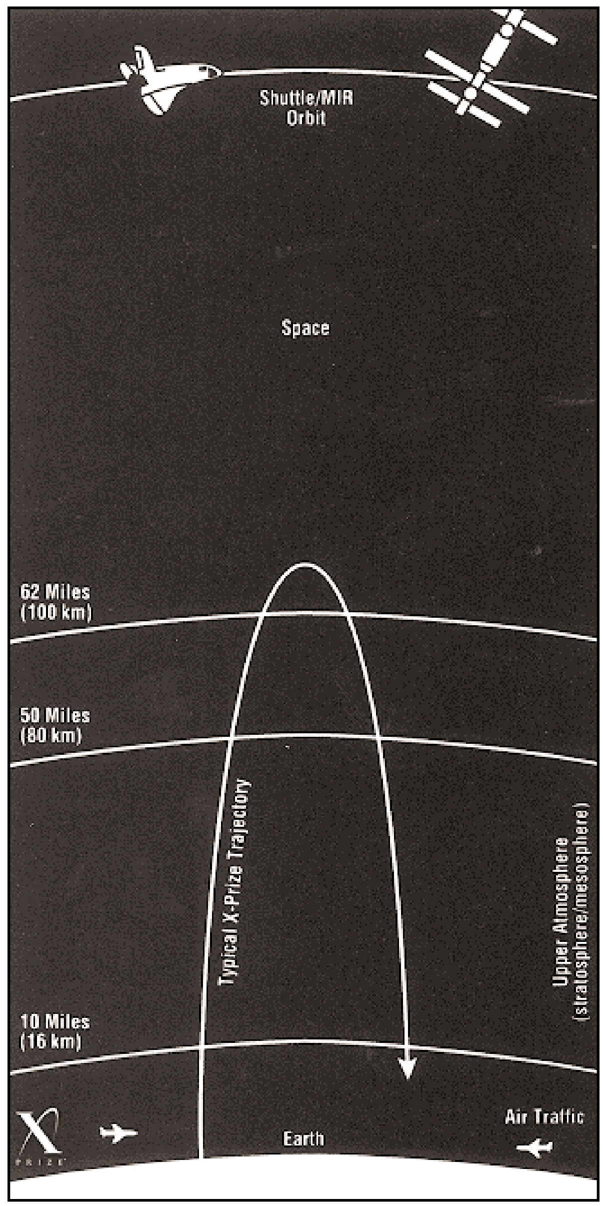
In the spirit of the early 20th-century aviation prizes, such as the Orteig Prize that Charles Lindbergh won for crossing the Atlantic in 1927, the X PRIZE® Foundation was established in 1994 as an educational, non-profit corporation dedicated to inspiring private, entrepreneurial advancements in space 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 to 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 to a 100-kilometer (62-mile) sub-orbital altitude and repeating the flight within two weeks (only one person and ballast for two others are required to actually make the flights). There is no deadline for winning the X PRIZE®.

The X PRIZE® competition currently has 21 entrants from five countries proposing a variety of different RLV concepts, including the already-discussed Pioneer Rocketplane Pathfinder and Kelly Space and Technology Astroliner (see Table 2 for a complete list). The commercial vehicles under development for the X PRIZE® competition are uniquely designed for sub-orbital space tourism operations carrying three to six passengers. These designs use many different takeoff, landing, and design concepts.

During 2001, Canadian Arrow and the Ontario-based da Vinci Project both unveiled their prototype vehicles. The year also marked a significant achievement for Pablo de Leon and Associates of Argentina. The team successfully released a sub-scale test capsule using balloons to an altitude of 293,000 meters (96,000 feet). Upon achieving altitude, squibs severed the balloon cables to permit a drop test of the capsule. The small capsule contained a Global Positioning System receiver, a transponder, and at least one camera.[51]

In November 2001, Steve Bennett's Starchaser Foundation became the fourth X PRIZE entrant to successfully test an unpiloted prototype vehicle. His group



Typical X PRIZE® Trajectory

Table 2: X PRIZE® Contenders

Vehicle	Developer	Description
Ascender	David Ashford, Bristol Spaceplanes Ltd. (Bristol, England)	RLV powered by two conventional jet engines and a liquid-fueled rocket engine. The vehicle will take off and land horizontally.
Astroliner	Kelly Space and Technology (San Bernardino, CA)	Horizontal takeoff and landing vehicle that is towed to an airborne launch site by a modified Boeing 747.
Aurora	Fundamental Technology Systems (Altamonte Springs, FL)	Horizontal takeoff and landing double-delta-winged RLV powered by a single throttleable kerosene and hydrogen-peroxide engine.
Canadian Arrow	Canadian Arrow (Ontario, Canada)	Vertically launched two-stage vehicle with water landing of both booster and passenger stages.
Cosmos Mariner	Lone Star Space Access Corporation (Houston, TX)	RLV powered by two air-breathing engines and one rocket engine. The vehicle will launch and land horizontally.
Gauchito	Pablo De Leon and Associates (Argentina)	Two-stage vehicle that will launch vertically. The first stage booster and the second stage passenger capsule return to Earth using parachutes.
Green Arrow	Graham Dorrington (London, England)	Cylinder-shaped rocket using liquid-fueled rocket engines. The vehicle will launch vertically and land vertically using parachutes and air bags.
Kitten	CFFC, Inc. (Oroville, WA)	Methane- and LOX-powered space plane that takes off and lands from conventional runway. Structure is aluminum sandwich foam with boron nitride ceramic coating.
Lucky Seven	Mickey Badgero (Owosso, MI)	Cone-shaped vehicle powered by rocket engines. The vehicle will launch vertically and land using a parafoil.
Mayflower (CAC-1), or Advent	Advent Launch Services (Houston, TX)	Cylinder-shaped glider powered by liquid-fueled rocket engines. The vehicle will launch vertically from water and land horizontally in water.
MICHELLE-B	TGV Rockets (Bethesda, MD)	The vehicle will launch vertically and land vertically using ascent engines in a deep throttle mode.
PA-X2	Rick Fleeter, AeroAstro Inc. (Herndon, VA)	Cylinder-shaped vehicle using a liquid-fueled engine. The vehicle will launch vertically and land horizontally using a steerable parafoil.
Pathfinder	Pioneer Rocketplane (Ann Arbor, MI)	RLV powered by both air-breathing jet engines and LOX/kerosene rocket engines. The RLV will take off horizontally and meet a tanker aircraft for air-to-air refueling.
Proteus	Burt Rutan, Scaled Composites (Mojave, CA)	Two-stage vehicle consisting of the turbo-fan powered Proteus aircraft and a rocket-powered second stage.
The Space Tourist	John Bloomer, Discraft Corporation (Portland, OR)	Disc-shaped vehicle powered by air-breathing “blastwave-pulsejets.” The vehicle will take off and land horizontally.
Thunderbird	Steven M. Bennett, Starchaser Foundation (Cheshire, England)	Cylinder-shaped rocket using air-breathing engines and liquid-fueled rocket engines. The vehicle will launch and land vertically.
X Van	Pan Aero, Inc., Third Millennium Aerospace (Washington, DC)	Pan Aero has publicized two designs for the X Van. The entry may be a TSTO system comprised of a booster stage and orbiter stage, or a single-stage system flying a sub-orbital trajectory.
Unnamed	William Good, Earth Space Transport System Corporation (Highlands Ranch, CO)	No information on this entry has been released.
Unnamed	Cosmopolis XXI (Moscow, Russia)	Cylinder-shaped rocket that is launched from a carrier aircraft “Geophisika.” The vehicle will take off vertically and land horizontally.
Unnamed	The da Vinci Project (Ontario, Canada)	Air-launched, LOX/kerosene rocket deployed from large piloted hot air balloon. Recovery system features a high-drag reentry ballute and parachute. Air bags are used to cushion touchdown on landing.
Unnamed	Anonymous	Unknown

also successfully tested a two-stage prototype vehicle in July 2000. His team is on track for a piloted test of the Thunderbird launch vehicle, with plans to capture the prize by mid-2003.[52]

Several of the competitors have commercial plans for their vehicles after the X PRIZE®. In addition to the plans of Pioneer Rocketplane and Kelly Space and Technology, Scaled Composites plans to use its Proteus aircraft for atmospheric research, reconnaissance, microsatellite launch, and telecommunications over metropolitan areas.[53] The Mayflower and Ascender will be used as commercial space tourism platforms. The X Van, Cosmos Mariner, and Aurora have been proposed for both satellite launch and space tourism missions.

More Commercial RLV Concepts

Several other companies and entrepreneurs are developing RLVs, primarily designed to serve sub-orbital markets. Table 3 lists these organizations and their respective vehicle concepts. These efforts are not contenders for the X PRIZE®.

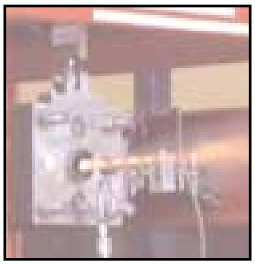
Table 3: Summary of More RLV Concepts

Vehicle	Developer	Vehicle Type
Armadillo	Armadillo Aerospace	Vertically-launched sub-orbital vehicle
Bladerunner	Air Force Research Laboratory (AFRL)	Horizontally-launched orbital vehicle
Hyperion	Applied Astronautics	Horizontally-launched sub-orbital/orbital vehicle
Millennium Express	Third Millennium Aerospace	Horizontally-launched orbital TSTO vehicle
Neptune	Interorbital Systems	Sea-launched orbital vehicle
Pogo	Olson	Horizontally-launched orbital vehicle
SC-1	Space Clipper International	Vertically-launched sub-orbital 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 sub-orbital vehicle specifically designed to ferry passengers
SpaceCub	Burkhead	Vertically-launched sub-orbital vehicle
Starbooster	Starcraft Boosters, Inc.	Vertically-launched sub-orbital 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 sub-orbital vehicle
(undisclosed)	XCOR	Horizontally-launched sub-orbital vehicle
(unnamed)	SpaceDev	Sub-orbital[54]
Commercial Space Transportation Architecture	Andrews Space and Technology	Horizontally-launched orbital vehicle

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 developed by companies for their own launch vehicles and for sale to other companies. There is a trend of development of new liquid-propellant engines that use room-temperature propellants and either pressure-fed or pump-fed systems. Such engines are considerably less complex, and potentially less expensive, than engines that use turbopumps and cryogenic propellants; this simplicity, however, may be offset by reduced performance.

Hybrid Rocket Motors - SpaceDev, Inc.


Hybrid Rocket Test

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.[55] SpaceDev completed tests of a small hybrid rocket motor in August 2001 that is designed for use in the company's Maneuvering 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). The company has also proposed developing larger hybrid motors that could be used on manned sub-orbital RLVs, such as X PRIZE vehicles.[56]

Hypersonic Engine – NASA X-43

The National Aeronautics and Space Administration's (NASA) X-43 program is designed to study and improve air-breathing hypersonic engine technologies. In an X-43 flight, the vehicle is accelerated to Mach 10 by the first stage of an Orbital Sciences Pegasus XL launch vehicle and is then separated from the booster for independent flight at high speed. The X-43 program involves three flights in an effort to understand intake and combustion chamber airflow patterns. The first of these flights, X-43A, on June 2, 2001, failed due to a first-stage anomaly in the Pegasus XL booster stage, but two more flights are still planned.[57]


X-43

Linear Aerospike Engine - Rocketdyne Propulsion & Power


XRS-2200

Rocketdyne Propulsion & Power, a division of The Boeing Company in Canoga Park, California, 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-force) thrust at sea level, using liquid hydrogen and liquid oxygen as propellants.[58] One XRS-2200 engine was tested at NASA's Stennis Space Center between December 1999 and May 2000, accumulating over 1,500 seconds of firing time during 14 tests. A single dual-engine test took place at Stennis in February 2001 before the X-33 program ended. Three additional dual-engine tests, funded by the Space Launch Initiative (SLI), took place in July and August 2001. Those firings were made to test electromechanical actuators, designed to regulate propellant flow in the engine, which could be used in future engine designs.[59]

Liquid Engines - Interorbital Systems Corporation

Interorbital Systems, based in Mojave, California, is currently developing a liquid-propellant, pressure-fed engine for use in its planned sounding rocket and RLV (see Interorbital's RLV concept listed in the previous section). The engine uses hypergolic propellants, inhibited white-fuming nitric acid and furfuryl alcohol. The current engine design produces a 3,000-newton (675-pound-force) thrust and has a nominal burn time of 50 seconds.[60] The company has completed static and flight tests of the engine.

Interorbital is using four of its new engines in its Research Series X-2 (RSX-2) sounding rocket. A test bed for the company's two-stage orbital vehicles, the

RSX-2 rocket can launch 2.25 kilograms (5 pounds) on a sub-orbital trajectory to 200 kilometers (125 miles), or 11 kilograms (25 pounds) to 97 kilometers (60 miles). The company anticipates the first launch of the RSX-2 for late 2002 from the Pacific island nation of Tonga.[61] The company plans to use larger versions of the engine in Neptune, its proposed RLV capable of launching cargo and passenger payloads of up to 3,175 kilograms (7,000 pounds) into LEO.

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-force) engine using liquid oxygen and jet fuel as propellants. This engine was successfully tested on the company's SR-XM sounding rocket in March 2001. The engine will also be used as the sustainer engine for the Sprite Mini-Lift orbital vehicle. A larger version, a 89,000-newton (20,000-pound-force) engine, is under development. This engine will be used on the booster pods of the Sprite Mini-Lift.

Liquid Engines - Rocket Propulsion Engineering Company

Rocket Propulsion Engineering Company is developing a series of liquid-propellant engines for use in its sub-orbital and orbital launch vehicles. The engines use hydrogen peroxide and kerosene as propellants, directly injecting the hydrogen peroxide into the engine rather than using catalyst beds, as in other engines that use hydrogen peroxide. This allows the use of less-expensive, lower-purity sources of hydrogen peroxide that would contaminate catalyst beds. The company has demonstrated this technology with its M1-B test engine, which generates a 1,780-newton (400-pound-force) thrust.

The company is currently developing two larger engines. The R6 engine, capable of a 26,700-newton (6,000-pound-force) thrust, will be pressure fed and ablatively cooled. The engine will be used on the company's SV-1 sub-orbital vehicle under development.[62] The R40 engine will use a simple turbopump powered by an open-cycle, fuel-rich gas generator to feed propellants into the engine, rather than use the pressure-fed design of the R6. The R40 will provide up to a 178,000-newton (40,000-pound-force) thrust. The engine will be used on the SV-2 sub-orbital vehicle and the first stage of its LV-1 orbital vehicle.

Liquid Engines - XCOR Aerospace

XCOR EZ-Rocket

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-force), pressure-fed regeneratively-cooled, liquid-oxygen and alcohol engine. Two such engines have been built and, combined, have been fired over 400 times for over 1,800 seconds. The engines have also been flown on EZ-Rocket, a modified Long-EZ aircraft fitted with the two engines. EZ-Rocket has completed several successful flight tests since July 2001.[63] A key technology is XCOR's proprietary ignition system.

XCOR has built two smaller engines. A 67-newton (15-pound-force) 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 1,200 firings, with a cumulative burn time of 68 minutes. XCOR's XR3B4 regeneratively-cooled engine is capable of a 220-newton (50-pound-force) thrust using nitrous oxide and isopropyl alcohol as propellants. This engine has completed over 700 firings with a cumulative burn time of over 812 seconds.[64] XCOR designed this engine for use as a maneuvering thruster on spacecraft. The company has plans to develop larger engines for potential use on sub-orbital RLVs.

Propellant Production – Andrews Space & Technology, Inc.

Andrews Space & Technology, Inc. of Seattle, Washington, has proposed the development of a propulsion system that would generate liquid oxygen propellant from the atmosphere. The "Alchemist" Air Collection and Enrichment System (ACES) would take high-pressure air from a turbofan jet engine and liquefy it by passing it through a heat exchanger cooled by liquid nitrogen and/or liquid hydrogen. Liquid oxygen would then be separated out and stored in propellant tanks for use by a liquid hydrogen-liquid oxygen rocket engine. This would 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 TSTO RLV design as well as for use in other horizontal-takeoff launch vehicles.[65]

Andrews Space & Technology carried out initial studies of the ACES concept, in cooperation with Pratt & Whitney, using internal funds and a NASA Small Business Innovative Research (SBIR) contract. A detailed feasibility and risk analysis study is in progress under a NASA SLI contract.

RLV Technologies – NASA/The Boeing Company X-37 and X-40A

X-37

NASA and Boeing are currently developing the X-37 reusable aerospace vehicle under a cooperative agreement 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 40 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 a highly durable, high-temperature thermal protection system; storable, non-toxic liquid propellants; and new aerodynamic features. 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.[66] Initial unpowered X-37 drop tests are planned for later this year from a NASA B-52 at Edwards AFB.

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 proposed Space Maneuver Vehicle, the X-40A is an 85-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 has completed a flight test program of seven successful flights at NASA's Dryden Flight Research Center, with the last flight completed 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.

X-40A

Spaceports

Spaceports are the nation's gateways to space. Although their individual capabilities vary, these facilities characteristically 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 spaceports in the United States emerged in the 1940s and 1950s, 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 of these facilities, commercial payload customers have become frequent users of federal spaceports as well.

Federal spaceports are not the only portals to orbit. Indeed, the commercial dimension of U.S. space activity is evident not only in the annual numbers of commercially-procured launches but also in the expanding list of commercial launch sites supplementing federally operated sites.[67] Today, four licensed commercial launch sites exist. These spaceports serve commercial payload customers as well as government payload owners that have commercially procured launch services. The recently formed National Coalition of Spaceport States (NCSS) is working to advance the development of additional state and commercially owned and operated spaceports through a variety of grant and legislative activities (see box below).

This section describes both the federal and licensed commercial 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 commercial spaceports with launch and landing capabilities is also included. In each subsection, the spaceports are presented in alphabetic order. The information about the spaceports was obtained from publicly available sources and interviews with the spaceport operators and proposers and related organizations. Table 4 shows a summary of the types of spaceports by state.

Table 4: Spaceport Summary by State

State	Commercial	Federal	Proposed
Alabama			☑
Alaska	☑		
California	☑	☑	☑
Florida	☑	☑	
Montana			☑
Nebraska			☑
Nevada			☑
New Mexico		☑	☑
Oklahoma			☑
South Dakota			☑
Texas			☑
Utah			☑
Virginia	☑	☑	
Washington			☑
Wisconsin			☑

*Current as of December 2001

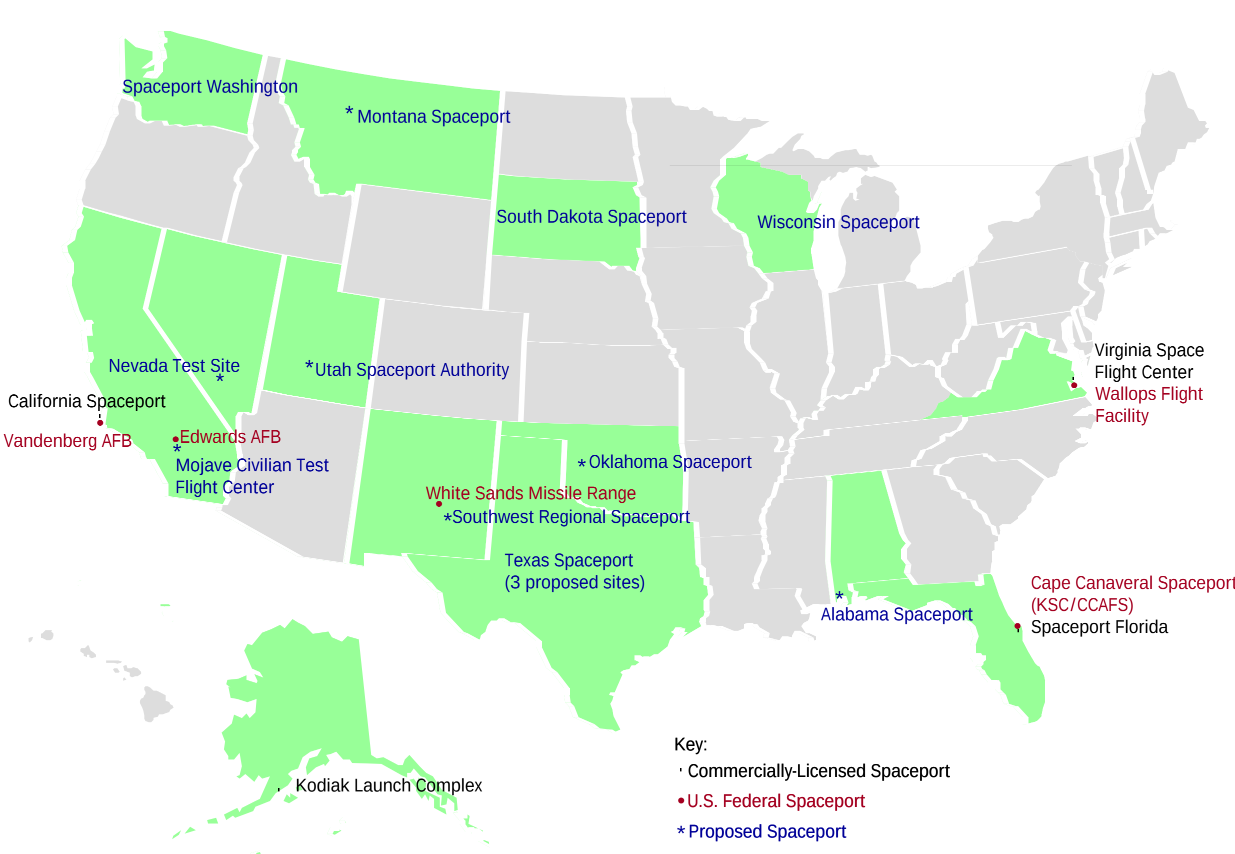
National Coalition of Spaceport States[68]

In October 2000, the states of California and Florida convened a space summit meeting in Washington, D.C. Representatives from all states with interests in spaceports attended the meeting and decided to form a coalition in order to create a mechanism for influencing space policy and commercial space development, including the development of spaceports. Fourteen states established the NCSS on February 5, 2001. The NCSS vision is for the United States to develop a strong, internationally competitive, commercial space launch industry utilizing the infrastructure of spaceports and space operations nationwide. The members aim to accomplish this goal by improving existing infrastructure and promoting the development of new spaceports in the Coalition states.

The goals of the NCSS for the next five years are to work with policy makers and space-related federal agencies to shape space policy and to create a framework that permits the development of spaceports. In July 2001, the NCSS released its views on seven key space transportation policy issues including export licensing, space access modernization, spaceport development bonds, and space flight safety.

Voting member states of the NCSS must have submitted a formal request for membership from their governors' offices and must have a formal plan to develop a physical spaceport with at least either a launch or landing site. States without spaceport plans or plans not yet approved by their governments may become associate, non-voting members. The founding member states of NCSS are: Alabama, Alaska, California, Florida, Montana, Nevada, New Mexico, Oklahoma, South Dakota, Texas, Utah, Virginia, Washington, and Wisconsin. Nebraska joined the NCSS as an associate member in the fourth quarter of 2001.

U.S. Spaceport Locations



Federal Spaceports

Since the first licensed commercial launch in 1989, the federal ranges have continually supported commercial launch activity. (See Table 5 for an overview of the ranges.) The importance of commercial launch is evident in the changes taking place at federal launch sites. Launch pad development with commercial, federal, and state government support is continuing at the two major federal sites for U.S. orbital launches—Cape Canaveral Spaceport (Cape Canaveral Air Force Station [CCAFS] and Kennedy Space Center [KSC]) and Vandenberg Air Force Base [VAFB]—for the latest generation of the Delta and Atlas launch vehicles (Delta 3 and Atlas 3) and the upcoming Evolved Expendable Launch Vehicles (EELV). With the transition underway to EELV and the phase out of some vehicle variants imminent, the number of launch pads utilized by Delta, Atlas, and Titan launch vehicles at both sites will eventually decrease from ten to four standardized pads.

Anticipating a continuing demand for commercial launches from federal sites and 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 Federal Aviation Administration (FAA) will sign a memorandum of agreement in early 2002 to establish a process for collecting commercial sector range support and modernization requirements, communicating these requirements to the Air Force, and considering these requirements in the existing Air Force requirements process.

Cape Canaveral Spaceport

Cape Canaveral Spaceport, consisting of Cape Canaveral Air Force Station (CCAFS) and the National Aeronautics and Space Administration's (NASA) John F. Kennedy Space Center (KSC), is located on the "Florida Space Coast" at Cape Canaveral and is co-located with the commercially-oriented Spaceport Florida (see the Spaceport Florida description below).[69] The Cape Canaveral area has endured several name changes and an expanding list of tenants. In 1949, the Banana River Naval Air Station was transferred to the

Spaceport: CCAFS

Operating authority: U.S. Air Force

Year of first orbital launch: 1957

Total orbital launches: 551

Vehicles served: Atlas 1, Atlas 2, Atlas 3, Atlas 5, Blue Scout, Delta 2, Delta 3, Delta 4, Juno, Jupiter, Pegasus, Saturn, Thor-Able, Titan 2, Titan 3, Titan 4, Vanguard

Orbits served: LEO, MEO, GEO, EXT, ELI

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 "re-designated" 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.

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 flight 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/from inter- and intra-range sensors in real or near-real time for each missile, space launch, or space-track support. The Eastern Range extends over the Atlantic Ocean as far north as Canada and as far southeast as Africa. There is currently one active launch complex (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 including the implosion of the launch tower used by Titan 4. The Florida Space Authority has entered into an arrangement for ownership of LC-41 and support integration facilities and will lease them to Lockheed Martin. Refurbishing and construction of the launch pad, gantry, and support facilities was completed in 2001. Lockheed Martin also completed construction of the launch control center and a horizontal launch facility in 2001. The first Atlas 5 launch is scheduled to take place from LC-41 in early May 2002. Boeing has a similar agreement with the Florida Space Authority for lease of the Delta 4 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 complex is ready for operations. The first Delta 4 launch also is scheduled for 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

Spaceport: KSC

Operating authority: NASA

Year of first orbital launch: 1967

Total orbital launches: 127

Vehicles served : Pegasus, Saturn, Shuttle

Orbits served: LEO, MEO, GEO, EXT, ELI

Payload Processing Facility, and the Shuttle Landing Facility, all of which are now dedicated to the Space Shuttle. 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 is expected to be complete by 2003. Also in 2001, KSC broke ground for the new Space Experiments Research and Processing 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 may be developed as an international space research park. The state of Florida provided $26 million for the development of the Space Experiments Research and Processing Laboratory and another $4 million for road construction in the facility's vicinity.

Edwards Air Force Base

Located in Mojave, California, Edwards AFB was the original landing site for the Space Shuttle.[70] 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). As a result, a 4.5-kilometer (2.8-mile) runway was built at Edwards AFB to be used for future Shuttle landings. 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 291,000 gallons (1.1 million liters) of cryogenic materials. A water tower with a height of 76 meters (250 feet) could supply nearly 265,000 gallons (one million liters) 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, no new X-33-specific infrastructures are planned, and the government and associated contractors are redistributing the components of the X-33 infrastructure for the SLI Program.

The federal government is investing several million dollars into refurbishing and modernizing two generic rocket test stands that were formerly used by the Air Force to test a range of launch vehicles. 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 co-located NASA's 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. The Air Force used a helicopter to conduct seven successful X-40A flight tests during 2001. The Air Force will continue funding X-37 testing at Edwards AFB through late 2002. The X-38, a demonstrator for the ISS Crew Return Vehicle (CRV), continues to be tested at Edwards AFB.

Vandenberg Air Force Base

In 1941, the Army activated this site in Lompoc, California, as Camp Cook.[71] 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. VAFB is currently the headquarters of the 30th Space Wing, which conducts space and missile launches and operates the Western Range. The Range extends into the Pacific Ocean as far west as the island of

Spaceport: Vandenberg AFB

Operating authority: U.S. Air Force

Year of first orbital launch: 1959

Total orbital launches: 619

Vehicles served: Athena, Atlas 1, Atlas 2, Delta 2, Delta 4, Minotaur, Pegasus, Scout, Taurus, Thor, Thor-Able, Titan 2, Titan 3, Titan 4

Orbits served: Polar

Kwajalein, with boundaries to the north as far as Alaska and to the south near Central America.

VAFB infrastructure includes a 4,500-meter (15,000-foot) runway, 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 1,100 buildings. VAFB hosts a variety of federal agencies and attracts commercial aerospace companies and activity, including the California Spaceport effort (see the California Spaceport description below).

VAFB partnered with Boeing to develop launch infrastructure for the Delta 4 EELV. The Space Launch Complex (SLC) 6 is being converted from a Space Shuttle launch pad into an operational facility for the Delta 4. The refurbished SLC-6 is currently under construction and is expected to be complete by 2003. 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 will include enlarging the existing mobile service tower and completing the construction of the West Coast Horizontal Integration Facility, where the Delta 4 will be assembled.

VAFB is also upgrading its range instrumentation and control centers to support the space launch industry. These upgrades are scheduled to be completed by 2008. In addition, the state of California is looking into refurbishing some launch pads that are not currently in use to make "generic" pads available for academic research in the future. 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 2, Titan 4, Taurus, Minotaur, and Pegasus XL. SLC-2, from which Delta 2 vehicles are launched, is owned by NASA. Construction is underway at SLC-6 for Delta 4. Pegasus XL vehicles are processed at Orbital Sciences' facility at VAFB and then flown to various worldwide launch areas.

Two RLV developers have contacted VAFB to inquire about launch services: Pioneer Rocketplane and Kelly Space and Technology. Both have expressed interest in using VAFB facilities for testing purposes and possibly for launch activities once the testing sequence is completed.

At this time, VAFB has 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.

Wallops Flight Facility

The National Advisory Committee for Aeronautics, the predecessor of NASA, established a range at Wallops Island, Virginia in 1945.[72] Since then, over 14,000 small rocket launches have taken place from the site, which is currently operated by NASA's Goddard Space Flight Center. The first orbital launch was in 1961, 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 (when the carrier airplane originated from Wallops), the most recent in 1999. The retired Scout made its last orbital launch from Wallops in 1985.

In April 1996 the Air Force designated Wallops as a launch site for converted Minuteman 2 missiles under the Orbital/Sub-orbital Program (along with Kodiak Launch Complex and the California Spaceport), so possible future users include the Minotaur vehicle developed under that program.

Spaceport: Wallops Flight Facility

Operating authority: NASA

Year of first orbital launch: 1960

Total orbital launches: 29

Vehicles served: Conestoga, Pegasus, Scout

Orbits served: LEO

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 would be used by both orbital and sub-orbital missions. Three blockhouses and payload preparation facilities are operational. Wallops launches about ten to 20 sub-orbital vehicles per year. The facility also supports northerly launches from KSC or CCAFS as well as worldwide orbital and sub-orbital 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.

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 Ballistic Missile Defense Organization (now the 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.

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.

Licensed Commercial Spaceports

In order to operate a commercial launch or landing site in the United States, it is necessary to obtain a license from the federal government through FAA/AST. 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. To date, FAA/AST has licensed four non-federal launch sites (see Table 6). Three of these are co-located with federal launch sites, including the California Spaceport at VAFB, Spaceport Florida at Cape Canaveral, and the 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 Spaceport Florida.

California Spaceport

On September 19, 1996, the California Spaceport became the first commercial launch site licensed by FAA/AST.[73] In 2001, FAA/AST renewed the spaceport's license for another five years. The California Spaceport is a commercial launch services company operated and managed by Spaceport Systems International (SSI), L.P., 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 34º North latitude, the California Spaceport can support a variety of mission profiles to low polar orbit inclinations, with possible launch azimuths ranging from 220º to 150º.

Initial construction at California Spaceport's Commercial Launch Facility (CLF) began in 1995 and was completed in 1999. The CLF 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 CLF currently is configured to support solid propellant vehicles, plans are in place to equip the CLF with commodities required by liquid fueled boosters. The current configuration of the CLF consists of the following infrastructure: pad deck, support equipment building, launch equipment vault, launch duct and stand, communications equipment, and launch control room. Final CLF configuration awaits customer requirements. When fully developed, the CLF will be able to accommodate a wide variety of launch vehicles including the Minuteman-based Minotaur, the Delta 3, 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 (IPF). Today, payload-processing activities occur on a regular basis. The IPF supports booster processing and administrative activities. The IPF 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 IPF 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.

Spaceport: California Spaceport

Operating authority: SSI/California Spaceport

Year of original FAA license: 1996

Year of first orbital launch: 2000

Total orbital launches: 1

Vehicles served: Delta 3, Minotaur, Castor 120-based vehicles

Orbits served: Polar

The state of California has also provided some support for promoting 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.

With the CLF and the IPF, the California Spaceport provides both payload processing and orbital launch support services for commercial and government users. The California Spaceport provided payload-processing services for the NASA Lewis satellite and has contracts to provide payload processing for two Earth Observation System satellites. The California Spaceport's first orbital launch occurred when it supported the launch 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.

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 of SLC-2W on VAFB.

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.[74] This launch complex is the first new U.S. launch site since the 1960s and is the only FAA/AST-licensed 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 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. There are no permanent range assets currently on site; however, there are plans to build a range safety system that is expected to be operational by March 2003. The system will consist of Global Positioning System tracking, S-band telemetry, and command destruction.

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.

Spaceport: Kodiak Launch Complex

Operating authority: AADC

Year of original FAA license: 1998

Year of first orbital launch: 2001

Total orbital launches: 1

Vehicles served: Athena 1, Athena 2, Castor 120-based vehicles

Orbits served: Polar

Located at 57° North latitude, Kodiak provides a wide launch azimuth and unobstructed downrange flight path. Kodiak's target markets are government and commercial telecommunications, remote sensing, and space science payloads of up to 990 kilograms (2,200 pounds). These can be delivered into 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 sub-orbital rockets.

Kodiak has conducted a total of five launches to date. The first launch from Kodiak was that of a sub-orbital 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.

Spaceport Florida

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.[75] 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 issued the state organization a license for Spaceport Florida's operations on May 22, 1997.

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 a variety of launch vehicle configurations with lift capacities of up to 1,771 kilometers (1,100 miles) to LEO. In the future, LC-46 could accommodate vehicles carrying payloads in excess of 585 kilograms (1,300 pounds) to LEO.

Spaceport: Spaceport Florida

Operating authority: FSA

Year of original FAA license: 1997

Year of first orbital launch: 1998

Total orbital launches: 2

Vehicles served: Athena

Orbits served: LEO, EXT

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 Spaceport Florida in January 1998.

FSA has also recently upgraded LC-20, made up of former Titan 1, Titan 2, and sub-orbital pads, to service a variety of small launch vehicles for both orbital and sub-orbital launches. LC-20 includes three launch pads, a launch control blockhouse, and an on-site facility for small payload preparation and storage. FSA hopes to use these facilities to provide a rapid response capability for various types of LEO payloads. FSA plans to refurbish the LC-20 blockhouse to offer a multi-user launch control and data monitoring system that will serve a variety of vehicle and payload systems. In addition, LC-20 facilities are being assigned to the custody of the Florida National Guard for use in support of NASA's Advanced Technology Development Center, a cryogenic development facility to be co-located at LC-20.

Thus far the FSA has invested over $500 million in new space industry development. It has upgraded LC-46 and LC-20, built a reusable launch vehicle (RLV) support complex (adjacent to the Shuttle landing site on KSC grounds), and developed a new space operations support complex. It has also financed the Atlas 5 launch facilities at CCAFS, financed and constructed the Delta 4 Horizontal Integration Facility for Boeing, and provided financing for a Titan 4 storage/processing facility.

The FSA is in the process of obtaining a five-year license from the Air Force to use the LC-47 facility to support sub-orbital sounding rocket launches and educational initiatives.

The FSA is currently managing the development and construction of the Space Experiments Research and Processing Laboratory. This facility is funded by a $26 million appropriation from the state of Florida. In addition, FSA is directing a $4 million grant from the Florida Department of Transportation for road upgrades in the vicinity of the facility.

Virginia Space Flight Center

The Virginia Space Flight Center (VSFC) traces its beginnings to the Center for Commercial Space Infrastructure (CCSI), created in 1992 at Virginia's Old Dominion University to establish commercial space research and operations facilities in the state.[76] CCSI worked with NASA's Wallops Flight Facility on Wallops Island, Virginia, to develop a commercial launch infrastructure at Wallops. In 1995, CCSI became the Virginia Commercial Space Flight Authority (VCSFA), a public organization focused on developing a commercial launch capability in Virginia.

On December 19, 1997, FAA/AST issued VCSFA a commercial launch site operator's license for the VSFC. 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.

The VCSFA has a partnership agreement with DynSpace Corporation, a subsidiary of DynCorp, of Reston, Virginia, to operate the spaceport. Funded by a contract with the state and through spaceport revenues, DynSpace operates the VSFC for the VCSFA. The state maintains ownership of the spaceport's assets. The federal government owns 90 percent of the spaceport's land and makes it available under a long-term use agreement. The VCSFA receives $700,000 a year in direct support from the state government as well as resources from several state agencies.

VCSFA owns two launch pads at Wallops. Launch pad (LP) 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 LP 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 subsequent phases, a 60-meter (200-foot) service tower and 68,000-kilogram (150,000-pound) bridge crane will be added. The site also includes a complete command, control, and communications interface with the launch range. No launches have yet been conducted from LP 0-B.

Spaceport: Virgnia Space Flight Center

Operating authority: VCSFA

Year of original FAA license: 1997

Year of first orbital launch: N/A

Total orbital launches: 0

Vehicles served: Athena1, Athena 2, Minotaur, Taurus

Orbits served: LEO

In March 2000, VSFC acquired a second pad at Wallops, LP 0-A. EER Systems of Seabrook, Maryland, built this site in 1994 for its Conestoga launch vehicle. The Conestoga made one launch from LP 0-A in October 1995 but failed to place the METEOR microgravity payload in orbit. VSFC started refurbishing LP 0-A and its 25-meter (82-foot) service tower in June 2000, a project it expects to complete in April 2002. LP 0-A will support launches of small ELVs with gross liftoff weights of up to 90,000 kilograms (198,000 pounds), capable of placing up to 1,350 kilograms (3,000 pounds) into LEO.

From its location on Virginia's southeastern 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. LP 0-A can support a number of small solid-propellant boosters, including the Athena 1, Minotaur, and Taurus. LP 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, and inspection to ensure 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, capable of handling payloads up to 5,700 kilograms (12,600 pounds). The facility, which includes high bay and clean room environments, is scheduled for completion in October 2003.

Proposed Commercial 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 their inland geography-a contrast to the coastal location of all present-day U.S. spaceports-as well as their interest in hosting RLV operations. Descriptions of specific efforts to establish spaceports are presented below and summarized in Table 7. All states from which these proposals have emerged are full members of the NCSS.

Alabama Spaceport

The Alabama Spaceport plans to create a full-service launch facility with departure and return capability for government and commercial customers.[77] It is targeting 3rd generation RLVs for launches to LEO, medium-Earth orbits (MEO), and geosynchronous (GEO) orbits and expects to become operational in ten years. The Alabama Commission on Aerospace and the governor's office are working to develop the Alabama Aerospace Development Authority and are in the process of creating a spaceport development plan. The Alabama Commission on Aerospace has proposed Baldwin County, across the bay from the city of Mobile, as the site for a future spaceport. The state of Alabama would like to lease part of the land for the flight safety zone and would purchase part of the land for construction of the launch and landing site. The proposed site currently consists of open field space with basic power, water, and utilities. Future launch infrastructure development will depend on customer needs.

Gulf Coast Regional Spaceport

The Gulf Coast Regional Spaceport is one of three independent Texas spaceport proposals being supported by the Texas Aerospace Commission.[78] The Gulf Coast Regional Spaceport Development Corporation has proposed constructing a spaceport in Brazoria County, Texas, 80 kilometers (50 miles) south of Houston, which would begin operations in ten to 15 years. The spaceport would be used primarily for medium- and heavy-lift commercial RLVs to LEO, MEO, and GEO. The Corporation has identified a potential site—undeveloped land currently used for agriculture—and is working with the private owner of the land to acquire the property. The Corporation is currently working on an official development plan for the spaceport that will determine what infrastructure is necessary. Local governments have invested nearly $300,000 in the project over the last three years, primarily for site selection work.

Mojave Civilian Flight Test Center

The East Kern County, California, government established the Mojave Airport in 1935 in Mojave, California.[79] The original facility was equipped with taxiways and basic support infrastructure for general aviation. A few years later, the airport was taken over by the federal government and converted into a Marine Corps auxiliary air station. In 1961, East Kern County re-acquired the airport and turned the facility into the Civilian Flight Test Center.

East Kern Airport owns and operates the facility and the local government is in the process of creating a development plan for the 13.4 square kilometers (5.1 square miles) on which the Civilian Flight Test Center is located. The spaceport would conduct payload processing, payload integration, testing, and launch services for horizontal launches of RLVs.

The Civilian Flight Test Center consists of four rocket test sites, three runways, an air control tower, a rotor test stand, engineering facilities, and a high bay building. Plans to build another taxiway are being developed. East Kern County is working on the preliminary planning stage for the taxiway, and funding is expected to become available in October 2002. Construction of the new taxiway is scheduled for completion in 2003.

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. Between 1998 and 2000, Rotary Rocket Company used a small portion of the Mojave site for manufacturing and testing. During those years, Rotary built its Rotor Test Stand and a complex that included an engineering “workshop and campus” and a high bay. The infrastructure that was constructed by Rotary still exists, although the company is in the process of selling its facilities.

Montana Spaceport

The state of Montana established the Montana Space Development Authority under the state’s Department of Commerce to coordinate and lead Montana’s commercial space efforts.[80] Montana’s space strategy involves creating the organizational and educational infrastructure necessary to support state space activities and to ultimately construct a licensable commercial spaceport.

The state of Montana has $20 million in aerospace bonding (state general obligation bonds) available to finance activities directly related to aerospace research and development or the development of spaceport infrastructure. Commercial proposals for incentive financing will be evaluated in terms of the number of jobs created and tax revenues generated by the project. Companies will not have to repay the state for any bonding covered by increased tax revenues.

Montana had proposed to launch RLVs from two sites: one site is at Malmstrom AFB in Great Falls, Montana and the other is a former military base in Glasgow, Montana. In 2000, the spaceport worked with officials from both Lockheed Martin’s VentureStar™ program and Rotary Rocket to bring commercial space launch to the state. The Montana Space Development Authority had begun consultations with FAA/AST to apply for a commercial spaceport license for the Great Falls site; however, since the VentureStar™ program has been cancelled, the licensing process has been put on hold. The future of the spaceport is uncertain, and the state of Montana is not actively pursuing development of the spaceport at this time.

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.[81] Kistler Aerospace Corporation selected it as a spaceport for the K-1 RLV in addition to their Woomera, Australia, facility in order to increase scheduling flexibility and to widen the range of launch azimuths available to customers. Although it does not have any launch infrastructure, the Nevada Test Site has existing basic infrastructure such as a paved runway, water, roads, and power that can be used to support launch and landing activities.

The Nevada Test Site Development Corporation obtained an economic development use permit in 1997 from the U.S. Department of Energy. Shortly thereafter, the Corporation issued a sub-permit allowing Kistler to operate a launch and recovery operation at the Nevada Test Site.

Oklahoma Spaceport

The state of Oklahoma is interested in developing a broader space industrial base and a spaceport.[82] 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. A year earlier, the legislature passed a law creating the Oklahoma Space Industry Development Authority (OSIDA). OSIDA, consisting of five full-time employees and directed by seven governor-appointed board members, promotes the development of spaceport facilities, space exploration, space education, and space-related industries in Oklahoma. The state of Oklahoma provides operating costs for the OSIDA.

The former Clinton-Sherman AFB at Burns Flat is one of the designated sites for a future spaceport in Oklahoma. Existing infrastructure includes a 4,100-meter (13,500-foot) runway, a large hangar space, utilities, a rail spur, and 12.4 square kilometers (4.8 square miles) of open land. There are plans to build a rocket engine manufacturing plant and training facilities. The OSIDA expects to break ground in June 2002 to begin construction of these facilities.

The city of Clinton currently owns the spaceport and will convey ownership to the OSIDA in the near future. As an inland site, the Oklahoma Spaceport will be limited to launch and support services for RLVs and may become operational in late 2006 or early 2007. The OSIDA has signed a memorandum of understanding with Pioneer Rocketplane for Pioneer’s use of the Burns Flat site along with six other vehicle companies. In September 2001, the OSIDA also signed a memorandum of understanding with FAA/AST to define each of their roles in the development and licensing of the commercial spaceport.

South Dakota Spaceport

The state of South Dakota has identified a site in the western part of the state, near Ellsworth AFB, where it could construct a spaceport.[83] While South Dakota may own a portion of the proposed spaceport site, the spaceport's operating entity has not been determined. Most of South Dakota's planning to date has come in response to NASA and private expressions of interest in a South Dakota spaceport. All planning to date has involved a mix of local and state officials and members of the National Guard. No infrastructure exists, and the size of the site and any future infrastructure will depend on government or commercial needs.

Southwest Regional Spaceport

The state of New Mexico proposes to construct and operate the Southwest Regional Spaceport for use by private companies and government organizations conducting space activities and operations.[84] 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. The spaceport proposal is to support all classes of RLVs serving equatorial, polar, and ISS orbits, providing support for payload integration, launch, and landing. The facility will be able to accommodate vertical launches and horizontal landings and include two launch complexes, a landing strip, an aviation complex, a payload assembly complex, support facilities, and a cryogenic plant.

The Southwest Regional Spaceport is supported by the state through the New Mexico Office of 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. However, this funding 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 tax deductions, bonds, and investment and job training credits.

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.[85] 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.

Utah Spaceport Authority

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.[86] 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 proposes 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. However, the proposed spaceport would include construction of a new 4,575-meter-long (15,000-foot-long) space vehicle recovery and aircraft runway at an elevation of 1,525 meters (5,000 feet) above sea level and two space-vehicle launch facilities located 2,300 meters (7,550 feet) above sea level. Additionally, assembly, testing, processing, and office facilities would be constructed.

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 VentureStarTM programs. No additional action is being taken at this time.

West Texas Spaceport

The West Texas Spaceport is one of the three Texas spaceport proposals being supported by the Texas Aerospace Commission.[87] The Pecos County/ West Texas Spaceport Development Corporation, established in mid-2001, has proposed the development of a spaceport 16 kilometers (10 miles) south of Fort Stockton, Texas. The spaceport would serve vertical-takeoff and -landing RLVs, with a particular emphasis on Kistler Aerospace Corporation's K-1, as well as sub-orbital sounding rockets. The spaceport would 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. The spaceport would be able to support launches into GEO, SSO, and ISS orbit.

Willacy County Spaceport

The Willacy County Spaceport is one of the three Texas spaceport proposals being supported by the Texas Aerospace Commission.[88] In December 2001, the Willacy County Commissioners Court established the Willacy County Development Corporation for Spaceport Facilities. The Corporation is investigating the feasibility of developing a spaceport on a 40-square-kilometer (15.4-square-mile) parcel of unused land on the Gulf coast, 150 kilometers (93 miles) south of Corpus Christi. The spaceport would be designed primarily to support commercial RLVs, although some expendable orbital and sub-orbital rockets could also use the facility. The Willacy County project replaces an earlier proposal for a spaceport in neighboring Kenedy County, 65 kilometers (40 miles) to the north, which met opposition from county residents.

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.[89] The goal of the spaceport is to support space research and education through sub-orbital launches for student projects. The city of Sheboygan owns the spaceport; "Rockets for Schools," a program run by Space Explorers, Inc., and developed by the Aerospace States Association runs the student program. The spaceport began operating approximately four years ago. While sub-orbital sounding rocket launches to altitudes of up to 55 kilometers (34 miles) have been conducted to date, future plans include adding the capability of orbital launches of RLVs. The existing infrastructure includes a vertical pad for sub-orbital launches in addition to portable launch facilities, such as mission control, which are put up and taken down as needed. Plans for developing launch infrastructure are uncertain at this time.

Table 5: Federal Spaceports: Infrastructure and Status

Federal Spaceports				
Spaceport	Location	Owner/Operator	Launch Infrastructure at Site	Current Development Status
Cape Canaveral Spaceport (CCAFS/KSC)	Cocoa Beach, 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.	Development of RLV spaceport and processing facilities is in progress.
Edwards AFB	Mojave, California	U.S. Air Force	Telemetry and tracking facilities, jet and shuttle capable runways, X-33 launch pad, operations control center, movable hangar, fuel tanks, 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 runway.	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	Launch pads, blockhouses and processing facilities.	Wallops Flight Facility has not supported any orbital flights since the failure of Conestoga in 1995. NASA is committed to maintain 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 Commercial Spaceports: Infrastructure and Status

Licensed Commercial Spaceports				
Spaceport	Location	Owner/Operator	Launch Infrastructure at Site	Current Development Status
California Spaceport	Lompoc, California	Spaceport Systems International, L.P.	Existing launch pads, runways, payload processing facilities, telemetry and tracking equipment.	Currently in place are the concrete flame ducts, communication, electrical, and water infrastructure.
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 for the launch control center, the payload processing facility and the integration and processing facility were completed in 2000.
Spaceport Florida	Cocoa Beach, Florida	Florida Space Authority (FSA)	Two launch complexes including pads and a control center, a small payload preparation facility and an RLV support facility.	FSA has invested over $200 million to upgrade LC 46 and LC 20, build an RLV support complex adjacent to the Shuttle landing facilities, and develop a new space operation support complex.
Virginia Space Flight Center	Wallops Island, Virginia	Virginia Commercial Space Flight Authority	Launch pad and service tower, payload processing facility, downrange tracking facility.	Pad 0-B was completed in December 1998. VSFC obtained a commercial license from the FAA in 1997.

Table 7: Proposed Commercial Spaceports: Infrastructure and Status

Proposed Commercial Spaceports				
Spaceport	Location	Owner/Operator	Launch Infrastructure at Site	Current Development Status
Alabama Spaceport	Baldwin County, Alabama	Alabama Commission on Aerospace	No launch infrastructure at this time. Basic utilities infrastructure available.	Plans for developing launch infrastructure are uncertain at this time
Mojave Civilian Flight Test Center	Mojave, California	Mojave Airport Authority	Air control tower, runway, rotor test stand, engineering facilities, high bay building.	The infrastructure in place is part of a $5.5 million project.
Montana Spaceport	Great Falls, Montana	Montana Space Development Authority	No infrastructure at this time.	Montana Spaceport is primarily seeking RLV business. The Montana Space Development Authority is in the process of obtaining a commercial spaceport license for the Great Falls site.
Nevada Test Site	Nye County, Nevada	Department of Energy/Nevada Test Site Development Corporation (NTSDC)	No launch infrastructure at this time. Power and basic facilities available.	NTSDC has issued a sub-permit allowing Kistler to operate a launch and recovery operation. NTSDC is actively promoting the site as a spaceport for both RLVs and conventional launchers.
Oklahoma Spaceport	Washita County, Oklahoma	Oklahoma Space Industry Development Authority (OSIDA)	4,130-meter (13,552-foot) main runway and 1,000-meter (3,280-foot) overrun. Power and basic facilities available. Air control tower, high bay hangers (B-52 size).	OSIDA designated the old Clinton-Sherman AFB at Burns Flat as the future spaceport. No state money has been allocated for development yet.
South Dakota Spaceport	Near Ellsworth AFB, South Dakota	To be determined	No infrastructure at this time.	All planning to date has involved a mix of local and state officials and members of the National Guard
Southwest Regional Spaceport	White Sands, 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 operation control center, and a cryogenic plant.
Spaceport Washington	Grant County International Airport, Washington	Port of Moses Lake	4,100-meter (13,452-foot) main runway and a 3,200-meter (10,500-foot) crosswind runway.	The site is certified as an emergency-landing site for the Space Shuttle. No additional infrastructure has been planned for the site.
Texas Spaceport	To be determined	State of Texas Spaceport Authority	No infrastructure at this time.	The final Texas Spaceport site(s) has not been selected yet. Three sites are being considered at this time.
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, a maintenance and integration facility for both payloads and craft, launch pads, a flight operation control center, and a propellant storage facility.
Wisconsin Spaceport	Sheboygan, Wisconsin	Owner: City of Sheboygan; Operator: Rockets for Schools	A vertical pad for sub-orbital launches in addition to portable launch facilities, such as mission control.	Plans for developing additional launch infrastructure are uncertain at this time.

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