2003 U.S. Commercial Space Transportation Developments and Concepts: Vehicles, Technologies, and Spaceports

Associate Administrator for Commercial Space Transportation
Federal Aviation Administration
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About the Associate Administrator for Commercial Space Transportation

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

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List of Acronyms

AADC - Alaska Aerospace Development Corporation

ACES - Air Collection and Enrichment System

AFB - Air Force Base

AST - Associate Administrator for Commercial Space Transportation

CCAFS - Cape Canaveral Air Force Station

COBRA - Co-optimized Booster for Reusable Applications

DARPA - Defense Advanced Research Projects Agency

DoD - U.S. Department of Defense

EELV - Evolved Expendable Launch Vehicle

ELI - Elliptical Orbit

ELV - Expendable Launch Vehicle

FAA - Federal Aviation Administration

FSA - Florida Space Authority

GEO - Geosynchronous Earth Orbit

GTO - Geosynchronous Transfer Orbit

ICBM - Inter-Continental Ballistic Missile

ISS - International Space Station

ISTAR - Integrated System Test of an Air-breathing Rocket

ISTP - Integrated Space Transportation Plan

KSC - Kennedy Space Center

LC - Launch Complex

LEO - Low Earth Orbit

LOX - Liquid Oxygen

MEO - Medium Earth Orbit

MIPCC - Mass-Injected Pre-Compressor Cooling

NASA - National Aeronautics and Space Administration

NCSS - National Coalition of Spaceport States

NGSO - Non-Geosynchronous Orbit

OSIDA - Oklahoma Space Industry Development Authority

RASCAL - Responsive Access, Small Cargo, and Affordable Launch

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, *2003 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 Associate Administrator for Commercial Space Transportation (FAA/AST) first published the report in 1998 with an exclusive focus on reusable launch vehicles (RLV). The current edition addresses not only RLVs but also expendable launch vehicles (ELV), propulsion technologies, and launch and reentry sites—commonly referred to as "spaceports"—to provide a complete picture of the U.S. commercial space transportation industry.

This report objectively reviews space transportation programs and projects as well as launch and reentry sites that will impact and support the development of commercial space activities and applications. The private sector plays a prominent role in the management, development, and funding of these activities; the federal government and several state governments substantially contribute to or provide leadership for many of the technologies and facilities described herein as well. 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

Although commercial launch activity remained lower than in recent past years, the year 2002 was a milestone for the U.S. ELV industry. The two Evolved Expendable Launch Vehicles (EELV)—the Boeing Company's Delta 4 and Lockheed Martin Corporation's Atlas 5—made their inaugural flights in 2002, each carrying satellites owned by the French company Eutelsat. These boosters represent a new generation of medium- and heavy-lift launchers for both commercial and government payloads. Both launcher companies intend to phase out the older Atlas and Delta variants in the upcoming years as the EELV boosters enter service and as the launch market warrants.

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. One company, the Space Exploration Technologies Corporation, or Space X, intends to make the first launch of its Falcon ELV as early as the end of 2003. Indeed, there should be a number of key developments for these ELVs during the year as they pursue private investment and construct and test components needed for future launches.

Reusable Launch Vehicle Industry

The Space Shuttle remains the first and only currently operational, partially reusable launch vehicle.[1] Development of new RLVs nonetheless remains of great interest to many national governments and private companies. The appeal of RLVs rests in their ability not only to launch from but also to return to Earth for reuse—a quality desirable for various types of missions, including human trips to and from space. Many also have considered RLV development attractive because the construction cost of an RLV could be amortized over multiple launches, thus potentially reducing the cost of access to space for government and commercial users.

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

Once again, limited funds and competing performance requirements have forced NASA to reevaluate its RLV development efforts. In 2002 NASA proposed in an amendment to its fiscal year 2003 budget a new ISTP to better coordinate its space transportation efforts with its International Space Station (ISS) and science and research needs. The proposed ISTP continues to support the Space Shuttle but restructures SLI to accommodate the near-term development of an ISS crew transfer vehicle called the Orbital Space Plane and the continued support of future generations of launch technology. As a result of a recent NASA-Air Force joint study, the two agencies may work together to develop RLVs that meet mutual requirements.

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

Despite the challenges, the commercial RLV industry remained resilient in 2002. Several commercial RLV companies remain committed to the goal of developing and operating their vehicles and are aggressively pursuing private investment. Many have abandoned NGSO payloads as their target market in favor of human space travel, which now seems to be a more promising enterprise. In addition, twenty organizations are vying for the X PRIZE®, several of which entered contention in 2002. At least one contender has begun testing its vehicle concepts.

Finally, the year 2002 underscored the fact that "RLV" may prove to be an ambiguous term as "hybrid" vehicles emerge. In 2002 the Defense Advanced Research Projects Agency (DARPA) awarded contracts to six companies to develop designs for its Responsive Access, Small Cargo, and Affordable Launch (RASCAL) program, which may yield a vehicle that can meet the demand for launch on short notice. The contending designs combine reusable and expendable stages.

Enabling Technologies

There are a number of efforts underway to develop new propulsion technologies for launch vehicles, including ELVs and RLVs. These efforts include government-funded research projects as well as engines and motors being developed by companies for their own launch vehicles and for sale to other companies. NASA's SLI is funding several companies to conduct propulsion work. There is a trend of development of new liquid-propellant engines that use room-temperature propellants instead of cryogens or pressure-fed systems instead of turbopumps. These engines are considerably less complex, and potentially less expensive, than engines that use turbopumps and cryogenic propellants.

Spaceports

Launch and reentry sites—often referred to as "spaceports"—may house launch pads and runways as well as the infrastructure, equipment, and fuels needed to process launch vehicles and their payloads prior to launch. While U.S. military and civil government agencies were the original and still are the primary developers and users of launch facilities, commercial launch activity now comprises a substantial portion of federal launch site operations. One of the recent major developments at federal launch sites that will benefit both commercial and government payload customers was the construction of new launch infrastructure at the two major federal sites—Cape Canaveral Spaceport and Vandenberg Air Force Base (VAFB)—to support the Delta and Atlas EELVs. These facilities were developed with commercial, federal, and state government funds.

The commercial dimension of U.S. space activity is evident not only in the numbers of commercially-procured launches but also in the list of non-federal launch sites supplementing federally operated sites. FAA/AST has licensed the operations of spaceports in four different U.S. states, and these sites are currently available to serve commercial as well as government payload owners. With the launch market rather low, however, these spaceport operators now are also seeking out new opportunities such as payload processing and space research facility development. Organizations in several states nonetheless see the potential of spaceports to accommodate future RLVs and are actively working to turn their spaceport visions into reality.

2002 Highlights

January 25: Aerojet delivered to NASA the deorbit propulsion stage for the X-38, a prototype of a proposed crew return vehicle for the International Space Station (ISS).

February 6: Boeing Phantom Works completed the construction of the wings for the X-37, an experimental reusable launch vehicle technology demonstrator, and shipped them to the X-37 assembly facility in Palmdale, California.

February 11: A Boeing Delta 2 7920 launched five replacement spacecraft for Iridium Satellite LLC from Vandenberg Air Force Base (VAFB).

February 21: A Lockheed Martin Atlas 3B launched the EchoStar 7 direct television broadcasting satellite for EchoStar from Cape Canaveral Air Force Station (CCAFS). The launch was the first for the Atlas 3B.

March 11: Space Adventures, Ltd., and US Airways announced a partnership to offer the airline's frequent flyer club members the opportunity to redeem or earn miles for a variety of space-related activities. The agreement marked the first time an airline has offered to apply or award mileage for space travel.

March 23: The Oklahoma Space Industry Development Authority (OSIDA) officially opened the Oklahoma Spaceport at Burns Flat, Oklahoma, with the ceremonial launch of high-altitude balloons.

March 25: InterOrbital Systems signed up its first passenger, Wally Funk, for an orbital ride on its Neptune Spaceliner, currently in development. Ms. Funk trained with the Mercury 7 astronauts but never flew in space. The cost of her ticket is estimated to be $2 million.

March 28: NASA's Marshall Space Flight Center began hot-fire tests of a liquid-oxygen/liquid-hydrogen reaction control engine built by TRW as part of the Space Launch Initiative (SLI).

April 10: Aerojet validated the design for a tri-fluid propellant injector for a hydrogen peroxide engine for use on the Advanced Reusable Rocket Engine, an engine Aerojet is designing for the U.S. Air Force's Space Maneuver Vehicle.

April 19: The Defense Advanced Research Projects Agency (DARPA) awarded six Phase 1 contracts for its Responsive Access, Small Cargo, and Affordable Launch (RASCAL) air-launch program. Winners were Coleman Research Corporation; Northrop Grumman Corporation; Pioneer Rocketplane Corporation; Space Launch Corporation; Space Access, LLC; and Delta Velocity.

April 29: NASA announced its cancellation of the X-38 program to allow the space agency to focus its resources on other aspects of the ISS program.

April 30: The SLI program completed its first milestone review, the Initial Architecture Technology Review, narrowing the number of proposed reusable launch vehicle (RLV) architectures to 15.

May 20: The Co-optimized Booster for Reusable Applications (COBRA), a liquid-oxygen liquid-hydrogen engine developed by Pratt & Whitney and Aerojet for SLI, passed its preliminary design review.

May 21: NASA and the U.S. Air Force announced that they agreed with the conclusions of a 120-day study completed in February by the two organizations, which called for continued study of a jointly-developed RLV.

May 22: The Federal Aviation Administration/Associate Administrator for Commercial Space Transportation (FAA/AST) renewed the license for the Florida Space Authority to conduct spaceport operations for another five years.

June 5: Boeing announced plans to develop the RS-84, a liquid-oxygen and kerosene engine capable of producing 4.68 million newtons (1.05 million pounds force) of thrust, for SLI.

June 15: A Sea Launch Zenit 3SL launched the Galaxy 3C communications spacecraft from a mobile platform on the Equator in the Pacific Ocean.

July 22: XCOR Aerospace and Space Adventures, Ltd., announced plans to develop Xerus, a reusable suborbital launch vehicle capable of carrying a pilot and one passenger to an altitude of 100 kilometers (62 miles). The vehicle will be built by XCOR and marketed for commercial space tourism flights by Space Adventures.

July 30: A Terrier-Orion Mk 70 sounding rocket launched the Hyshot hypersonic flight experiment payload from Woomera Test Range, Australia. The flight marked the first successful flight test of a scramjet, a supersonic combustion air-breathing engine.

August 21: A Lockheed Martin Atlas 5 401 launched the Hot Bird 6 communications spacecraft for Eutelsat from CCAFS. The launch was the first for the Atlas 5, a vehicle developed as part of the Evolved Expendable Launch Vehicle (EELV) program.

August 22: The Pecos County/West Texas Spaceport Development Corporation signed a contract with JP Aerospace for use of the *Las Escaleras a las Estrellas* ("Stairway to the Stars") spaceport. JP Aerospace plans to use the facility to loft balloons carrying rockets that will launch microsatellite payloads under a contract the company has with the Air Force.

August 28: Kennedy Space Center, CCAFS, and Florida Space Authority officials released a 50-year master plan for the development of the Cape Canaveral Spaceport.

September 5: The U.S. Army and the State of New Mexico signed a Memorandum of Agreement permitting the development of a commercial spaceport at White Sands Missile Range.

September 18: A Lockheed Martin Atlas 2AS launched the Hispasat 1D communications satellite from CCAFS.

September 28: Armadillo Aerospace conducted the first piloted, low-level flight test of its vertical-take-off/vertical-landing technology testbed vehicle.

September 30: NASA terminated SLI funding for the COBRA engine, electing to focus on other engine development programs.

October 5: The Pecos County/West Texas Spaceport had its first launch: a 4.3-meter (14-foot) rocket built by JP Aerospace that reached an altitude of 6,100 meters (20,000 feet) in 34 seconds.

October 8: NASA and the Air Force signed a memorandum of agreement concerning RLV development, dividing responsibilities and increasing cooperation between NASA's SLI and the Air Force's National Aerospace Initiative.

October 21: NASA announced the postponement of the SLI System Requirements Review, originally scheduled for November. No future date was announced.

November 13: NASA released a revised version its Integrated Space Transportation Plan (ISTP). The new ISTP de-emphasizes the development of a second-generation RLV in favor of general RLV technology research. The ISTP also includes a new Orbital Space Plane to be launched atop an expendable launch vehicle to ferry crews to the ISS, with first flight planned for 2010. The Administration submitted to Congress a request to amend NASA's FY 2003 budget to transfer some SLI funding to the Space Shuttle and Orbital Space Plane programs.

November 20: A Boeing Delta 4 Medium-Plus (4,2) launched the Eutelsat W5 communications satellite from CCAFS. The launch was the first for the Delta 4, developed as part of the EELV program.

November 20: NASA awarded Boeing Phantom Works a $301 million contract to complete the X-37. The contract covers a series of atmospheric landing tests in mid-2004 and an orbital test flight in mid-2006. NASA also awarded Lockheed Martin a $53 million contract to develop a reusable system to test technologies in a launch pad abort situation.

December 19: FAA/AST renewed the license for the Virginia Commercial Space Flight Authority (VCSFA) to operate the Virginia Space Flight Center (VSFC) spaceport for another five years.

Expendable Launch Vehicles

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

Current ELV Systems

The ELV systems available in the United States today are summarized in Table 1.[2] Three ELVs—Minotaur, Titan 2, and Titan 4B—are restricted to government payloads.[3] The remaining six—Athena, the Atlas variants, the Delta variants, Pegasus, Taurus, and Zenit 3SL (the Sea Launch vehicle)—are available for commercial use; all but the Zenit 3SL can also carry U.S. government payloads. The two newest members of the U.S. launcher stable, the Atlas 5 and Delta 4 Evolved Expendable Launch Vehicles (EELV), made their debuts in 2002. The other Atlas and Delta boosters will be gradually phased out in favor of the EELV variants as market conditions warrant.

Athena - Lockheed Martin Corporation

The Athena family of launch vehicles was created by Lockheed Martin to serve the small satellite market. Lockheed started development of what was first known as the Lockheed Launch Vehicle in 1993; the vehicle became the Lockheed Martin Launch Vehicle after Lockheed's merger with Martin Marietta in 1995 and was renamed the Athena in 1997. The Athena vehicles use Castor 120 solid-propellant motors: the Athena 1 uses a single Castor 120 as its first stage, while the larger Athena 2 uses Castor 120 motors for its first and second stages for enhanced payload performance. Both vehicles also use either one solid and one liquid or two solid and two liquid propellant upper stages.[4]

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

Atlas Family - Lockheed Martin Corporation

The Atlas launch vehicle family traces its roots to the development of the Atlas inter-continental ballistic missile (ICBM) in the 1950s. The Atlas family is in a stage of transition as older versions of the vehicle, the Atlas 2A and Atlas 2AS, as well as the Atlas 3A and Atlas 3B, gradually will be retired to make way for the Atlas 5 EELV. For the next few years, all three Atlas variants will be in service to launch commercial and government payloads.

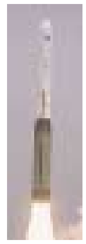
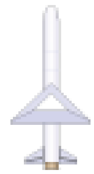
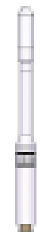
Atlas 2

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

Atlas 3

The Atlas 3A and Atlas 3B represent a transition between the older Atlas vehicles and the Atlas 5 EELV. The Atlas 3 abandons the stage-and-a-half design of the older Atlases for a single RD-180 main engine developed by the Russian company NPO Energomash and marketed under a joint Russian-American partnership with Pratt & Whitney. The RD-180 is a derivative of the RD-170 used by the now-defunct Russian Energia heavy-lift launch vehicle. Because the RD-180 has 70-percent component commonality with the proven RD-170, it was less risky to develop than a totally new design while giving better performance than available U.S.-built engines. The Atlas 3A, introduced in 2000, uses

Table 1: Currently Available Expendable Launch Vehicles

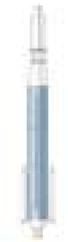
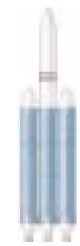
	Small				Medium	
						
Vehicle	Athena	Minotaur	Pegasus	Taurus	Delta 2	Titan 2
Company	Lockheed Martin	Orbital Sciences	Orbital Sciences	Orbital Sciences	Boeing	Lockheed Martin
First Launch	1995	2000	1990	1994	1990	1988*
Stages	3 (Athena 1) 4 (Athena 2)	4	3	4	3	2
Payload Performance (LEO)	820 kg (1,805 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
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.)
Payload Performance (GTO)	N/A	N/A	N/A	N/A	1,870 kg (4,120 lbs.)	N/A
Launch Sites	CCAFS, VAFB, Kodiak	VAFB	CCAFS, WFF,** VAFB, EAFB, Kwajalein, Canary	VAFB	CCAFS, VAFB	VAFB

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

a single-engine Centaur upper stage. The Atlas 3B, first launched on February 21, 2002, uses a stretched Centaur upper stage with one or two engines. The Atlas 3 will be phased out in favor of the Atlas 5 by mid-decade. One Atlas 3A and two Atlas 3B launches are scheduled for 2003.

Atlas 5

The Atlas 5 family of launch vehicles, developed under the EELV program, is based on a common first stage design known as the Common Core Booster™ that uses the NPO Energomash RD-180 engine introduced on the Atlas 3. In order to meet national security requirements, Pratt & Whitney was selected to build this engine in the United States for government uses 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. The stretched version of the Centaur upper stage introduced on the Atlas 3B is also used on the Atlas 5, in both single- and dual-engine versions. The first Atlas 5 launch took place on August 21, 2002, when an Atlas 5 401 vehicle successfully launched the Eutelsat Hot Bird 6 spacecraft from CCAFS.

	Intermediate					Heavy		
								
Vehicle	Delta 3	Delta 4	Atlas 2	Atlas 3	Atlas 5	Delta 4 Heavy	Titan 4B	Zenit 3SL
Company	Boeing	Boeing	Lockheed Martin	Lockheed Martin	Lockheed Martin	Boeing	Lockheed Martin	Sea Launch
First Launch	1998	2002	1990	2000	2002	2003	1997	1999
Stages	2	2	2	2	2	2	2	3
Payload Performance (LEO)	8,290 kg (18,280 lbs.)	8,120 kg (17,905 lbs.) (Delta 4 M) 11,475 kg (25,300 lbs.) (Delta 4 M+ (5,4))	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)	10,300 kg (22,711 lbs.) (Atlas 5 502) 20,520 kg (45,250 lbs.) (Atlas 5 552)	23,040 kg (50,800 lbs.)	21,680 kg (47,800 lbs.)	N/A
Payload Performance (LEO polar)	N/A	6,870 kg (15,150 lbs.) (Delta 4 M) 10,400 kg (22,930 lbs.) (Delta 4 M+ (5,4))	6,190 kg (13,650 lbs.) (Atlas 2A) 7,210 kg (15,900 lbs.) (Atlas 2AS)	N/A	N/A	20,800 kg (45,865 lbs.)	17,600 kg (38,800 lbs.)	N/A
Payload Performance (GTO)	3,810 kg (8,400 lbs.)	4,210 kg (9,285 lbs.) (Delta 4 M) 6,565 kg (14,480 lbs.) (Delta 4 M+ (5,4))	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)	3,970 kg (8,750 lbs.) (Atlas 5 501) 8,670 kg (19,120 lbs.) (Atlas 5 551)	13,130 kg (28,950 lbs.)	5,760 kg (12,700 lbs.) (GEO)	6,000 kg (13,230 lbs.)
Launch Sites	CCAFS	CCAFS, VAFB	CCAFS, VAFB	CCAFS	CCAFS	CCAFS, VAFB	CCAFS, VAFB	Pacific Ocean

The Atlas 5 also marks a significant departure in launch preparations compared to previous Atlas versions. The Atlas 5 is prepared for launch in a vertical configuration in an assembly building near the pad. Hours before launch, it is moved out to the pad fully prepared for launch.

The Atlas 5 is available in the 400 and 500 series and will accommodate 4-meter (13.1 foot) and 5-meter (16.4-foot) fairings and up to five strap-on solid rocket motors. The Atlas 400 series can place payloads between 4,950 and 7,640 kilograms (10,910 and 16,843 pounds) into geosynchronous transfer orbit (GTO), while the Atlas 500 series can place payloads between 3,970 and 8,670 kilograms (8,750 and 19,120 pounds) into GTO. Lockheed Martin is designing but has chosen not to produce a heavy version of the Atlas 5 at this time. Unlike the Delta 4, the Atlas 5 will only be launched from CCAFS. Two commercial Atlas 5 launches are currently scheduled for 2003.[5]

Delta Family - The Boeing Company

The Delta family of launch vehicles can trace its heritage to the Thor missile program of the

1950s. Like the Atlas program, the Delta family is undergoing a transition prompted by the introduction of the Delta 4 vehicles developed under the EELV program. The older Delta 2 and Delta 3 vehicles will eventually be phased out, although the Delta 2 is likely to remain in service through most of this decade.

Delta 2

The Delta 2 uses a liquid-oxygen (LOX)-kerosene first stage and a nitrogen tetroxide-Aerozine second stage, along with an optional solid-propellant upper stage. The Delta 2 can also use between three and nine strap-on solid rocket motors, depending on the performance required. A "heavy" version of the Delta 2, which uses the larger graphite epoxy motors 46 strap-on boosters developed for the Delta 3, will enter service in early 2003 with the launch of NASA's Space Infrared Telescope Facility spacecraft. Although the Delta 2's small payload capacity has limited its usefulness for commercial GTO payloads, it is expected to remain in service through most of the decade, primarily launching military and civil government payloads. Up to 12 government Delta 2 launches are planned for 2003.[6]

Delta 3

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 graphite epoxy motors 46 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 inaugural launch attempts in 1998 and 1999, the Delta 3 successfully launched a test payload in August 2000; no Delta 3 launches have taken place since then. Boeing plans to phase out the Delta 3 as the Delta 4 becomes operational.[7]

Delta 4

The Delta 4 family of launch vehicles has a common booster core first stage that uses the first new large liquid rocket engine developed in the United States since the Space Shuttle Main Engine (SSME), which was designed in the 1970s. This engine, the Rocketdyne RS-68, is based on the J-2 engine used on the second stage of the Saturn 5 launch vehicle and technology from the SSME. It is, however, both larger and simpler than the SSME. The RS-68 can be 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. The first Delta 4 launch took place on November 20, 2002, successfully lofting the Eutelsat W5 spacecraft from 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 common booster core, and one heavy-lift version that will use three parallel common booster core stages. Three of these versions, the Delta 4 Medium-Plus vehicles, will be optimized for commercial use. The Medium and Heavy versions are largely intended for government use. Payload capacities to low Earth orbit (LEO) range from 8,120 kilograms (17,905 pounds) for the Medium to 23,040 kilograms (50,800 pounds) for the Heavy; GTO capacities range from 4,210 to 13,130 kilograms (9,285 to 28,950 pounds). Boeing plans to replace the Delta 3 with the Delta 4 over the next few years; subsequently, Boeing expects to phase out the Delta 2. Up to eight Delta 4 launches are scheduled for 2003, including the first flight of the Heavy variant.

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 period of time. In addition to making the launch vehicle easier to work on by keeping it closer to the ground, this integration method also greatly reduces time spent occupying the launch pad. Boeing expects to reduce pad time from Delta 2's 24 days to a period of about a week for the Delta 4. Since the availability of launch pads is one of the factors limiting launch rates, Boeing's integration process contributes to the economic advantages that are a major part of the EELV program's goals.[8]

Minotaur - Orbital Sciences Corporation

The Orbital/Suborbital Program Space Launch Vehicle, also known as Minotaur, was developed by Orbital Sciences Corporation under contract to the U.S. Air Force to launch small government payloads.

The booster uses a combination of rocket motors from decommissioned Minuteman 2 ICBMs and upper stages from Orbital's Pegasus launch vehicle. The Minotaur's first two stages are Minuteman 2 M-55A1 and SR-19 motors, and the upper two stages are Orion 50 XL and Orion 38 motors from the Pegasus XL. All four stages use solid propellants.[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. The next announced Minotaur launch, of Taiwan's ROCSAT-3 microsatellite constellation, is scheduled for early 2005.[10]

Pegasus - Orbital Sciences Corporation

The Pegasus is an air-launched ELV used to place small payloads into a variety of low Earth orbits (LEO). Developed by Orbital Sciences Corporation in the late 1980s, Pegasus became the first commercial air-launch system. The Pegasus booster has three solid-propellant stages and an optional hydrazine mono-propellant upper stage. The booster is carried aloft under Orbital Sciences' "Stargazer" L-1011 carrier aircraft (early Pegasus launches used a B-52 leased from NASA) to an altitude of 11,900 meters (39,000 feet), where it is released. The booster drops for five seconds before igniting its first stage motor and beginning its ascent to orbit. The original Pegasus booster entered service in 1990. Orbital Sciences created a new version of the Pegasus, the Pegasus XL, with stretched first and second stages to enhance the booster's payload capacity. While the first Pegasus XL launch was in 1994, the first successful Pegasus XL flight did not occur until 1996. The original, or standard, version of the Pegasus was retired in 2000, and only the Pegasus XL is used today. The air-launched nature of the Pegasus permits launches from a number of different facilities, depending on the orbital requirements of the payload. Pegasus launches have been staged from six sites to date: Edwards Air Force Base (AFB) and VAFB, California; CCAFS, Florida; NASA's Wallops Flight Facility, Virginia; Kwajalein Missile Range, Marshall Islands; and Gando AFB, Canary Islands. Five government and one commercial Pegasus launches are planned for 2003.[11]

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 (DARPA) 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.[12,13]

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 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.[14] A Taurus is slated to launch Taiwan's ROCSAT-2 spacecraft in 2003.

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. Eleven of these boosters have been launched since 1988, most recently on June 24, 2002. 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 could be increased to 3,540 kilograms (7,800 pounds) to the same orbit. The last Titan 2 launch is planned for mid-2003.[15]

The Titan 4 program dates back to 1985, when the U.S. Air Force commissioned Martin Marietta (now Lockheed Martin) to develop an upgraded version of the existing Titan 34D ELV that could launch Space Shuttle-class payloads as an alternative to the Shuttle. The Titan 4A was based on the Titan 34D but featured stretched first and second stages, two more powerful solid rocket motors, and a larger payload fairing. The Titan 4A was used between 1989 and 1998. The Titan 4B, introduced in 1997, is the most powerful ELV in the United States today.[16] It uses upgraded solid rocket motors that increase the payload capacity of the vehicle by 25 percent.[17] The Titan 4B is used solely for U.S. military payloads, with the exception of the October 1998 launch of NASA's Cassini mission. Four Titan 4B launches are planned for 2003. 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.[18] 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 Federal Aviation Administration Associate Administrator for Commercial Space Transportation (FAA/AST), the multinational nature of the system prevents it from carrying U.S. government payloads at this time. Six Zenit 3SL launches are scheduled for 2003.

ELV Development Efforts

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

AirLaunch – The Boeing Company/ATK Thiokol Propulsion

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

The Boeing Company and ATK Thiokol Propulsion are currently studying a launch vehicle system called AirLaunch that features a solid-propellant ELV launched from an aircraft. The AirLaunch booster will use Castor 120 solid rocket motors for its first and second stages with a custom-designed third stage provided by ATK Thiokol. The launch vehicle will be carried aloft atop a modified Boeing 747-400F aircraft; at an altitude of 7,300 meters (24,000 feet) it will separate from the aircraft and continue toward LEO, propelled by its rocket engines. Wing and tail assemblies attached to the launch vehicle will provide lift and stability during this initial phase of the flight; the assemblies will later be jettisoned as the booster accelerates 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 will have the capability to operate out of any airport with a runway longer than 3,650 meters (12,000 feet); launch and range control could be managed onboard the aircraft, so, potentially, only down-range ground tracking may be required. 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]

Aquarius - Space Systems/Loral

Space Systems/Loral of Palo Alto, California, has proposed Aquarius, a low-cost launch vehicle designed to carry small, inexpensive payloads into LEO. Aquarius will be designed to trade reliability for low launch costs: while the vehicle could launch

Vehicle: Aquarius	
Developer: Space Systems/Loral	
First launch: To be determined	
Number of stages: 1	
Payload performance: 1,000 kg (2,205 lbs.) to LEO	
Launch sites: To be determined	

payloads far less expensively than existing boosters, up to one third of its launches will be expected to fail. The vehicle will be primarily intended to launch into orbit bulk products, like water, fuel, and other consumables, that are inexpensive to replace in the event of a launch failure.

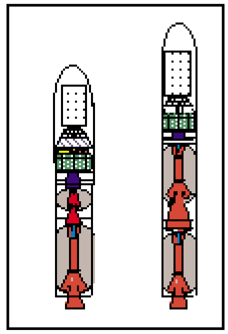
As currently designed, Aquarius will be a single-stage vehicle 43 meters (141 feet) high and 4 meters (13.1 feet) in diameter and powered by a single engine using liquid hydrogen and oxygen propellants. The vehicle will be launched from the ocean to minimize launch infrastructure and will be able to place a 1,000-kilogram (2,205-pound) payload into a 200-kilometer (125-mile), 52-degree orbit. The payload, located in the base of the vehicle, will be extracted by an orbiting space tug for transfer to its ultimate destination, after which the vehicle will deorbit and be destroyed.[21]

Space Systems/Loral studied Aquarius under a $110,000 grant awarded by the state of California in April 2001 and delivered a final report in June 2002. Space Systems/Loral teamed with Microcosm of El Segundo, California, and Wilson Composite Technologies of Folsom, California, for the study. Future plans for the Aquarius concept have not been announced.[22]

Eagle S-Series - E'Prime Aerospace Corporation

Vehicle: Eaglet/Eagle	
Developer: E'Prime Aerospace	
First launch: To be determined	
Number of stages: 2	
Payload performance: 580 kg (1,280 lbs.) to LEO (Eaglet); 1,360 kg (3,000 lbs.) to LEO (Eagle)	
Launch sites: Kennedy Space Center (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 will be ejected from a ground-based silo using a compressed-gas system. At a height of 61 meters (200 feet), the vehicle's engines will ignite. The smallest vehicle, the Eaglet, could launch 580 kilograms (1,280 pounds) into LEO, while a somewhat larger version, the Eagle, could put 1,360 kilograms (3,000 pounds) into LEO. Both will use solid-propellant lower stages and liquid-propellant upper stages. E'Prime has also proposed larger vehicles, designated S-1 through S-7, that will be able to place considerably larger payloads into LEO and add a geosynchronous Earth orbit (GEO) capability.



Eaglet and Eagle

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. 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.[23]

Falcon - Space Exploration Technologies Corporation

Vehicle: Falcon	
Developer: Space Exploration Technologies Corporation	
First launch: Late 2003	
Number of stages: 2	
Payload performance: 454 kg (1,000 lbs.) to LEO	
Launch sites: VAFB, CCAFS	

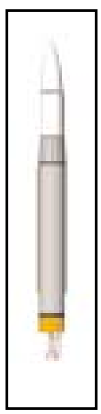
Elon Musk, an Internet entrepreneur, founded Space Exploration Technologies Corporation (Space X) of El Segundo, California, in June 2002. The company is currently developing the Falcon launch vehicle, a small launcher capable of placing up to 454 kilograms (1,000 pounds) into LEO. The two-stage vehicle will use liquid oxygen and kerosene propellants in engines the company is developing internally.[24] Space X initially plans to launch the Falcon two to three times a year from Space Launch Complex (SLC)-3W at VAFB and Launch Complex (LC)-46 at CCAFS, eventually ramping up to five to six flights a year at a price of $6-10 million per launch. The company plans to begin engine test firings in early 2003 and to assemble its first vehicle by June 2003 in preparation for launch later in the year.[25] The Falcon may later be used as the second and third stages of a larger vehicle the company is currently contemplating.

Falcon

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	

Rocket Propulsion Engineering Company of Mojave, California, has proposed developing the LV-1. The LV-1 is a two-stage ELV capable of launching 204 kilograms (450 pounds) into LEO. The vehicle uses hydrogen peroxide and kerosene pump-fed engines and graphite-epoxy tanks. The company is working on two suborbital vehicles, the SV-1 and SV-2, that will test the engines and other technologies used in the LV-1 and anticipates beginning test launches of those suborbital vehicles no earlier than 2004.[26]



LV-1

Scorpius Family - Microcosm, Inc.

Microcosm, Inc. of El Segundo, California, is developing the Scorpius family of ELVs. The boosters feature a modular design, using a number of identical propulsion pods, each with its own liquid-propellant engines and graphite-composite propellant tanks. The Sprite Mini-Lift vehicle, the smallest orbital version of the Scorpius family, will use six booster pods, each with a 89,000-newton (20,000-

Vehicle: Scorpius Sprite Mini-Lift	
Developer: Microcosm	
First launch: Mid-2005	
Number of stages: 2	
Payload performance: 315 kg (700 lbs.) to LEO, 150 kg (330 lbs.) to sun-synchronous orbit (SSO)	
Launch sites: California Spaceport	

pound-force) engine, clustered around a sustainer pod with a 22,250-newton (5,000-pound-force) engine. The Sprite Mini-Lift will be able to place 315 kilograms (700 pounds) into LEO and 150 kilograms (330 pounds) into sun-synchronous orbit (SSO). 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.

In March 2001 Microcosm successfully launched its SR-XM sounding rocket from the White Sands Missile Range, New Mexico.[27] 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 middle of 2005, with the vehicle entering commercial service nine months later at a cost per launch to Microcosm of $2 million.[28]

Scorpius Sprite Mini-Lift LEO Vehicle

SLC-1 - Space Launch Corporation

Vehicle: SLC-1	
Developer: Space Launch Corporation	
First launch: Late 2004	
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 an 800-kilometer (500-mile) SSO. The company is targeting microsatellites and other small payloads that will otherwise be launched as secondary payloads on larger vehicles. The company anticipates the first launch of its system by the end of 2004. Development of an avionics and propulsion module for the SLC-1 is being funded under a contract awarded by DARPA in April 2002. At the same time, DARPA awarded Space Launch Corporation a Phase 1 study contract for the Responsive Access, Small Cargo, and Affordable Launch (RASCAL) small payload launch system.[29]

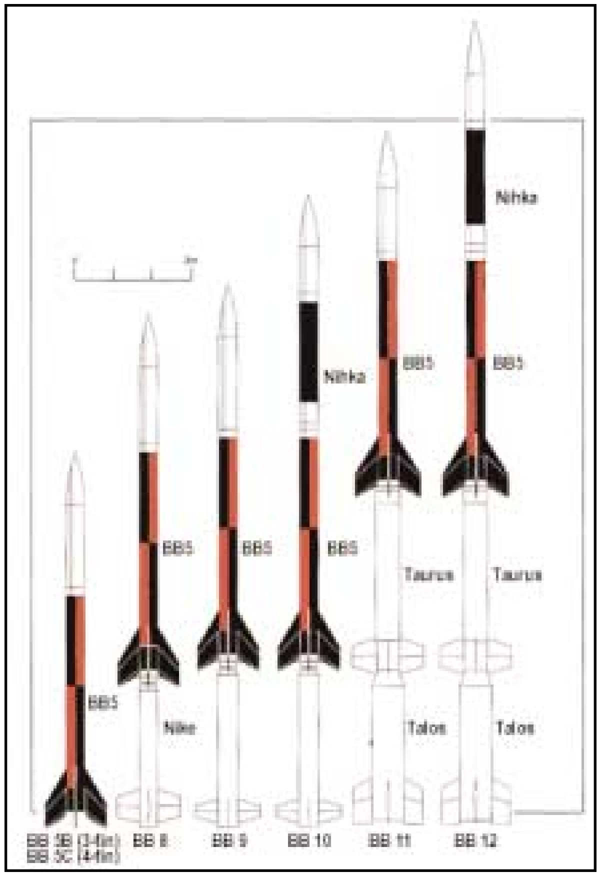
Sounding Rockets

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

Black Brant

Black Brant rockets have been manufactured since 1962, with over 800 vehicles having been launched during that time. The Black Brant motor and Nihka motors used on some Black Brant versions are manufactured in Canada by Bristol Aerospace while the Nike, Talos, and Taurus motors used on some Black Brant versions are built in the United States. The vehicles are integrated by the launch operator. In the United States, NASA has been a frequent user of Black Brant vehicles. Versions of the Black Brant can carry payloads ranging from 70 to 850 kilograms (154 to 1,874 pounds) to altitudes of 150 to 1,500 kilometers (93 to 932 miles). Black Brant vehicles can provide up to 20 minutes of microgravity time during a flight.[30]

The smallest version of the Black Brant family is the single-stage Black Brant 5 vehicle. The rocket is 533 centimeters (210 inches) long and 43.8 centimeters (17.26 inches) in diameter, and produces an average thrust of 75,731 newtons (17,025 pounds-force). The Black Brant 5 motor is used as the second or third stage in larger multi-stage versions of the Black Brant. The most powerful Black Brant



Black Brant Variants

model, the Black Brant 12, is a four-stage vehicle that uses the Black Brant 5 motor as its third stage. The Black Brant 12 can launch a 113-kilogram (250-pound) payload to an altitude of at least 1,400 kilometers (870 miles), or a 454-kilogram (1,000-pound) payload to an altitude of at least 400 kilometers (249 miles).[31]

Oriole

Astrotech Space Operations developed the Oriole sounding rocket in the late 1990s to provide launch services for commercial and scientific payloads. The Oriole was the first new sounding rocket developed in the United States in 25 years and is the first privately-developed sounding rocket. The Oriole is a single-stage vehicle with a graphite epoxy motor 22 manufactured by Alliant Techsystems in Rocket Center, West Virginia. The vehicle can also be combined with other motors to create two-stage sounding rockets with the Oriole serving as the second stage. The Oriole is 396 centimeters (156 inches) long and 56 centimeters (22 inches) in diameter, and generates an average thrust of 92,100 newtons (20,700 pounds-force). The Oriole can provide payloads with six to nine minutes of microgravity during flight.

The first flight of the Oriole took place on July 7, 2000, when the Oriole was launched from the NASA Wallops Flight Facility in Virginia. The launch took place in a two-stage configuration with the Oriole serving as the second stage and a Terrier Mk 12 motor as the first stage. The Oriole reached a peak altitude of 368.5 kilometers (229 miles) 315 seconds after launch during the test flight.[32] In July 2001 SPACEHAB sold the Oriole program to DTI Associates, who integrates the vehicle and offers it commercially.[33]


Oriole

Terrier-Orion

Terrier-Orion is a two-stage, spin-stabilized sounding rocket using a Terrier Mk 12 Mod 1 engine for the first stage and an Improved Orion motor for the second stage. The Terrier is a surplus U.S. Navy missile motor, while the Orion is a surplus U.S. Army missile motor. DTI Associates of Arlington, Virginia (formerly a part of Astrotech Space Operations, a SPACEHAB, Inc., subsidiary), is the general contractor for vehicle integration. The Terrier-Orion is 10.7 meters (35.1 feet) long; the Terrier stage is 46 centimeters (18 inches) in diameter, and the Orion is 36 centimeters (14 inches) in diameter. The Terrier-Orion can place payloads of up to 290 kilograms (639 pounds) to altitudes of up to 190 kilometers (118 miles).[34]


Terrier-Orion

A different version of the Terrier-Orion booster uses the more powerful Terrier Mk 70 motor on the first stage. This version was used for two FAA/AST-licensed suborbital launches carried out by Astrotech Space Operations/DTI at the Woomera Instrumented Range in Australia in 2001 and 2002. The second flight, in July 2002, successfully flew the HyShot scramjet engine experiment.[35]

Reusable Launch Vehicles

This section describes active and emerging reusable launch vehicle (RLV) programs in the United States. Emphasis is placed on vehicles being developed by private companies without the assistance of the government; many of these companies are developing space hardware for the first time. Government RLV programs are also included to provide context, particularly since the Space Shuttle is considered a first-generation RLV and the precursor of what may become a long line of commercial and government next-generation systems. Experiences gained by operating the Space Shuttle for over 20 years have helped solve, as well as introduce, crucial problems related to the design of more efficient RLV systems. Current government programs to develop follow-on RLVs (such as the Space Launch Initiative [SLI]) depend heavily on private sector innovation and may lay the foundation for future, privately developed RLVs for commercial and selected government applications. The first section addresses three RLV developments being pursued by the National Aeronautics and Space Administration (NASA) as a well as a project sponsored by the Defense Advanced Research Projects Agency (DARPA). Commercial RLV projects underway or under consideration, including those vying for the X PRIZE®, comprise the balance of the section.

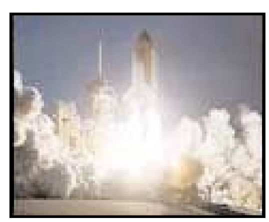
Government RLV Development Efforts

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

Today, NASA and DoD both still endeavor to develop new, reliable RLVs. Still the world’s only operational RLV, NASA’s Space Shuttle is aging and never achieved the launch rates and economies of scale the space agency originally anticipated for the vehicle. In 1999 NASA introduced its Integrated Space Transportation Plan (ISTP), an investment strategy for its space transportation needs. The ISTP included a program of Space Shuttle upgrades; SLI, a $4.8-billion technology development program to support NASA in making a decision on a new RLV to replace the Shuttle; and a program to develop the technologies for third- and fourth-generation RLVs. The space agency also funded several RLV research vehicles. DoD supported an assortment of military space plane and related technology concepts.

In 2002 both NASA and the military reevaluated their RLV efforts. NASA has proposed a new ISTP to better coordinate its space transportation efforts with its International Space Station (ISS) and science and research needs. The proposed ISTP continues to support the Space Shuttle but restructures SLI to accommodate the development of an ISS crew transfer vehicle called the Orbital Space Plane in the near term and the continued support of next-generation and subsequent generations of launch technology for the far term. The Air Force and NASA also conducted a joint study to explore their respective RLV requirements and, after finding several common requirements, agreed to cooperate as appropriate on RLV development. In addition, some military space requirements may be met by DARPA’s Responsive Access, Small Cargo, and Affordable Launch (RASCAL) program, which may yield a vehicle that can meet the demand for launch on short notice.

Space Shuttle


Space Shuttle

Consisting of an expendable external tank, two reusable solid rocket boosters, and one of four reusable orbiters, NASA’s Space Transportation System, commonly referred to as the Space Shuttle, remains the world’s only operational RLV. The Shuttle has conducted more than 100 launches since its introduction in 1981. The orbiters *Columbia*, *Atlantis*, and *Endeavour* collectively performed five successful missions in 2002, with four of these missions supporting the ISS and one servicing the

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, a joint venture between Boeing and Lockheed Martin

First launch: April 12, 1981

Number of stages: 1.5

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

Launch site: Kennedy Space Center (KSC), Florida

Markets served: Non-commercial payloads and ISS access

Hubble Space Telescope. The Space Shuttle is the only means available today for completing assembly of the ISS.

Intending to fly the Shuttle until at least the middle of the next decade, NASA is committed to investing in the Space Shuttle fleet to maintain safety and reliability and extend orbiter service life until a replacement RLV system is developed. In 2002 the space agency restructured its Shuttle upgrades program to better align investments with agency goals and the ISTP. Now called the Service Life Extension Program, the program's primary objective is to reduce risk and preserve Shuttle safety and viability through investments in Shuttle upgrades and infrastructure revitalization. NASA will consider factors including safety, reliability, supportability, performance, and cost reduction in prioritizing improvement projects.

NASA is presently pursuing two major upgrades. The Advanced Health Management System Phase 1, scheduled for first flight in 2004, is an upgrade to the Space Shuttle Main Engines to provide improved real-time engine vibration monitoring and improved engine anomaly response capabilities. A second phase of the upgrade has yet to be funded. The Cockpit Avionics Upgrade, whose first flight is expected in 2006, will enhance new situational awareness and reduce crew workload by providing automated control of complex procedures. It will also permit implementation of new software to manage flight aborts. NASA is also working to improve the durability of Shuttle landing gear assemblies as well as to use new welding procedures to improve External Tank reliability and lower its production time and cost.[36]

The Space Shuttle's day-to-day operations have been managed by United Space Alliance, a Boeing-Lockheed Martin joint venture, since 1996. NASA as well as others in the space community have raised the possibility that even more responsibility for the Shuttle might be shifted from government to private sector control. A task force commissioned by NASA to examine this possibility suggested in 2002 a variety of options through which the space agency could further competitive outsourcing of Shuttle operations. NASA has not yet announced how it will proceed.[37]

Orbital Space Plane

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

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

NASA expects to approach the program aggressively and complete preliminary designs by 2005. The space agency awarded SLI contracts in November 2002 to Boeing and Lockheed Martin for flight demonstrator technologies to reduce the risks associated with the development of the Orbital Space Plane. Boeing will continue development of the X-37 experimental vehicle to demonstrate key flight technologies (described in greater detail in the "Enabling Technologies" section), while Lockheed Martin will develop a launch pad abort demonstrator to prove emergency crew escape technologies.

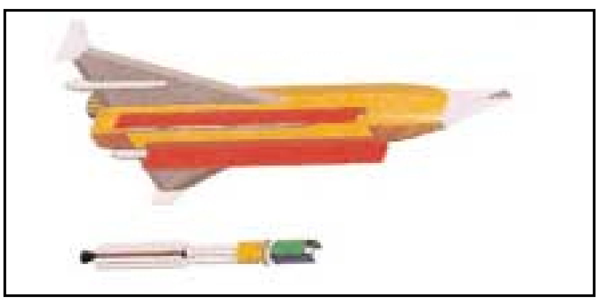
Next Generation Launch Technology

The second component of NASA's proposed restructure of SLI, the Next Generation Launch Technology program combines ongoing RLV development efforts with the Third Generation RLV program. It consists of investments in RLV propulsion, structures, and operations, focusing on research into kerosene-based first-stage engine designs as well as advanced hypersonics. NASA does not intend to make a decision on the development of a next-generation RLV any earlier than 2009, with a first flight no sooner than 2015. NASA plans to work with DoD to assess common requirements and opportunities for cooperation on future RLV development.

RASCAL

DARPA started work in 2002 on a project to create a low-cost partially reusable launch vehicle for small payloads. The Responsive Access, Small Cargo, and Affordable Launch (RASCAL) program seeks to develop a two-stage air launch system that can place payloads weighing up to 100 kilograms (220 pounds) into low Earth orbit (LEO). The RASCAL first stage will be a jet aircraft that flies to an altitude of at least 30,500 meters (100,000 feet). The aircraft will then deploy an expendable rocket to place the payload into orbit. The vehicle will be able to put at least 50 kilograms (110 pounds) into any inclination, including 75 kilograms (165 pounds) into sun-synchronous orbit (SSO) and heavier payloads into equatorial orbits. The RASCAL vehicle will be able to take off within one hour of a launch command and fly again within 24 hours at a cost of no more than $750,000 per flight.

To achieve these performance goals, RASCAL will use an engine technology called Mass Injected Pre-Compressor Cooling (MIPCC) on its aircraft stage. A MIPCC engine injects a coolant, such as water or liquid oxygen, into the engine inlet. This process cools and compresses the airflow, extending the engine's limits and allowing it to operate at higher altitudes and greater speeds than otherwise possible. MIPCC will allow a vehicle powered by conventional turbofan engines to achieve a speed of Mach 4, an altitude over 30,500 meters (100,000 feet), and a dynamic pressure of less than 4.9 kilograms per square meter (1 pound per square foot). At that dynamic pressure, the rocket's upper stage can be released without a fairing protecting the payload. Conventional solid- or liquid-propellant engines can be used for the upper stage.[38]



RASCAL

In April 2002 DARPA awarded six Phase 1 contracts to companies to initiate studies of the RASCAL design. Those contracts, valued at between $1 and $2 million each, were awarded to Coleman Research Corporation, Northrop Grumman Corporation, Pioneer Rocketplane Corporation, Space Launch Corporation, Space Access, LLC, and Delta Velocity. DARPA plans to select two companies in early 2003 for Phase 2 studies, leading to the selection of a single contractor to build the vehicle one year later. Flight tests of a RASCAL vehicle are scheduled for 2006.[39]

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

Targeted markets: Public space transportation and other emerging markets

Kelly Space and Technology, Inc., is developing an RLV to address the needs of various suborbital markets, ISS customers, and small payloads to destinations higher than LEO. Kelly's piloted Astroliner will be based on its patented, horizontal-takeoff, tow-launch technique and is designed to carry humans and cargo to and from suborbital 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

Kelly Astroliner

aircraft during the initial ascent. The RLV system will be released at altitude and, using its rocket engines, will ascend to 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 believes 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 other air-dropped system concepts.

Under a cooperative program with NASA's Dryden Flight Research Center and the Air Force Flight Test Center at Edwards Air Force Base (AFB), California, Kelly has successfully demonstrated its tow-to-launch concept. 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 suborbital flights later in 2004. The first orbital flight is planned for mid-2005, with operations planned for early 2006.[40]

Kelly teamed with Vought Aircraft Industries in January 2001 to submit a joint proposal for the development of an RLV under NASA's SLI. NASA, however, did not award the companies a contract when the first cycle of the SLI Phase 1 contract awards was announced in May 2001.

Black Armadillo - Armadillo Aerospace

Vehicle: Black Armadillo

Developer: Armadillo Aerospace

First launch: December 2003

Number of stages: 1

Payload performance: To be determined

Possible launch sites: Oklahoma Spaceport and White Sands, New Mexico

Targeted markets: Public space transportation and other emerging markets

Success in the development of an X PRIZE® vehicle is Armadillo Aerospace's first step to considering future suborbital and potentially orbital launch services. The company's specific objective beyond winning the X PRIZE® is to adapt its X PRIZE® vehicle for space tourism and provide a suborbital platform for small microgravity research payloads. The X PRIZE® vehicle will consist of an autonomously-guided single stage powered by four canted motors fueled with hydrogen peroxide monopropellant. The vehicle will be designed to carry three 91-kilogram (200-pound) passengers to an altitude of 100 kilometers (62 miles).

Armadillo has been making significant progress in the development of test articles and

Armadillo's Test Article

components. Several key milestones were reached during 2002 in preparation for the group's first X PRIZE® flight attempt in December 2003.

After about a year of modifications to its first-generation test article capable of carrying one person, the first crewed test flight was performed in September 2002. The vehicle, powered by a single engine fed by two hydrogen peroxide tanks, lifted off smoothly and remained in the air for about six seconds before coming to rest. The flight was designed as a full systems test, and was not intended to achieve an operational flight altitude. This represented the first crewed flight test by any of the X PRIZE® contenders.

In November, Armadillo traveled to Burns Flat, Oklahoma, a proposed site of the future Oklahoma Spaceport, to conduct an uncrewed flight test of a single-engine rocket powered by hydrogen peroxide. The vehicle lifted into the air with its engine producing about 2,669 newtons (600 pounds-force) of thrust. At an altitude of about 30 meters (98 feet), the main engine shut off due to a computer failure and the vehicle fell to Earth. Most of the critical components, such as the guidance systems, were salvaged for use in an improved test article expected to be launched in early 2003.[41]

K-1 – Kistler Aerospace Corporation

Vehicle: K-1

Developer: Kistler Aerospace Corporation

First launch: To be determined

Number of stages: 2

Payload performance: 4,535 kg (10,000 lbs.) to LEO; 1,570 kg (3,460 lbs.) to geosynchronous transfer orbit (GTO)

Possible launch sites: Woomera, Australia; Nevada Test Site

Targeted markets: Deployment of LEO payloads, GTO payloads (with Active Dispenser), ISS re-supply and cargo return missions

On May 17, 2001, Kistler Aerospace Corporation was awarded a contract worth up to $135 million under NASA's SLI to use the K-1 as a flight demonstrator under NRA 8-30.[42] 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 award followed less than a year after Kistler was awarded a three-month study contract from NASA's 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.[43]


K-1

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 a then-expected market price of $17 million per launch. Kistler has completed a conceptual design for an Active Dispenser that will deploy payloads to medium Earth orbits (MEO), geosynchronous transfer orbits (GTO), and interplanetary trajectories. The Active Dispenser will expand the K-1's capability beyond LEO (approximately 1,570 kilograms [3,460 pounds] to GTO) at a launch price of $25 million. The K-1 also will be capable of providing cargo re-supply and return services for the ISS.

The K-1 will be able to launch multiple small payloads on dedicated missions or as secondary payloads. Kistler is working with Astrium, Ltd., in the United Kingdom to develop reusable payload dispensers for multiple small payloads.

The K-1 will launch vertically like a conventional expendable launch vehicle (ELV) but will use a unique combination of parachutes and air bags to recover its two stages. The vehicle, designed to operate with a small complement of ground personnel, will be transported to the launch site and erected with a mobile transporter. The K-1 will measure about 37 meters (121 feet) in height and have a launch mass of 382,300 kilograms (843,000 pounds).

The K-1 employs off-the-shelf technology and components in its design. The first stage, known as the Launch Assist Platform, is powered by three liquid oxygen (LOX)/kerosene GenCorp Aerojet AJ26 engines. These engines include elements of the NK-33 engines originally built by the Soviet Union in the 1960s. After launch, the Launch Assist Platform separates from the second stage and restarts its center engine to fly a return trajectory to a landing area near the launch site. The Launch Assist Platform deploys parachutes and descends to the landing area where air bags are deployed to cushion its landing.

The second stage, or Orbital Vehicle, continues into LEO, where it releases its payload. The Orbital Vehicle is powered by a single Aerojet AJ26-60 engine (derived from the Russian NK-43 engine). Following payload separation, the Orbital Vehicle continues on orbit for about 24 hours, after which a LOX/ethanol orbital maneuvering system performs a deorbit burn. The Orbital Vehicle ends its ballistic re-entry profile by deploying parachutes and air bags in a manner similar to the Launch Assist Platform.

Kistler expects to operate the K-1 from two launch sites: Woomera, Australia, and the Nevada Test Site. Kistler Woomera Pty., Ltd., a wholly owned subsidiary of Kistler Aerospace Corporation, will operate the K-1 from Woomera. Kistler received authorization from the Australian government to begin construction of launch facilities at Woomera in April 1998 and held a groundbreaking ceremony at the site several months later. The launch pad's design is complete, and Kistler will conduct its initial K-1 flights and commercial operations from Woomera. In 1998, Kistler signed an agreement with the Nevada Test Site Development Corporation to permit Kistler to occupy a segment of the U.S. Department of Energy's Nevada Test Site for its launch operations. The Federal Aviation Administration Associate Administrator for Commercial Space Transportation (FAA/AST) environmental review process was completed for the Kistler project in 2002.

Pathfinder – Pioneer Rocketplane

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: No earlier than 2006
Number of stages: 2 (Second "stage" is an air refueling aircraft)
Payload performance: 1,818 kg (4,000 lbs.) to LEO
Possible launch sites: Oklahoma Spaceport
Targeted markets: Launch of small- and medium-class payloads

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.


Pathfinder

The vehicle will be operated by a crew of two pilots with experience in high-performance aircraft and will have accommodations to carry two passengers. Both air-breathing jet engines and LOX/ kerosene rocket engines will power the vehicle. The 23-meter- (75-foot-) long vehicle will take off horizontally using conventional turbofan jet engines. When it reaches an altitude of 6,000 meters (19,685 feet), Pathfinder will receive 59,000 kilograms (130,000 pounds) of LOX from a tanker aircraft. After disconnecting from the tanker, Pathfinder will ignite its RD-120 rocket engine and climb to an altitude of 112 kilometers (70 miles) at a speed of about Mach 12. Once out of the atmosphere, Pathfinder will be able to open its cargo bay doors and release its payload with a conventional rocket upper stage. The payload will proceed to its orbit while Pathfinder re-enters the atmosphere. After deceleration to subsonic speeds, Pathfinder will re-start its turbofan engines and land horizontally.[44] Pathfinder's maximum payload capacity to LEO will be 1,818 kilograms (4,000 pounds). The first air-breathing test flights are planned for three to four years after the acquisition of funding and will be followed two to three months later by rocket-powered test flights.[45]

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 suborbital trajectories. Pioneer Rocketplane has an agreement with the U.S.-based company Space Adventures to offer suborbital flights to customers paying between $98,000 and $100,000 per seat.[46]

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. In 2002 Pioneer agreed to conduct launch operations from the proposed Oklahoma Spaceport at the former Clinton-Sherman AFB in Washita County, Oklahoma. Currently, Pioneer plans to base its vehicles at the Oklahoma Spaceport and ferry-fly to approved launch sites on the East or West Coasts.[47] In 2002 DARPA awarded Pioneer Rocketplane an estimated $1- to $2-million contract.[48]

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 suborbital 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 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).[49] One of the company's subcontractors, Kaiser Marquardt, has tested elements of the propulsion system,[50] 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. SPACE ACCESS® has wind-tunnel tested the ejector ramjet engine at all of the altitudes and speeds of the SA-1's planned flight profile.[51]

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

Targeted markets: Launch of LEO and GTO payloads

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.[52]

SA-1

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 payload capability and reliability will also make the SA-1 well suited for conducting re-supply missions to the ISS.[53]

In 1999, SPACE ACCESS®, LLC, received 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 will 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.[54]

Xerus - XCOR Aerospace

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

Since XCOR's founding in 1999, the company has been focusing on the development of reusable engines with high reliability, efficient turnaround and maintenance, and safe operations. XCOR has developed an airborne platform called the EZ-Rocket to test the most successful of its engine designs (see the "Liquid Engines - XCOR Aerospace" entry in the "Enabled Technologies" section). The EZ-Rocket is powered by two engines, each capable of 1,779 newtons (400 pounds-force) of thrust, and is piloted by veteran test pilot Dick Rutan.

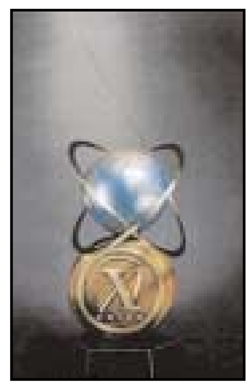
By demonstrating the reusability, efficiency, and safety of its engines, XCOR expects to gather enough data and experience to pursue its follow-on suborbital vehicle project. The vehicle, called Xerus, will be designed to carry one commercial pilot and one passenger. XCOR's philosophy is to take one step at a time toward suborbital, and perhaps later orbital, launch operations.

Xerus

XCOR hopes to provide suborbital flights on Xerus for about $10,000 per passenger and may develop a "stretched" version capable of taking two passengers at a time. XCOR expects to build Xerus within 18 months of securing $3 million and expects to offer commercial flights three years later.[55]

X PRIZE® Contenders

In the spirit of the early 20th-century aviation prizes, such as the Orteig Prize that Charles Lindbergh won for crossing the Atlantic in 1927, the X PRIZE® Foundation was established in 1995 as an educational, non-profit corporation dedicated to inspiring private, entrepreneurial advancements in space travel. The X PRIZE® is being offered to help speed development of space vehicle concepts that will reduce the cost of access to space and to allow human spaceflight to become routine.



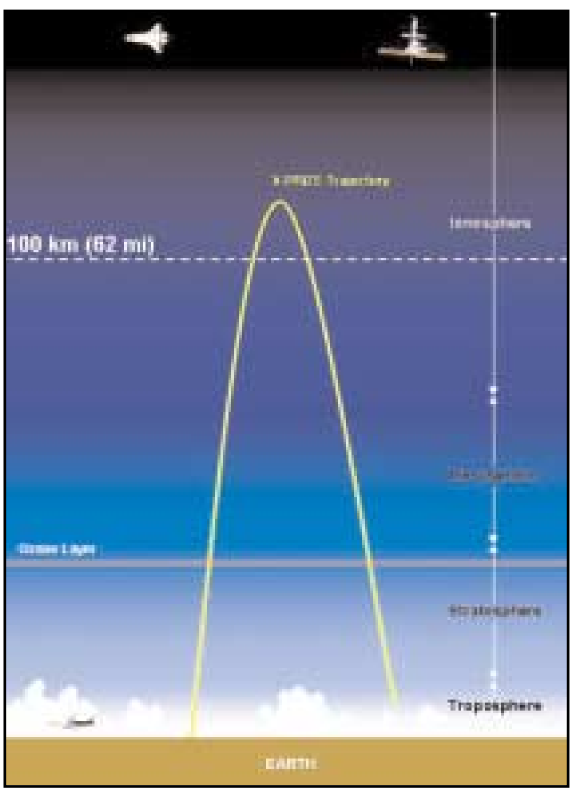
X PRIZE® Trophy

The St. Louis-based X PRIZE® Foundation is offering a $10-million prize to the first team that launches a vehicle capable of carrying three people (or one person and ballast for two others) on a suborbital trajectory to a 100-kilometer (62-mile) altitude and repeats the flight within two weeks in the same vehicle. The X PRIZE® is fully funded through January 1, 2005.

The X PRIZE® competition currently has more than 20 entrants from six countries proposing a variety of different RLV concepts (see Table 2 for a complete list). Most of the commercial vehicles under development for the X PRIZE® competition are uniquely designed for suborbital space tourism operations carrying three passengers. These designs use a variety of takeoff, landing, and design concepts.

In 2002 two new teams joined the roster of X PRIZE® registered teams. The first, Armadillo Aerospace of Mesquite, Texas, is led by John Carmack, the developer of several popular computer games. The Armadillo team has successfully developed, tested, and flown its own hydrogen peroxide mono- and bi-propellant engines on vehicles capable of carrying one person. The team also flight-tested their "tube rocket" in 2002. The second new X PRIZE® team is the Aeronautical and Cosmonautics Romanian Association led by Dimitru Popescu. The team has constructed a half-scale technology demonstrator of their vehicle design.

In May 2002 Pablo de León & Associates of Buenos Aires, Argentina, performed a second drop test of a capsule design. For this test, the capsule was dropped from a height of 29,261 meters (96,000 feet) and carried Global Positioning System receivers, basic telemetry transmitters, external thermocouples, accelerometers, and two video cameras.



Typical X PRIZE® Trajectory

The Advent Launch Services team has erected a 12-meter (40-foot) propulsion system (tanks and engine) in a rice field near Houston, Texas, and has conducted cryogenic tank tests. Hot-fire engine tests are scheduled but have been delayed due to problems with propellant delivery.

The Canadian Arrow team, from London, Ontario, Canada, performed a successful hot-fire test of a single injector cup in July 2002. A rocket engine test facility to handle a full-scale V-2 engine 253,549 newton (57,000 pounds-force) thrust was completed in October. Plans for a full-scale engine test in October were delayed due to problems with hardware delivery. In November, Canadian Arrow announced its worldwide search for three astronauts to fly in X PRIZE® competition flights.

Starchaser Industries, Ltd., of Cheshire, England, successfully fired a 12,259-newton- (2,756-pound-force-) thrust hybrid rocket engine and a 4,906-newton- (1,103-pound-force-) thrust LOX/kerosene rocket engine. The team also conducted two successful rocket launches investigating thermal conditions its X PRIZE® vehicle will encounter. The rockets carried nose cone temperature sensing equipment. Team leader Steve Bennett also continued his pilot training by attending the Gagarin Cosmonaut training Centre at Star City near Moscow during the last week of October.

Advent, Canadian Arrow, and Starchaser have publicly announced plans to make X PRIZE® competition launches sometime in 2003.[56]

More Commercial RLV Concepts

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

Table 2: X PRIZE® Contenders

Vehicle	Team – Leader - Location	Launch System and Mission Description
Advent	Advent Launch Services – Jim Akkerman - Houston, TX	Cylinder-shaped glider powered by LOX/methane rocket engines. The vehicle will launch vertically from water and land horizontally at the launch site. Hardware has been built and tested.
Orizont	Aeronautics and Cosmonautics Romanian Association – Dimitru Popescu –Valcea, Romania	Cylinder-shaped vehicle of standard rocket design with vertical launch plan. Hardware has been built and tested.
Black Armadillo	Armadillo Aerospace - John Carmack - Mesquite, TX	Development work has focused on mono- and bi-propellant hydrogen peroxide engines. Hardware has been built and tested.
Ascender	Bristol Spaceplanes, Ltd. - David Ashford - Bristol, England, UK	RLV powered by two conventional jet engines and a liquid-fueled rocket engine. The vehicle will take off horizontally and land horizontally. Hardware has been built and tested.
Canadian Arrow	Canadian Arrow – Geoff Sheerin, London, Ontario, Canada	Stretched, two-stage version of the V-2 rocket. It launches vertically and performs a parachute, water landing of the booster and passenger stages. Hardware has been built and tested.
Cosmopolis – XXI (C-21)	Suborbital Corp. - Sergey Kostenko - Moscow, Russia	Space plane carried to take-off altitude on the back of an M55-X carrier aircraft. The vehicle ejects the solid rocket motor after burn-out and glides to a horizontal landing. Hardware has been built and tested.
Wild Fire	The da Vinci Project – Brian Feeney, Toronto, Ontario, Canada	Air-launched, LOX/kerosene rocket deployed from a large helium balloon. Recovery system features a high-drag reentry ballute and a Global Positioning System-guided parafoil. Hardware has been built and tested.
Gauchito	Pablo De León and Associates – Pablo de León – Buenos Aires, Argentina	Single-stage vehicle that will launch vertically. The first stage booster and the passenger capsule return to Earth using parachutes. Hardware has been built and tested.
The Space Tourist	Discraft Corporation - John Bloomer - Portland, OR	Disc-shaped vehicle powered by air-breathing “blastwave-pulse jets.” The vehicle will take off and land horizontally.
Exo-Clipper	Earth Space Transportation Systems – William Good – Highlands Ranch, CO	Prototype aerospace plane that has an air-breathing configuration for suborbital ballistic flight. The vehicle will takeoff and land horizontally.
Green Arrow	Flight Exploration - Graham Dorrington - London, England, UK	Cylinder-shaped rocket using liquid-fueled rocket engines. The vehicle will launch vertically and land vertically using parachutes and air bags.
Aurora	Fundamental Technology Systems – Jim Toole and Ray Nielsen – Orlando, FL	Horizontal takeoff and landing double-delta-winged RLV powered by a single kerosene and hydrogen peroxide engine capable of being throttled.
(Name not disclosed)	Kelly Space and Technology – Mike Kelly - San Bernardino, CA	Air-launched, lifting body vehicle that is taken to altitude by a tow aircraft. The vehicle will perform an unpowered horizontal landing. Hardware has been built and tested.
Kitten	Kittyhawk Technologies – Douglas Drummond - Oroville, WA	Methane- and LOX-powered spaceplane that takes off and lands from a conventional runway.
Cosmos Mariner	Lone Star Space Access Corporation - Norm LaFave - Houston, TX	RLV powered by two air-breathing engines and one rocket engine. The vehicle will launch and land horizontally.
Lucky Seven	Mickey Badgero & Associates - Mickey Badgero - Bath, MI	Cone-shaped vehicle powered by rocket engines. The vehicle will launch vertically and land using a parafoil.
SabreRocket	PanAero, Inc. – Len Cormier – Fairfax, VA	Modified Sabre Jet with seven small LOX/Kerosene engines. The vehicle will perform a horizontal takeoff and powered, horizontal landing.
XP	Pioneer Rocketplane – Mitchell Burnside Clapp – Solvang, CA	Powered by both air-breathing jet engines and LOX/kerosene rocket engines. XP will takeoff horizontally and perform a powered, horizontal landing.
(Name not disclosed)	Scaled Composites - Burt Rutan - Mojave, CA	Two-stage vehicle consisting of a turbo-fan-powered carrier aircraft and a rocket-powered second stage. Hardware has been built and tested.
Thunderbird	Starchaser Foundation - Steve Bennett - Cheshire, England, UK	Traditional, multi-stage rocket using solid booster and liquid-fueled rocket engines. The vehicle will launch vertically and make a ballistic, guided--parachute landing. Hardware has been built and tested.
MICHELLE-B	TGV Rockets – Kent Ewing - Bethesda, MD	MICHELLE-B will launch vertically, perform a straight-up, straight-down flight trajectory, and perform a powered, vertical landing.

Table 3: Summary of More RLV Concepts

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

Enabling Technologies

There are a number of efforts underway to develop new propulsion technologies for launch vehicles, including expendable launch vehicles (ELV) and reusable launch vehicles (RLV). These efforts include government research projects as well as engines and motors being developed by companies for their own launch vehicles and for sale to other companies. Many companies are attempting to build considerably less complex and potentially less expensive rocket engines. Some of these designs use room-temperature propellants instead of cryogenics, while others use pressure-fed engines instead of turbopumps. The gains achieved in simplifying the engines, however, may be offset by reduced performance.

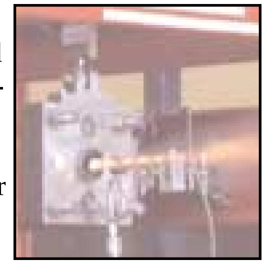
In addition to the technologies listed below, a number of launch vehicle technologies are being developed as part of National Aeronautics and Space Administration's (NASA) Space Launch Initiative (SLI). While these technologies are being developed for use on future RLVs, some may have applications on other vehicles as well. Table 4 summarizes some of these technologies.

Air-Breathing Engines - NASA

NASA's Integrated System Test of an Air-breathing Rocket (ISTAR) program is an effort to develop the technology required for a rocket-based combined cycle engine that could be used on future RLVs. Such an engine will initially accelerate to Mach 2 using rocket propulsion, then switch to an air-breathing mode to fly to beyond Mach 10 before reverting to conventional rocket mode to complete the ascent to orbit. An air-breathing engine has the potential to be more efficient than conventional liquid-propellant rocket motors and will also reduce the amount of oxidizer the vehicle will have to carry.

The ISTAR program is currently developing a ground test engine to demonstrate the technologies of a rocket-based combined cycle engine. The engine, dubbed ARGO, passed its first major systems requirements review in July 2002, three months ahead of schedule. Conceptual system design and subsystem testing was completed in late 2002, with ground tests of the engine scheduled to begin in 2006. NASA eventually plans to flight-test an engine based on the ARGO design, possibly as part of the agency's Hyper-X program (see below).[57]

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. SpaceDev completed tests in August 2001 of a small hybrid rocket motor that is designed for use in the company's Maneuver and Transfer Vehicle, an upper stage that can move small spacecraft, such as secondary payloads on larger launch vehicles, from geosynchronous transfer orbit (GTO) to low Earth orbit (LEO) or geosynchronous orbit (GEO). In May 2002 the Air Force Research Lab awarded SpaceDev a contract to develop a hybrid propulsion module to deploy small payloads from the Space Shuttle.[58] The company has also proposed developing larger hybrid motors that could be used on crewed suborbital RLVs, such as X PRIZE® vehicles.[59]

Hypersonic Engine Design - NASA

NASA's Hyper-X program is designed to study and improve air-breathing hypersonic engine technologies. Three different vehicle designs, designated X-43A, B, and C, are planned to conduct a variety of tests of hypersonic vehicle design. In an X-43A flight, the 3.7-meter- (12-foot-) long vehicle is accelerated to Mach 10 by the first stage of an Orbital Sciences Corporation Pegasus XL launch vehicle and is then separated from the booster for independent flight at high speed. The X-43A program involves three flights in an effort to understand intake and combustion chamber airflow patterns. The first X-43A flight, on June 2, 2001, failed due to an anomaly in the Pegasus

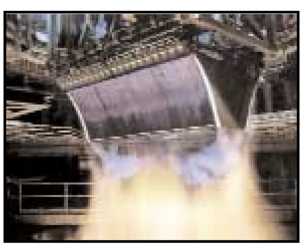
X-43A

XL booster stage. The second X-43A test flight is tentatively planned for mid-2003.[60]

The X-43A will be followed by the X-43C, a 4.9-meter- (16-foot-) long vehicle that will test a different scramjet engine design. The X-43C will use three Ground Demonstrator Engine-1 engines developed by Pratt & Whitney for the U.S. Air Force's HyTech project, reaching speeds of Mach 5 to 7 for up to ten minutes. Like the X-43A, the vehicle will use a rocket booster stage to accelerate to speeds where the scramjet can function. The first X-43C flight is scheduled for 2008. The last Hyper-X vehicle, the X-43B, will test a rocket- or turbine-based combined-cycle engine to accelerate to hypersonic speeds.[61] The first flight of the 12.2-meter- (40-foot-) long X-43B is planned for between 2010 and 2012.[62]

Linear Aerospike Engine - Rocketdyne Propulsion & Power

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. 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 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.[63]



XRS-2200

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 its proposed RLV, Neptune. 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. 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 suborbital 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 in 2003 from the Pacific island nation of Tonga. The company plans to use larger versions of the engine in the Neptune RLV.[64]

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, an 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 suborbital 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 will 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 suborbital vehicle under development.[65] 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 company's SV-2 suborbital vehicle and the first stage of its LV-1 orbital vehicle.

In May 2002 the Missile Defense Agency awarded Rocket Propulsion Engineering Company a Small Business Innovation Research (SBIR) contract. The six-month SBIR Phase 1 contract covered the preliminary engineering design of a storable liquid propellant engine that uses hydrogen peroxide and NavFuel, a fuel developed by the Naval Air Warfare Center. The engine is primarily designed for use in an upper stage of the Navy Standard Missile for air and missile defense applications, as well as future suborbital and orbital vehicles. Construction of a working prototype engine will be carried out under a future, Phase 2 contract.[66]

Liquid Engines - Space Exploration Technologies Corporation

Space Exploration Technologies Corporation (Space X) of El Segundo, California, is developing two new liquid-propellant engines for use on its Falcon launch vehicle. One engine, designed for the first stage of the Falcon, will be a 267,000-newton (60,000-pound-force) engine, operating on a gas generator cycle. The Falcon's second stage will use a 33,300-newton (7,500-pound-force) pressure-fed engine based on the engine used in the descent stage of the Apollo Lunar Module. Both engines will use liquid oxygen and kerosene propellants. Space X is planning to conduct the first test firings of the engines in early 2003.

Liquid Engines - XCOR Aerospace

XCOR Aerospace, located in Mojave, California, specializes in the development of engines for use on launch vehicles and spacecraft. The company has developed and extensively tested three different liquid-propellant engines. XCOR's largest engine, designated XR4AE, is a 1,780-newton (400-pound-force), pressure-fed, regeneratively-cooled, liquid-oxygen and alcohol engine. Four such engines have been built and, combined, have been fired 536 times for over 6,250 seconds. The engines have also been flown on EZ-Rocket, a modified Long-EZ aircraft fitted with two of the engines. EZ-Rocket has completed 15 successful flight tests since July 2001, including two flights at the Experimental Aircraft Association's AirVenture 2002 air show in Oshkosh, Wisconsin in July 2002. A key technology is XCOR's proprietary ignition system.

XCOR EZ-Rocket

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 700 firings, with a cumulative burn time of 82.6 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 216 firings with a cumulative burn time of over 812 seconds.[67] XCOR designed this engine for use as a maneuvering thruster on spacecraft. In April 2002 XCOR acquired selected intellectual property assets of the former Rotary Rocket Company, including a 22,250-newton (5,000-pound-force) liquid oxygen and kerosene engine developed and tested by the company as well as hydrogen peroxide engine technology.[68] XCOR plans to use the technology for the development of larger engines for its Xerus suborbital RLV and other projects.

Liquid Engines and Thrusters - NASA/SLI Contractors

As part of SLI, NASA has supported development of several new engine designs. One area of research includes studies of engines that use liquid oxygen and kerosene propellants that can generate approximately 4.5 million newtons (1 million pounds-force) of thrust. A second area of research has focused on liquid oxygen and liquid hydrogen engines than can generate at least 2.67 million newtons (600,000 pounds-force) of thrust. Both engine designs will be reusable and designed for the first and second stages, respectively, of an RLV. In addition, SLI has funded development of reaction control thruster systems that use liquid oxygen and liquid hydrogen propellants; these thrusters will be used to maneuver spacecraft in orbit. Table 4 lists some of the technologies being developed for SLI.

Propellant Production - Andrews Space & Technology, Inc.

Andrews Space & Technology, Inc., of Seattle, Washington, has proposed a propulsion system that will generate liquid oxygen propellant from the atmosphere. The "Alchemist" Air Collection and Enrichment System (ACES) will take high-pressure air from a turbofan jet engine and liquefy it by passing it through a heat exchanger cooled by liquid nitrogen and/or liquid hydrogen. Liquid oxygen will then be separated out and stored in propellant tanks for use by a liquid hydrogen-liquid oxygen rocket engine. This will allow a horizontal-takeoff launch vehicle to leave the ground without any oxidizer, reducing its takeoff weight. The company has proposed ACES in conjunction with its own two-stage-to-orbit (TSTO) RLV design as well as for use in other horizontal-takeoff launch vehicles.[69]

Andrews Space & Technology carried out initial studies of the ACES concept, in cooperation with Pratt & Whitney, using internal funds and a NASA SBIR contract. A detailed feasibility and risk analysis study has been carried out under a NASA SLI contract.

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

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 advanced guidance, navigation, and control systems; thermal

X-37

protection systems; and high-temperature structures. 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.[70]

In November 2002 NASA awarded Boeing Phantom Works of Seal Beach, California, a $301-million contract to complete work on the X-37. The contract covers a progressive series of atmospheric approach and landing tests planned for mid-2004. The tests will be followed by an orbital flight on either the Space Shuttle or an ELV in mid-2006.[71]

X-40A

The X-40A is a concurrent test program designed to explore the low-speed atmospheric flight dynamics of the X-37 design. Originally developed as a prototype of the Air Force's 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 completed a program of seven successful flights at NASA's Dryden Flight Research Center in May 2001. During these flights, the uncrewed X-40A was released from a CH-47 Chinook helicopter at 4,570 meters (15,000 feet) and autonomously guided itself to the target runway and landed in a fashion similar to a conventional aircraft.[72]

Table 4: SLI Technologies

Name	Company	Type	Description	Status
Co-optimized Booster for Reusable Applications (COBRA)	Pratt & Whitney-Aerojet Propulsion Associates	Cryogenic reusable engine	A liquid oxygen-liquid hydrogen engine capable of generating 2.67 million newtons (600,000 pounds-force) with a 100-mission lifetime.	COBRA passed a milestone review in June 2002.[73] SLI funding for COBRA was terminated in September 2002.
Reaction Control Engine	TRW	Cryogenic orbital maneuvering engine	A liquid-oxygen liquid-hydrogen thruster system designed to maneuver spacecraft in orbit, providing between 111 and 4,450 newtons (25 and 1,000 pounds-force).	Hot-fire tests of the engine started in March 2002 at NASA's Marshall Space Flight Center.[74]
RS-83 engine	Boeing Rocketdyne	Cryogenic reusable engine	A liquid oxygen-liquid hydrogen engine capable of generating 2.94 million newtons (660,000 pounds-force) with a 100-mission lifetime.	Hot-fire tests of the RS-83 preburner, a component that powers the engine’s turbopumps, started in October 2002 at NASA’s Stennis Space Center.[75]
RS-84 engine	Boeing Rocketdyne	Hydrocarbon reusable engine	A liquid-oxygen kerosene reusable engine capable of generating 4.68 million newtons (1.05 million pounds-force).	Engine currently in the design phase.[76]
TR107 engine	TRW	Hydrocarbon reusable engine	A liquid-oxygen kerosene reusable engine capable of generating 4.46 million newtons (1 million pounds-force).	Engine currently in the design phase.[77]

Spaceports

Launch and reentry sites—often referred to as "spaceports"—are the nation's gateways to and from space. Although their individual capabilities vary, these facilities may house launch pads and runways as well as the infrastructure, equipment, and fuels needed to process launch vehicles and their payloads prior to launch. The first such facilities in the United States emerged in the 1940s, when the federal government began to build and operate space launch ranges and bases to meet a variety of national needs. While U.S. military and civil government agencies were the original and still are the primary users and operators of these facilities, commercial payload customers have become frequent users of federal spaceports as well.

Federal facilities are not the only portals to and from space. Indeed, the commercial dimension of U.S. space activity is evident not only in the numbers of commercially-procured launches but also in the presence of non-federal launch sites supplementing federally operated sites. The Federal Aviation Administration Associate Administrator for Commercial Space Transportation (FAA/AST) has licensed the operations of four non-federal launch sites. These spaceports have served both commercial and government payload owners.

This section describes both the federal and non-federal spaceports capable of supporting launch and landing activities that currently exist in the United States. A sub-section detailing state and private proposals for future spaceports with launch and landing capabilities is also included. Table 5 shows which states have non-federal, federal, and proposed spaceports. Tables 6, 7, and 8, located at the end of this section, summarize each spaceport's major characteristics.

Table 5: Spaceport Summary by State

State	Non-federal	Federal	Proposed
Alabama			✓
Alaska	✓		
California	✓	✓	✓
Florida	✓	✓	
Montana			✓
Nevada			✓
New Mexico		✓	✓
Oklahoma			✓
South Dakota			✓
Texas			✓
Utah			✓
Virginia	✓	✓	
Washington			✓
Wisconsin			✓

National Coalition of Spaceport States[78,79]

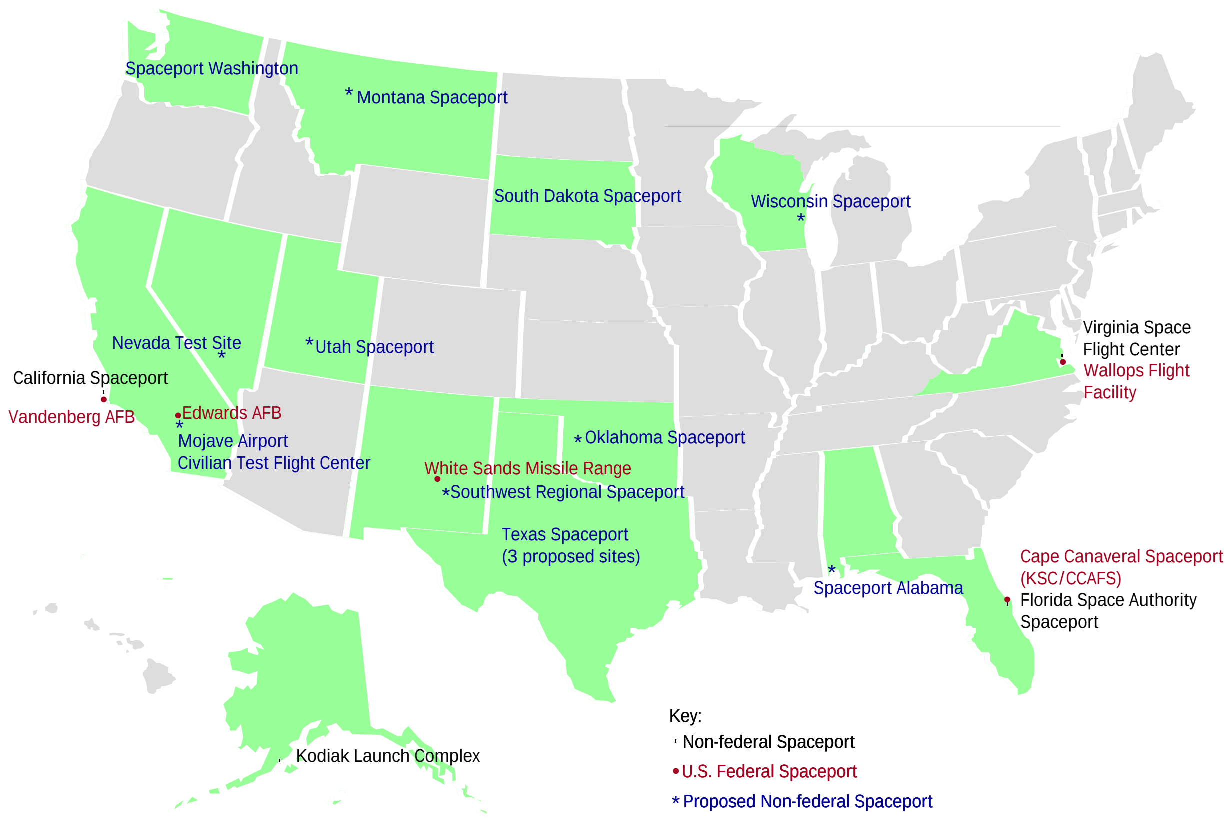
In October 2000, the states of California and Florida convened a space summit meeting in Washington, D.C. Representatives from all states with interests in spaceports attended the meeting and decided to form a coalition in order to create a mechanism for influencing space policy and commercial space 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 year 2002 found the National Coalition of Spaceport States (NCSS) aggressively pursuing activities true to its Vision Statement: "The vision of NCSS is that the U.S. will develop a strong, internationally competitive national commercial space launch industry capable of reliable, economical, and safe access-to-space, utilizing a nationwide infrastructure of spaceports and space operations."

Throughout 2002, NCSS has been an active proponent of increasing the development of space commerce, the necessary foundation of a robust access-to-space industry. Similarly, it has been a regular contributor to both the Advanced Range Technology Working Group and the Advanced Spaceport Technology Working Group, two initiatives aimed at creating roadmaps for the development of the nation's space transportation infrastructure in the years to come. Finally, NCSS has been formulating input regarding the review of national space policies currently being conducted by the Bush Administration. As a representative of the interests of the various operational and emerging space access facilities throughout the country, NCSS will remain actively involved in the various issues which have the potential to affect its membership.

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 without plans 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 orbital launch in 1989, the federal ranges have continually supported commercial launch activity. The importance of commercial launch is evident in the changes taking place at federal launch sites. Launch pads have been developed with commercial, federal, and state government support at the two major federal sites for U.S. orbital launches for the latest generation of the Delta and Atlas launch vehicles, including the Evolved Expendable Launch Vehicles (EELV). Cape Canaveral Spaceport (consisting of Cape Canaveral Air Force Station [CCAFS] and the National Aeronautics and Space Administration's [NASA] Kennedy Space Center [KSC])[80] hosts pads for Delta 4 and Atlas 5, while a pad under construction at Vandenberg Air Force Base (VAFB) will soon be able to accommodate Delta 4.

Recognizing that the ranges are aging, the U.S. government is engaged in range modernization. This effort includes the ongoing Range Standardization and Automation program, a key effort to modernize and upgrade the Eastern Range at CCAFS and portions of the Western Range at VAFB. The Air Force, the Department of Commerce, and the FAA signed a Memorandum of Agreement in January 2002 that established a process for collecting commercial sector range support and modernization requirements, communicating them to the Air Force, and considering them in the existing Air Force requirements process.

Cape Canaveral Spaceport

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

Spaceport: Cape Canaveral Spaceport/CCAFS

Operating authority: U.S. Air Force

Year of first orbital launch: 1957

Total orbital launches: 561

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: Low Earth orbit (LEO), medium Earth orbit (MEO), geosynchronous Earth orbit (GEO), Earth escape trajectory, elliptical orbit (ELI)

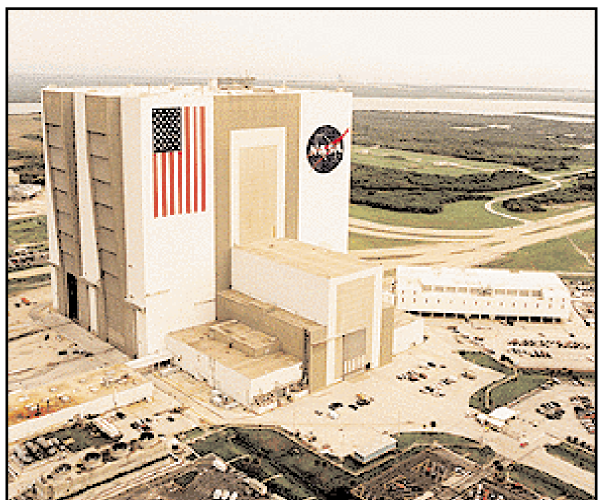
February 2000. The Cape developed rapidly during the space race of the 1950s and 1960s supporting Mercury, Gemini, and Apollo programs, as well as ballistic missile testing.

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 launch operations and provides range support for military, civil, and commercial launches.

The 45th Space Wing's Range Operations Control Center provides flight safety, weather, scheduling, and instrumentation control, along with target designation information and tracking data to and from inter- and intra-range sensors in real or near-real time for missile and space launch support. Range tracking capabilities extend over the Atlantic Ocean as far north as Canada and as far southeast as Africa. There is currently one active launch complex (LC), LC-40, for remaining Titan 4 vehicles launching from the East Coast. In 1999, Lockheed Martin began to work on new facilities for Atlas 5 at LC-41. FSA has entered into an arrangement for ownership of LC-41 and support integration facilities and is leasing them to Lockheed Martin. Refurbishment and construction of the launch pad, gantry, and support facilities was completed in 2001. The first Atlas 5 launch from LC-41 occurred on August 21, 2002.

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

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



Spaceport: Cape Canaveral Spaceport/KSC

Operating authority: NASA

Year of first orbital launch: 1967

Total orbital launches: 132

Vehicles served : Pegasus, Saturn, Shuttle

Orbits served: LEO, MEO, GEO, Earth escape trajectory, ELI 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 completed by 2003. Also in 2001 KSC broke ground for the new Space Experiment 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 will be developed as an international space research park. The state of Florida provided $26 million for the development of the Space Experiment 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 Air Force Base (AFB) was the original landing site for the Space Shuttle. The first two Shuttle flights landed on Rogers Dry Lake, a natural hard-pack riverbed measuring about 114 square kilometers (44 square miles). Unfortunately, the normally dry lakebed was flooded in 1982, rendering the site unavailable for the third Shuttle landing (the Space Shuttle landed at White Sands, New Mexico instead). 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 1.1 million liters (291,000 gallons) of cryogenic materials. A water tower with a height of 76 meters (250 feet) could supply nearly 1 million liters (265,000 gallons) of water to the concrete flame trench during launch. X-33 telemetry and tracking functions will have been performed using

Edwards Air Force Base

existing Air Force and NASA facilities at Edwards AFB and Wallops Flight Facility, Virginia. With X-33's cancellation, the government and associated contractors redistributed the components of the X-33 infrastructure for SLI projects.

The federal government is investing several million dollars 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 NASA's co-located, premier aeronautical flight research facility, Dryden Flight Research Center, hosts other NASA reusable X-vehicle demonstration programs. In 2001, NASA used a Pegasus XL launch vehicle to conduct a drop test of the X-43A demonstrator. The Air Force used a helicopter to conduct seven successful X-40A flight tests during 2001. NASA will fund X-37 testing at Edwards AFB in 2004.

Vandenberg Air Force Base

In 1941 the Army activated this site in Lompoc, California, as Camp Cook.[81] 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. Range tracking capabilities extend into the Pacific Ocean as

Spaceport: VAFB

Operating authority: U.S. Air Force

Year of first orbital launch: 1959

Total orbital launches: 624

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

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

VAFB infrastructure used for space launches includes a 4,500-meter (15,000-foot) runway, boat dock, launch facilities, payload processing facilities, tracking radar, optical tracking and telemetry facilities, and control centers. The 401-square-kilometer (155-square-mile) base also houses 53 government organizations and 49 contractor companies in 1,843 buildings. VAFB hosts a variety of federal agencies and attracts commercial aerospace companies and activities, including the California Spaceport effort (see the California Spaceport description below).

VAFB partnered with Boeing to develop launch infrastructure for the Delta 4 EELV. Space Launch Complex (SLC)-6 has been converted from a Space Shuttle launch pad into an operational facility for the Delta 4. The SLC-6 refurbishment has been completed, and tests of the new infrastructure will occur in February 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 included 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 2010. In addition, the state of California is looking into developing an alternate range operations control center to demonstrate Unmanned Aerial Vehicle wideband communication down-link technology. In 2001 VAFB opened a customer support office to provide a centralized interface for customers of launch and base services.

Current launch vehicles using VAFB include Atlas 2, Delta 2, Titan 2, Titan 4, Taurus, Minotaur, and Pegasus XL families. NASA operates SLC-2, from which Boeing Delta 2 vehicles are launched. Orbital Sciences' Taurus is launched from 576-E. Pegasus XL vehicles are processed at Orbital Sciences' facility at VAFB and then flown to various worldwide launch areas. A new commercial launch vehicle, Falcon, being developed by Space Exploration Technologies, plans to launch from VAFB.

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

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

Wallops Flight Facility

The National Advisory Committee for Aeronautics, the predecessor of NASA, established an aeronautical and rocket test range at Wallops Island, Virginia in 1945.[82,83] Since then, over 14,000

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

small rocket launches have taken place from the site, which is currently operated by NASA's Goddard Space Flight Center. The first orbital launch occurred 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, the most recent in 1999. The retired Scout made its last orbital launch from Wallops in 1985.

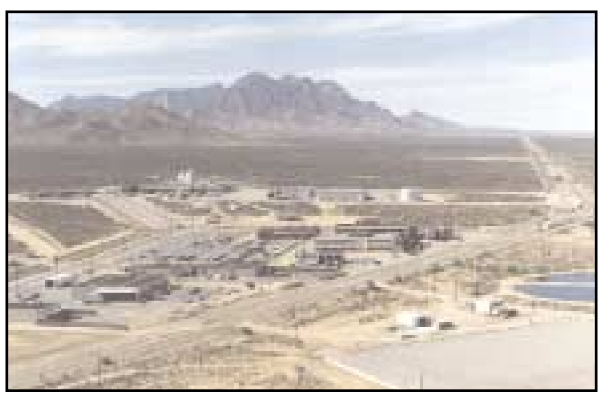
In April 1996 the Air Force designated Wallops as a launch site for converted Minuteman 2 missiles under the Orbital/Suborbital Program (along with Kodiak Launch Complex and the California Spaceport), so possible future vehicle users include the Minotaur and other vehicles developed under that program.

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

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

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 Missile Range

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.

Non-federal Spaceports with FAA/AST Licenses

While the majority of licensed launch activity still occurs at U.S. federal ranges, much future launch and landing activity may originate from private or state-operated spaceports. In order for a non-federal entity to operate a launch or landing site in the United States, it is necessary to obtain a license from the federal government through FAA/AST. To date, FAA/AST has licensed the operations of four non-federal launch sites, all of which are described in this subsection. Three of these are co-located with federal launch sites, including the California Spaceport at VAFB, the spaceport facilities operated by FSA at Cape Canaveral, and VSFC at Wallops Flight Facility. The fourth licensed, non-federal spaceport is Kodiak Launch Complex in Alaska. The first orbital launch from an FAA/AST-licensed site occurred on January 6, 1998, when a Lockheed Martin Athena 2 carrying NASA's Lunar Prospector spacecraft successfully lifted off from FSA's LC-46.

California Spaceport

Spaceport: California Spaceport

Operating authority: SSI/California Spaceport

Year of original FAA license: 1996

Year of first orbital launch: 2000

Total orbital launches: 2

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

Orbits served: Polar

On September 19, 1996, the California Spaceport became the first launch site licensed by FAA/AST.[84] In June 2001, FAA/AST renewed the spaceport's license for another five years. The California Spaceport offers commercial launch services and is operated and managed by Spaceport Systems International (SSI), a limited partnership between ITT Federal Service Corporation and California Commercial Spaceport, Inc. Co-located with VAFB on the central California coast, SSI signed a 25-year lease in 1995 for 0.44 square kilometers (0.17 square miles) of land. Located at 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 began in 1995 and was completed in 1999. The design concept is based on a "building block" approach. Power and communications cabling is routed underground to provide a "flat pad" with the flexibility to accommodate a variety of different launch systems. Although the facility currently is configured to support solid propellant vehicles, plans are in place to equip it with commodities required by liquid fueled boosters. The current configuration consists of the following infrastructure: pad deck, support equipment building, launch equipment vault, launch duct and stand, communications equipment, and launch control room. Final configuration awaits customer requirements. When fully developed, the Commercial Launch Facility will be able to accommodate a wide variety of launch vehicles including the Minuteman-based Minotaur, 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. Today, payload-processing activities occur on a regular basis. The facility supports booster processing and administrative activities. It is capable of handling all customer payload-processing needs. This includes Delta 2- and Delta 4-class payloads as well as smaller payloads as required.

The spaceport receives limited financial support from the state in the form of grants. In 2000 it received about $180,000 to upgrade the breech load doors in the Integrated Processing Facility transfer tower. The modification was completed in March 2001, and the new transfer tower is now capable of accommodating 18-meter (60-foot) payloads. This will enable SSI to process and encapsulate satellites in support of the EELV program. In May 2001 SSI received approximately $167,000 to upgrade the satellite command and telemetry systems. There are plans to upgrade the launch site infrastructure for liquid vehicles and to build a new launch control center in the future.

The state of California has also provided some support for California Spaceport business. In 2001 legislation was passed to remove the "sunset" clause on tax exemptions for commercial satellites and boosters launched from VAFB, including California Spaceport.

The California Spaceport provides payload processing and orbital launch support services for both commercial and government users. The California Spaceport provided payload-processing services for three NASA satellites: Landsat 7, 1995; TIMED/Jason, December 2001; and Aqua, May 2002. The California Spaceport's first orbital launch was that of JAWSAT, a joint project of the Air Force Academy and Weber State University, on a Minotaur launch vehicle in July 2000. To date, the site has launched two Minotaur launch vehicles.

In 2002 SSI won a ten-year Air Force satellite-processing contract for Delta 4-class four- and five-meter payloads. This contract complements an existing NASA ten-year payload-processing contract for Delta 2-class, three-meter payloads. SSI is working with several launch providers for National Missile Defense support.

The National Reconnaissance Office has contracted with SSI to provide space vehicle processing until 2011. This includes Delta 4-class payload processing support for multiple missions to be launched from VAFB. NASA and commercial Delta-class payloads are also processed for launch on the Delta 2, launched from SLC-2W on VAFB.

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.[85] This launch complex is the first new U.S. launch site since the 1960s and is the only non-federal spaceport not co-located with a federal launch site. In 1991 the Alaska state legislature created the AADC as a public company to develop aerospace-related economic, technical, and educational opportunities for the state of Alaska. Owned by the state of Alaska and operated by the AADC, the Kodiak Launch Complex has received funding from the Air Force, Army, NASA, the state of Alaska, and private firms. The commercial spaceport on Kodiak Island is located on a 12.4-square-kilometer (4.8-square-mile) site about 419 kilometers (260 miles) south of Anchorage and 40 kilometers (25 miles) southwest of the city of Kodiak. The launch site itself encompasses a nearly 5-kilometer (3-mile) arch around Launch Pad 1.

Kodiak 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

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

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 sometime in 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.

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

Kodiak has conducted a total of six launches to date. The first launch from Kodiak was that of a suborbital vehicle, Ait-1, built by Orbital Sciences for the Air Force in November 1998. A second Ait launch followed in September 1999. A joint NASA-Lockheed Martin Astronautics mission on an Athena 1 became the first orbital launch from Kodiak on September 29, 2001. In April 2002 Orbital Sciences launched a suborbital rocket, the Quick Reaction Launch Vehicle (QRLV-2), for the U.S. Air Force. The mission of the launch was missile defense flight testing.[86]

Spaceport Operated by Florida Space Authority

Established by the state of Florida as the Spaceport Florida Authority in 1989, the Florida Space Authority (FSA), renamed as such in 2001, is empowered like an airport authority to serve the launch industry and is responsible for statewide space-related economic and academic development.[87] FSA owns and operates space transportation-related facilities on about 0.29 square kilometers (0.11 square miles) of land at CCAFS owned by the Air Force. FAA/AST first issued the state organization a license for spaceport operations on May 22, 1997, and renewed the license in 2002 for another five years.

Spaceport: LC-46

Operating authority: FSA

Year of original FAA license: 1997

Year of first orbital launch: 1998

Total orbital launches: 2 (1 lunar)

Vehicles served: Athena

Orbits served: LEO, Earth escape trajectory

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

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

Thus far FSA has invested over $500 million in new space industry development. It has upgraded LC-46, built an RLV support complex (adjacent to the Shuttle landing site on KSC grounds), and developed a new space operations support complex. It has also financed 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 and processing facility.

As part of an overall effort to expand the utilization of the Cape for research and development and educational activities, FSA is in the process of obtaining a five-year license from the Air Force to use LC-47. The complex will be upgraded to support a significant number of suborbital and small LEO launches carrying academic payloads for research and training purposes.

Virginia Space Flight Center

The Virginia Space Flight Center (VSFC) traces its beginnings to the Center for Commercial Space Infrastructure, created in 1992 at Virginia's Old Dominion University to establish commercial space research and operations facilities in the state.[88] The Center for Commercial Space Infrastructure worked with NASA's Wallops Flight Facility on Wallops Island, Virginia, to develop commercial launch infrastructure at Wallops. In 1995 the organization became the Virginia Commercial Space Flight Authority (VCSFA), a political subdivision of the Commonwealth of Virginia, focused on promoting growth of aerospace business while developing a commercial launch capability in Virginia.

Spaceport: Virginia 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: Athena 1, Athena 2, Minotaur, Taurus

Orbits served: LEO

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

VCSFA has a partnership agreement with DynSpace Corporation, a subsidiary of DynCorp, of Reston, Virginia, to operate the spaceport. Funded by a contract with the state and through any spaceport revenues, DynSpace operates the VSFC for the

VCSFA. The state maintains ownership of the spaceport's assets. The federal government owns 90 percent of the spaceport's land and makes it available under a long-term use agreement. The VCSFA receives the majority of its operational funding from state sources. The remainder of support is from revenues generated through its operations.

VCSFA owns two launch pads at Wallops. Launch pad 0-B, its first launch pad, was designed as a "universal launch pad," capable of supporting a variety of small- and medium-sized expendable launch vehicles (ELV) with gross liftoff weights of up to 225,000 kilograms (496,000 pounds) that can place up to 4,500 kilograms (9,900 pounds) into LEO. Phase 1 construction of launch pad 0-B, including a 1,750-square-meter (18,830-square-foot) pad made of reinforced concrete, above-ground flame deflector, and launch mount, took place between March and December 1998. In 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 launch pad 0-B.

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

From its location on the Atlantic coast, VSFC can accommodate a wide range of orbital inclinations and launch azimuths. Optimal orbital inclinations accessible from the site are between 38 and 60 degrees; other inclinations, including sun-synchronous orbits (SSO), can be reached through in-flight maneuvers. Launch pad 0-A can support a number of small solid-propellant boosters, including the Athena 1, Minotaur, and Taurus. Launch pad 0-B can support larger vehicles, including the Athena 2. VSFC also has an interest in supporting future RLVs, possibly using its launch pads or three runways at Wallops Flight Facility.

VSFC also provides an extensive array of services including the provision of supplies and consumables to support launch operations, facility scheduling, maintenance, inspection to ensure timely and safe ground processing and launch operations, and coordination with NASA on behalf of its customers. VSFC is in the process of constructing a $4-million logistics and processing facility at NASA Wallops, capable of handling payloads of up to 5,700 kilograms (12,600 pounds). The facility, which includes high bay and clean room environments, is scheduled for completion in October 2003.

Proposed Non-federal Spaceports

Several states are planning to develop spaceports offering a range of launch and landing services. Two common characteristics of many of the proposed spaceports are inland geography—a contrast to the coastal location of all present-day U.S. spaceports—as well as interest in hosting RLV operations. Descriptions of specific efforts to establish spaceports, which are in various stages of development, are presented below.

Gulf Coast Regional Spaceport

The Gulf Coast Regional Spaceport is one of three independent Texas spaceport proposals being supported by the Texas Aerospace Commission.[89] The Gulf Coast Regional Spaceport Development Corporation has proposed constructing a spaceport in Brazoria County, Texas, 80 kilometers (50 miles) south of Houston. The spaceport may support medium- and heavy-lift commercial RLVs to LEO, MEO, and GEO. The Corporation has identified undeveloped land currently used for agriculture as a potential site and is working with the private owner of the land to acquire the property.

Local governments invested nearly $300,000 in the project between 1999 and 2001, primarily for site selection work. In February 2002 the state approved the Gulf Coast Regional Spaceport board's access to the first installment of $500,000 in state grant money.[90] The initial $150,000 paid contractor fees for an in-depth safety analysis of the site based on the use of different types of launch systems. The development plan will determine what infrastructure is necessary.

Mojave Airport Civilian Flight Test Center

The East Kern County, California, government established the Mojave Airport in 1935 in Mojave, California.[91,92] 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 1972 a special district, the East Kern Airport District, was created by law, and the Mojave Airport and its Civilian Flight Test Center were built.

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. An environmental impact assessment began in 2002 and is expected to take at least two years to complete.[93] Upon completion of the environmental impact assessment, an official spaceport development plan will be developed. The spaceport will conduct payload processing, payload integration, testing, and launch services for horizontal launches of RLVs.

The Civilian Flight Test Center consists of several test stands, three runways, an air control tower, a roton test stand, engineering facilities, and a high bay building. In 2002 the facility increased the number of test stands available from four to seven. Between $250,000 and $300,000 of local government and private funding was invested in construction of the new test stands. East Kern Airport District is planning for the construction of a new taxiway. Funding for the project, approximately $4.5 million, is expected to become available in June 2003. Construction of the new taxiway is scheduled for completion in late 2003.

Mojave Airport Civilian Flight Test Center

In the last two years, XCOR Aerospace has been performing flight tests at this facility and recently had multiple successful tests with the EZ-Rocket. XCOR Aerospace had three Rocketplane test flights up to 3,657 meters (12,000 feet) in 2002. In addition, rocket engines of up to 133,000 newtons (30,000 pounds-force) of thrust were tested at the site in 2002, and larger engines are expected to be tested at the site by the end of 2003.

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 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.[94] 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: Malmstrom AFB in Great Falls, Montana, and 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 launches 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.[95] 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.[96] 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). Consisting of five full-time employees and directed by seven governor-appointed board members, OSIDA promotes the development of spaceport facilities, space exploration, space education, and space-related industries in Oklahoma. Currently, the state of Oklahoma provides operating costs for OSIDA, but the organization expects to be financially independent in five years.

The former Clinton-Sherman AFB at Burns Flat is one of the sites proposed for a future spaceport in Oklahoma. Existing infrastructure includes a 4,100-meter (13,500-foot) runway, a large maintenance and repair hangar, utilities, a rail spur, and 12.4 square kilometers (4.8 square miles) of open land. In 2002 OSIDA entered into an agreement with a private corporation to conduct an environmental impact study. The study, expected to continue through December of 2003, is a critical step towards receiving a launch site operator license from FAA/AST.

Burns Flat, Proposed Site of the Oklahoma Spaceport

The city of Clinton conveyed ownership of the spaceport site to OSIDA in 2002. 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 state of Oklahoma offers several incentives, valued at over $128 million over ten years, to attract space companies to the state. For example, a jobs program provides quarterly cash payments of up to five percent of new taxable payroll directly to qualifying companies for up to ten years. Also, the state will provide a $15-million tax credit to one corporation that meets specific qualifying criteria, including equity capitalization of $10 million and the creation of at least 100 Oklahoma jobs. Some organizations also may qualify for other state tax credits, tax refunds, tax exemptions and training incentives. Besides state funding, NASA issued $241,000 to OSIDA for space-related educational grants to be used throughout the state.

OSIDA has signed Memoranda of Understanding with several companies for use of the Burns Flat site. In September 2001 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.[97] While South

Proposed South Dakota Spaceport Site
Near Ellsworth AFB

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.

South Texas Spaceport

The South Texas Spaceport is a joint undertaking of the South Texas Spaceport Consortium and the Willacy County Development Corporation for Spaceport Facilities.[98] The Spaceport Consortium is a 13-county regional coalition of local governments, economic development organizations, and higher education institutions that was created in 1998 to pursue commercial space launch operations. The Willacy County Develop-ment Corporation was created in 2001 to manage the spaceport site evaluation and other technical and administrative elements of the project under a Texas Aerospace Commission grant. In February 2002 the Texas Aerospace Commission awarded a $500,000 contract to the South Texas Spaceport.

Willacy County is investigating the feasibility of developing and operating a launch facility that could serve commercial launch operators as well as sounding rocket programs and other activities associated with current and proposed programs at educational institutions. The proposed spaceport site is a 40-square-kilometer (15.4-square-mile) undeveloped portion of Willacy County adjacent to the Laguna Madre and the Gulf of Mexico approximately 150 kilometers (93 miles) south of Corpus Christi and 65 kilometers (40 miles) north of Brownsville. The site initially may support the suborbital and small orbital launch systems currently in service or being developed for service in the near future, with a long-term focus on RLVs. Due to its extreme southern location, the site would become the U.S. site capable of supporting the largest payload launches to geosynchronous Earth orbit (GEO).

To date, no infrastructure has been built, and no launch activity has taken place at the proposed South Texas Spaceport. Initial planning will focus on the infrastructure needed to support activities of launch operators with current development programs. These operators have expressed a desire to use the site for ground-launched sounding rockets and deployment of balloon-supported platforms that will carry suborbital rockets to altitudes from which they can achieve orbit. Initial construction will likely be limited to a hangar, ramp area, and small payload preparation facilities.

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.[99] 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, vertical landings, and horizontal landings and will 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 for Space Commercialization, part of the New Mexico Economic Development Department. In 2001 the state legislature approved $1.5 million in funds for fiscal years 2002 through 2004 for spaceport development, including environmental studies and land acquisition; this funding, however, is contingent on the state receiving a written commitment from a private company or government organization to host an RLV program. The state has provided several other incentives for the spaceport, including gross receipt deductions, industrial revenue bonds, and investment and job training credits.

In 2002 the state of New Mexico and the U.S. Army White Sands Missile Range signed a Memorandum of Agreement supporting the development of the Southwest Regional Spaceport. The agreement enables the spaceport to share resources and integrate launch scheduling and operations with the Army test range.[100]

Spaceport Alabama

Spaceport Alabama is a proposed next-generation, full-service departure and return facility intended to support orbital and suborbital space access vehicles. Currently being developed by the Aerospace Development Center of Alabama, the Spaceport Alabama proposal will be presented to the Alabama Commission on Aerospace Science and Industry and the Alabama legislature for formal adoption during the 2003 legislative session. Under the current proposal, the legislature will establish the Spaceport Alabama Authority, which will oversee the development of Spaceport Alabama.

A site under consideration for a spaceport is in Baldwin County, across the bay from the city of Mobile. This site is seen as ideal for supporting both government and commercial customers. It allows for targeting next-generation RLVs for access to LEO, medium Earth orbit (MEO), and GEO.

Under the current spaceport development plan, a spaceport facility could become operational within 10 years depending on market demand. The current plan calls for the establishment of a "total spaceport enterprise" concept, consisting of a departure and return facility, processing and support facilities, full support infrastructure, a research and development park, a commerce park, supporting community infrastructure, intermodal connectivity, and other services and infrastructure necessary for providing a "turn key" capability in support of space commerce, research and development, security, and related services. The current plan focuses primarily on RLVs, though some suborbital ELVs in support of scientific and academic missions could be possible.[101]

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.[102] 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

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.[103] 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 will include construction of a new 4,575-meter- (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 will 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 VentureStar™ 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.[104] The Pecos County/West Texas Spaceport Development Corporation, established in mid-2001, has proposed the development of a spaceport 29 kilometers (18 miles) southwest of Fort Stockton, Texas. The spaceport will serve vertical-takeoff and -landing RLVs, as well as suborbital sounding rockets. The spaceport will be able to support launches to GEO, SSO, and International Space Station (ISS) orbits. Spaceport infrastructure will include a launch site with a 4,570-meter (15,000-foot) safety radius, an adjacent recovery zone 4,570 meters (15,000 feet) in diameter, and payload integration and launch control facilities.

In February 2002 the Texas Aerospace Commission awarded a $500,000 contract to the West Texas Spaceport. In June 2002 the Air Force approved the site for various test-launch projects. JP Aerospace began launching small suborbital rockets from the site in October 2002.[105]

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.[106,107] The goal of the spaceport is to support space research and education through suborbital 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. In 2002 the program hosted two launch events during which over 50 student-built rockets were launched. The spaceport began operating approximately four years ago. While suborbital 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 suborbital launches in addition to portable launch facilities, such as mission control, which are erected and disassembled as needed. The pier from which launches take place was widened and strengthened during 2002. Also, some existing structures were removed from the property to clear space for the construction of a proposed mission control and education center. Plans for developing additional launch infrastructure are uncertain at this time.

The spaceport developers are in the process of creating a development plan. Draft legislation is being reviewed by the Wisconsin Senate for development of a spaceport authority.

Table 6: Federal Spaceports: Infrastructure and Status

Spaceport	Location	Owner/Operator	Launch Infrastructure at Site	Current Development Status
Cape Canaveral Spaceport (CCAFS/KSC)	Cape Canaveral, Florida	U.S. Air Force, NASA, Florida Space Authority	Telemetry and tracking facilities, jet and shuttle capable runways, launch pads, hangar, vertical processing facilities and assembly building.	RLV and ELV spaceport is operational.
Edwards AFB	Mojave, California	U.S. Air Force	Telemetry and tracking facilities, jet and shuttle capable runways, Delta 4 launch pad, operations control center, movable hangar, fuel tanks, and water tower.	Site is operational.
Vandenberg AFB	Lompoc, California	U.S. Air Force	Launch pads, vehicle assembly and processing buildings, payload processing facilities, telemetry and tracking facilities, control center, engineering office space, shuttle-capable 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	Telemetry and tracking facilities, heavy jet and shuttle-capable runway, launch pads, vehicle assembly and processing buildings, payload processing facilities, range control center, blockhouses, large aircraft hangers, and user office space.	Wallops Flight Facility has not supported any orbital flights since the failure of Conestoga in 1995. NASA is committed to maintaining the existing infrastructure.
White Sands Missile Range	White Sands, New Mexico	U.S. Army	Telemetry and tracking facilities, runway, engine and propulsion testing facilities.	NASA flight test center is operational. RLV-specific upgrades will probably be required.

Table 7: Licensed Non-federal Spaceports: Infrastructure and Status

Spaceport	Location	Owner/Operator	Launch Infrastructure at Site	Current Development Status
California Spaceport	Lompoc, California	Spaceport Systems International	Existing launch pads, runways, payload processing facilities, telemetry and tracking equipment.	The Integrated Processing Facility has an upgraded power system, digital control systems, secure communication, HVAC systems, fuel and oxidized pads and fairing encapsulation in Cell 1. A new 30-ton crane has been added to the Transfer Tower as well as a new interior blast door. The Integrated Processing Facility is now fully configured to support Delta 2- and Delta 4-class payloads. Concrete flame ducts, communication, electrical, and water infrastructure are in place.
Kodiak Launch Complex	Kodiak Island, Alaska	Alaska Aerospace Development Corporation	Launch control center, payload processing facility, and integration and processing facility. Limited range support infrastructure (uses mobile equipment).	Construction of the launch control center, payload processing facility, and integration and processing facility was completed in 2000.
Spaceport owned by Florida Space Authority	Cape Canaveral, Florida	Florida Space Authority	One launch complex including a pad and a remote control center, a small payload preparation facility, and an RLV support facility.	Has invested over $200 million to upgrade launch sites, build an RLV support complex adjacent to the Shuttle landing facilities, and develop a new space operations support complex.
Virginia Space Flight Center	Wallops Island, Virginia	Virginia Commercial Space Flight Authority	Two orbital launch pads, payload processing and integration facility, vehicle storage and assembly buildings, on-site and downrange telemetry and tracking, and payload recovery capability.	Currently completing $6.6 million in launch range improvements. Construction of a new $2.4-million payload processing and integration facility underway.

Table 8: Proposed Non-federal Spaceports: Infrastructure and Status

Spaceport	Location	Owner/Operator	Launch Infrastructure at Site	Current Development Status
Gulf Coast Regional Spaceport	Brazoria County, Texas	To be determined	No infrastructure at this time.	The final Texas Spaceport site(s) has not been selected yet. Three sites are being considered at this time.
Mojave Airport Civilian Flight Test Center	Mojave, California	East Kern Airport	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.	Inactive at this time.
Nevada Test Site	Nye County, Nevada	Department of Energy/Nevada Test Site Development Corporation	No launch infrastructure at this time. Power and basic facilities available.	Kistler was issued a sub-permit allowing it to operate a launch and recovery operation. Nevada Test Site Development Corp-oration is actively promoting the site as a spaceport for both RLVs and conventional launchers.
Oklahoma Spaceport	Washita County, Oklahoma	Oklahoma Space Industry Development Authority	4,115-meter (13,500-foot) runway, a 5,200-square-meter (56,000-square-foot) manufacturing facility, a 2,785-square-meter (30,000-square-foot) maintenance and painting hangar, and 435 square kilometers (168 square miles) of land available for further construction.	The Clinton-Sherman AFB at Burns Flat was designated as the future spaceport. No state money has been allocated for development yet.
South Dakota Spaceport	Near Ellsworth AFB	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.
South Texas Spaceport	Willacy County, Texas	To be determined	No infrastructure at this time.	The final Texas Spaceport site(s) has not been selected yet. Three sites are being considered at this time.
Southwest Regional Spaceport	Upham, New Mexico	New Mexico Office of Space Commercialization	No infrastructure at this time.	Plans for this site include a spaceport central control facility, an airfield, a maintenance and integration facility, a launch and recovery complex, a flight operations control center, and a cryogenic plant.
Spaceport Alabama	Baldwin County, Alabama	To be determined	No infrastructure at this time.	Open field space with basic power, water, and utilities.
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.
Utah Spaceport	Wah Wah Valley, Utah	Utah Spaceport Authority	No infrastructure at this time.	Plans for the proposed Utah Spaceport include a central administrative control facility, an airfield, maintenance and integration facility for payloads and spacecraft, launch pads, a flight operation control center, and a propellant storage facility.
West Texas Spaceport	Pecos County, Texas	To be determined	No infrastructure at this time.	The final Texas Spaceport site(s) has not been selected yet. Three sites are being considered at this time.
Wisconsin Spaceport	Sheboygan, Wisconsin	Owner: City of Sheboygan; Operator: Rockets for Schools	A vertical pad for suborbital launches in addition to portable launch facilities, such as mission control.	Plans for developing additional launch infrastructure are uncertain at this time.

Endnotes

[1] The orbiter, main engines, and solid rocket boosters are refurbished and reused, but the external tank is irrecoverable.

[2] Although used in a multinational venture, Sea Launch's Zenit 3SL is included here because of U.S.-based Boeing's strong involvement in the venture and also because FAA/AST licenses Sea Launch launch operations.

[3] The Air Force has made at least one exception to fly a non-U.S. government payload on a Minotaur vehicle.

[4] Lockheed Martin Space Systems. "Athena - Facts" (http://www.ast.lmco.com/launch_athenaFacts.shtml), accessed 20 November 2002.

[5] Lockheed Martin Space Systems. "Atlas - Facts" (http://www.ast.lmco.com/launch_atlasFacts.shtml), accessed 20 November 2002.

[6] The Boeing Company. "Delta II Medium Launch Vehicle" (http://www.boeing.com/defense-space/space/delta/delta2/delta2.htm), accessed 20 November 2002.

[7] The Boeing Company. "Delta III Launch Vehicle" (http://www.boeing.com/defense-space/space/delta/delta3/delta3.htm), accessed 20 November 2002.

[8] The Boeing Company. "Delta IV Launch Vehicle" (http://www.boeing.com/defense-space/space/delta/delta4/delta4.htm), accessed 20 November 2002.

[9] U.S. Air Force. "Fact Sheet: The OSP Space Launch Vehicle ('Minotaur')" (http://www.losangeles.af.mil/SMC/PA/Fact_Sheets/minotaur_fs.htm), accessed 20 November 2002.

[10] Orbital Sciences Corporation. "ROCSAT-3/COSMIC" (http://www.orbital.com/SatellitesSpace/LEO/ROCSAT/index.html), accessed 20 November 2002.

[11] Orbital Sciences Corporation. "Pegasus" (http://www.orbital.com/LaunchVehicle/SpaceLaunchVehicles/Pegasus/index.html), accessed 20 November 2002.

[12] Orbital Sciences Corporation. "Taurus" (http://www.orbital.com/LaunchVehicle/SpaceLaunchVehicles/Taurus/index.html), accessed 20 November 2002.

[13] The first stage of a Peacekeeper ICBM was used as the Taurus' first stage for the first Taurus launch.

[14] "Investigators Find Problem that Doomed Taurus Launch," *Spaceflight Now* (http://spaceflightnow.com/taurus/t6/ 011107update.html), 7 November 2001.

[15] Lockheed Martin Space Systems. "Titan II - Facts" (http://www.ast.lmco.com/launch_titanIIfacts.shtml), accessed 20 November 2002.

[16] Once online, the Delta 4 Heavy will be even more powerful than the Titan 4B.

[17] Lockheed Martin Space Systems. "Titan IV - Facts" (http://www.ast.lmco.com/launch_titanIVfacts.shtml), accessed 20 November 2002.

[18] Sea Launch. "Sea Launch Launch Vehicle" (http://www.sea-launch.com/special/sea-launch/launch_vehicle.htm), accessed 20 November 2002.

[19] Boeing Phantom Works. "AirLaunch System" (http://www.boeing.com/phantom/als.html), accessed 20 November 2002.

[20] Interview with AirLaunch, 8 January 2002.

[21] Turner, Andrew E. "Aquarius Launch Vehicle: Failure *is* an Option," *Space Times*, vol. 40, no. 3, May-June 2001.

[22] Space Systems/Loral. "Aquarius: Economic Value of a Consumables Launcher," Final briefing on Competitive Space Grant C00-0200 for the California Technology, Trade and Commerce Agency and the California Space Authority, 25 June 2002.

[23] E'Prime Aerospace. "EPAC Eagle S-Series" (http://www.eprimeaerospace.com/eagle.htm), accessed 20 November 2002.

[24] Space Exploration Technologies Corporation. "Falcon LV Vehicle Explorer" (http://www.spacex.com/falcon/falcon2.htm), accessed 20 November 2002.

[25] Berger, Brian. "Web Entrepreneur Eyes Small Launcher Market," *Space News*, 11 November 2002.

[26] Rocket Propulsion Engineering Company. "LV-1" (http://www.rocketprop.com/lv-1.htm), accessed 15 January 2003.

[27] Microcosm, Inc. "Successful Launch of SR-XM," 26 March 2001.

[28] Conger, Robert E., Shyama Chakroborty, James R. Wertz, and Jack Kulpa. "SCORPIUS, A New Generation of Responsive, Low Cost Expendable Launch Vehicle Family [sic]" (http://www.smad.com/scorpius/world_paper.pdf), accessed 20 November 2002.

[29] Space Launch Corporation press release. "Space Launch Corporation Awarded over $2M in Contracts by DARPA," 23 April 2002.

[30] Bristol Aerospace, Ltd. "Black Brant Sounding Rockets" (http://www.bristol.ca/BlackBrant.html), accessed 20 November 2002.

[31] NASA Wallops Flight Facility. "Sounding Rocket Program Handbook" (http://www.nsroc.com/front/what/SRHB.pdf), accessed 20 November 2002.

[32] SPACEHAB, Inc., press release. "SPACEHAB's Astrotech Unit Completes Successful First Launch of New Oriole Sounding Rocket," 13 July 2000.

[33] SPACEHAB, Inc., press release. "SPACEHAB's Astrotech Sells Sounding Rocket Assets," 2 August 2001.

[34] NASA Wallops Flight Facility. "Terrier-Orion Characteristics" (http://www.wff.nasa.gov/pages/terrier-orion.html), accessed 20 November 2002.

[35] University of Queensland. "HyShot program secures place in flight history," 16 August 2002.

[36] Communication with Bobby Watkins, NASA Headquarters, 11 December 2002.

[37] Space Shuttle Competitive Sourcing Task Force, "Alternate Trajectories: Options for Competitive Sourcing of the Space Shuttle Program" (executive summary), September 2002.

[38] Carter, Preston H. "RASCAL: Space Access for Exploring Military Space CONOPS and Technology," 31 October 2002.

[39] DARPA press release. "RASCAL Contractors Selected," 19 April 2002.

[40] Interview with Kelly Space and Technology, 9 January 2002.

[41] Communication with Armadillo Aerospace, 12 November 2002.

[42] SLI news website (http://www.slinews.com/partners-commercial-05-01.html), accessed 7 January 2002.

[43] Interview with Kistler Aerospace Corporation, 8 January 2002.

[44] Pioneer Rocketplane, Operations Concept (http://www.rocketplane.com/OpsConcept.html).

[45] Interview with Pioneer Rocketplane, 8 January 2002.

[46] Interview with Pioneer Rocketplane, January 4, 2001.

[47] Interview with Pioneer Rocketplane, 8 January 2002.

[48] DARPA press release. "RASCAL Contractors Selected," 19 April 2002.

[49] "Space Access' Launch System Based on Airbreathing Ejector Ramjet," *Aviation Week and Space Technology*, 30 March 1998, pp. 75-77.

[50] "Rocket Planes," *Popular Science*, February 1999, pp. 44-45.

[51] "Space Access' Launch System Based on Airbreathing Ejector Ramjet," *Aviation Week and Space Technology*, 30 March 1998, pp. 75-77.

[52] "Space Access' Launch System Based on Airbreathing Ejector Ramjet," *Aviation Week and Space Technology*, 30 March 1998, pp. 75-77.

[53] Interview with SPACE ACCESS®, LLC, 3 January 2001.

[54] Interview with SPACE ACCESS®, LLC, 3 January 2001.

[55] Interview with XCOR, 1 November 2002.

[56] Communication with X PRIZE® Foundation, 21 November 2002.

[57] NASA Marshall Space Flight Center press release. "Revolutionary Air-breathing Engine Rockets Past Key Milestone Ahead of Schedule," 8 July 2002.

[58] SpaceDev, Inc., press release. "SpaceDev Awarded Air Force Contract for Space Vehicle Propulsion Module," 1 May 2002.

[59] SpaceDev, Inc. "SpaceDev Hybrid Rocket Propulsion Technology" (http://www.spacedev.com/newsite/templates/subpage3.php?pid=185), accessed 25 November 2002.

[60] NASA Dryden Flight Research Center. "Hyper X/X-43A" (http://www.dfrc.nasa.gov/Projects/hyperx/x43.html), accessed 25 November 2002.

[61] NASA Marshall Space Flight Center press release. "NASA Developing Hypersonic Technologies; Flight Vehicles Only Decades Away," 22 July 2002.

[62] Sweetman, Bill. "Scram!" *Popular Science* (http://www.popsci.com/popsci/aviation/article/0,12543,364514-1,00.html), accessed 25 November 2002.

[63] NASA Marshall Space Flight Center press release. "NASA's Second Generation Reusable Launch Vehicle Program Advances Propulsion Technology with Successful Engine Test Series," 7 August 2001.

[64] Interorbital Systems Corporation. "Sounding Rockets" (http://www.interorbital.com/Sounding_Rockets.htm), accessed 25 November 2002.

[65] Rocket Propulsion Engineering Company. "SV-1 and SV-2" (http://www.rocketprop.com/sv-1_and_sv-2.htm), accessed 25 November 2002.

[66] Missile Defense Agency Small Business Innovation Research Program. "High Performance Missile Upper Stage Liquid Rocket Engine" (http://www.winbmdo.com/scripts/sbir/abstract.asp?log=0565&Phase=1&Ph1Yr=02&firm_id=3752&int=02), accessed 25 November 2002.

[67] XCOR Aerospace. "Engine Projects" (http://www.xcor.com/engines.html), accessed 25 November 2002.

[68] XCOR Aerospace press release. "XCOR Aerospace Acquires Rotary Rocket Assets," 23 April 2002.

[69] Andrews Space & Technology, Inc. "ACES Alchemist" (http://www.andrews-space.com/en/corporate/Alchemist.html), accessed 25 November 2002.

[70] Boeing Phantom Works. "X-37 Reusable Spaceplane/X-40A Space Maneuver Vehicle" (http://www.boeing.com/phantom/x37.html), accessed 25 November 2002.

[71] NASA press release. "NASA Awards Contracts for Flight Demonstrators," 20 November 2002.

[72] NASA Marshall Space Flight Center press release. "X-40A Free Flights Completed at Dryden; X-37 Next," 23 May 2001.

[73] NASA Marshall Space Flight Center press release. "COBRA Engine, an Option for Space Launch Initiative, Completes Milestone Review," 14 June 2002.

[74] NASA Marshall Space Flight Center press release. "NASA's Marshall Center Tests New Breed of Auxiliary Propulsion for Space Launch Initiative," 28 March 2002.

[75] NASA Stennis Space Center press release. "Stennis Space Center to Begin Boeing Rocketdyne RS-83 Preburner Testing," 20 September 2002.

[76] The Boeing Company press release. "Boeing Designing First Large Reusable Hydrocarbon Rocket Engine," 5 June 2002.

[77] TRW. "TR107 Main Engine" (http://www.trw.com/marketplace/main/1,,39_1541_415_1367_4781_4787^6^4787^4787,00.html), accessed 25 November 2002.

[78] Interview with National Coalition of Spaceport States, 21 December 2001.

[79] Communication with National Coalition of Spaceport States, 11 November 2002.

[80] A 50-year comprehensive Master Plan for the future development of Cape Canaveral Spaceport was released in 2002. The Plan was prepared in partnership between NASA, the Air Force, and Florida Space Authority. Other participants were the Merritt Island National Wildlife Refuge, Canaveral National Seashore, and Navy Ordinance Test Unit.

[81] Survey response from the Customer Support Office, 30th Space Wing, 12 November 2002.

[82] Interview with Virginia Commercial Space Flight Authority, 11 December 2001.

[83] Survey response from Wallops Flight Facility, 28 October 2002.

[84] Survey response from Spaceport Systems International, 26 October 2002.

[85] Interview with Alaska Aerospace Development Corporation, 10 December 2001.

[86] Space-Launcher.com, Launch Log 2002, (www.orbireport.com/log.html), accessed 20 November 2002.

[87] Survey response from Florida Space Authority, 5 November 2002.

[88] Survey response from Virginia Commercial Space Flight Authority, 28 October 2002.

[89] Interview with Brazoria County Partnership (representing Brazoria County, Texas), 14 December 2001.

[90] Brazoria County Partnership Spaceport News Release. "Grant Money Released to Gulf Coast Spaceport," 1 March 2002.

[91] Interview with the Finance Office of the East Kern Airport District, 14 December 2001.

[92] Interview with Mojave Airport Civilian Flight Test Center, 20 November 2002.

[93] Interview with Mojave Airport Civilian Flight Test Center, 20 November 2002.

[94] Interview with Montana Department of Commerce, 7 December 2001; Interview with High Plains Development and Port Authority, Inc., 7 December 2001.

[95] Interview with Space Technology Group, 10 December 2001.

[96] Survey response from Oklahoma Space Industry Development Authority, 11 October 2002.

[97] Interview with South Dakota Governor's Office, 6 December 2001.

[98] Survey response from South Texas Spaceport, 22 October 2002.

[99] Survey response from New Mexico Office for Space Commercialization, 25 October 2002.

[100] Ramirez, Steve. "WSMR to Cooperate in Commercial Space Efforts," *Las Cruces Sun-News* (http://www.edd.state.nm.us/SPACE/news.htm), accessed 24 January 2003.

[101] Communication with Alabama Governor's Advisor on Aerospace Affairs, 13 December 2002.

[102] Interview with Washington Office of Trade and Economic Development, 12 December 2001.

[103] Interview with Utah State Department of Community and Economic Development, National Business Development Office, 10 December 2001.

[104] Interview with Texas Aerospace Commission (representing West Texas Spaceport), 10 December 2001.

[105] Pecos County West Texas Spaceport Development Corporation. *Launching West Texas Into an Exciting New Millennium*, 2002.

[106] Interview with Space Explorers, Inc. (representing Wisconsin), 6 December 2001.

[107] Interview with Space Explorers, Inc. (representing Wisconsin), 21 October 2002.