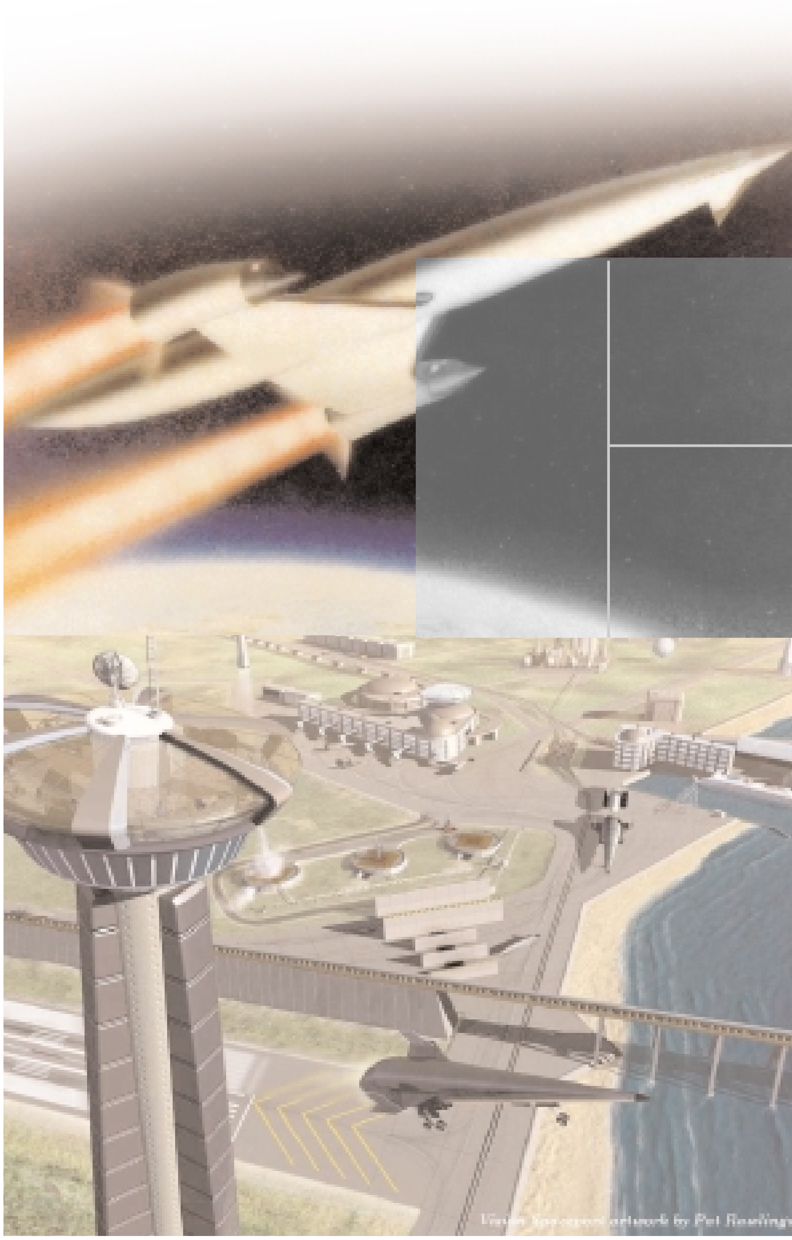
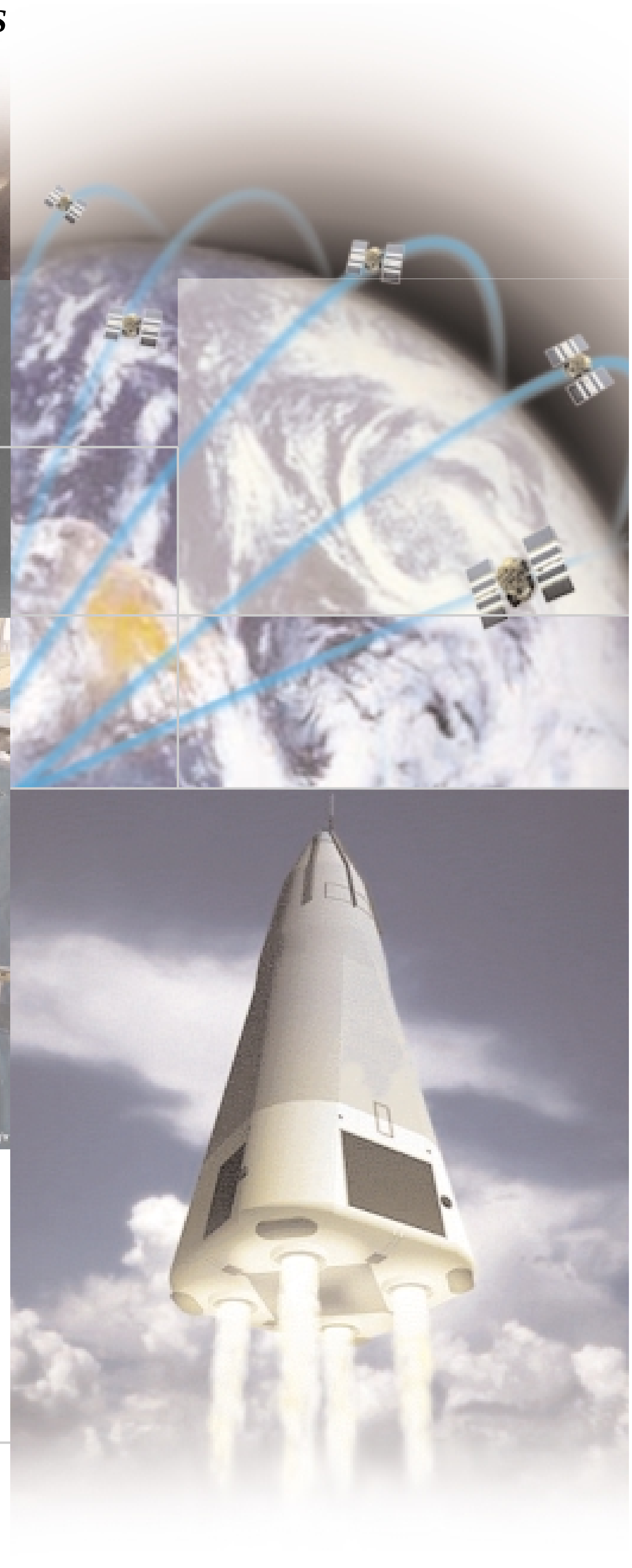
2000 Reusable Launch Vehicle Programs & Concepts

With a Special Section on Spaceports





January 2000
Associate Administrator for
Commercial Space Transportation (AST)

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Cover Page Images (clockwise, from top left)

"*Skylon*" RLV concept (courtesy: Reaction Engines Ltd., UK).

LEO satellite constellation, artist's conception (courtesy: Futron Corporation).

DC-XA RLV concept (courtesy: McDonnell Douglas).

Vision Spaceport (courtesy: Vision Spaceport Project, a joint-sponsored research agreement (NCA10-0030) between NASA, Industry, and Academia, initiated by NASA JCS).

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Introduction

The Publication

In January 1998, the Federal Aviation Administration (FAA) Associate Administrator for Commercial Space Transportation (AST) released the first edition of the *Reusable Launch Vehicle Programs and Concepts* report. The report provided company background, vehicle design, and technical information on commercial, government, and international reusable launch vehicle (RLV) programs. The report filled a need for up-to-date, objective information on reusable launch vehicle activities.

In January 1999, the second edition of this report was published, providing updated information on the important strides made by several of the RLV concepts during 1998. These strides included the development and testing of spacecraft components and systems, and in some cases flight testing.

This third edition of *Reusable Launch Vehicle Programs and Concepts* is similar to its predecessor, with some important additions and changes. Each individual entry has been updated with the most recent publicly available information on the RLV's financial, technical, testing, and manufacturing progress. A key addition to this edition is a section providing an overview of launch sites, i.e., Spaceports, including information on the relevant infrastructure in place at the site and the status of development of new facilities.

Following the introduction, this report provides a chronology of many events in the RLV industry in 1999. The report then divides the RLV programs into four categories: United States Commercial Programs, United States Government Programs, International Concepts, and X PRIZE® Competitors. The report also contains a summary table of all of the vehicles, which provides company, technical, performance, and market information at a glance. The final part of this report contains the new section on Spaceports.

RLV Industry Background

The United States Government and other governments have been exploring the design and development of RLVs for several decades. During the mid-1990s, however, several small "start-up" companies, staffed with entrepreneurs, engineers and other technical personnel with years of experience in the aerospace and launch vehicle industries, proposed to develop commercial reusable launch vehicles. While many of these vehicles are being built with the expectation that there will be significant demand for launches of communication and remote sensing satellites to low Earth orbit (LEO), some hope to serve other new markets such as space station resupply and commercial microgravity missions. Some RLV operators also hope to serve the market for geosynchronous Earth orbit (GEO) launches as well. In addition, over a dozen RLV designs are proposed specifically to help foster a market for space tourism.

Also during the mid-1990s, the National Aeronautics and Space Administration (NASA) began development of testbed vehicles that would prove technologies and operations concepts for next-generation RLVs. The X-33 vehicle is undergoing assembly, while one of the three X-34 vehicles has been constructed, with the second X-34 vehicle scheduled to make a powered flight test in 2000. The new X-37 vehicle is beginning development and is scheduled to be carried into orbit by the Space Shuttle in 2002. NASA hopes that the technologies tested and refined in these programs will be applied to future operational RLVs.

The RLV concepts proposed for development present a variety of launch, landing, and propulsion concepts. Several vehicles employ a "spaceplane" design that takes off and lands horizontally like an airplane, possibly incorporating air-breathing engines for atmospheric flight. These designs generally use upper stages to carry payloads to orbit, while the spaceplane remains on a sub-orbital trajectory. Several concepts plan single-stage-to-orbit (SSTO) vehicles to deliver payloads directly to orbit, while other vehicles use a multi-stage vertical-launched approach in which each stage returns to Earth for recovery and reuse. The X-vehicles under development by the United States government are designed to test technologies and operational concepts and therefore represent varied designs and mission profiles.

The development of RLVs is driven by the desire to reduce launch costs. Potential reduction in RLV long-term production costs is attributed to vehicle refurbishment and reuse after each flight, rather than replacement. RLVs are designed for quick-turnaround operations that will allow for a higher volume and launch rate, resulting in economies of scale. Many studies suggest that reductions in launch costs will enable the emergence and development of new space missions and businesses.

1999 Developments

Last year saw a number of significant steps toward the development of fully operational reusable launch vehicles. Several RLV companies conducted flight and component hardware tests. Rotary Rocket Company completed its initial translational flight of the Roton atmospheric test vehicle. NASA concluded its X-34 captive carry flight tests, gathering valuable information on the vehicle's aerodynamics. It was also during 1999 that three new vehicles were introduced. NASA and Boeing Co. signed an agreement to develop the X-37, and two new X-PRIZE entrants unveiled plans to develop RLVs. COSMOPOLIS XXI of Moscow, Russia stated their intention to build a RLV (as yet unnamed) and TGV Rockets, Inc. of Bethesda, Maryland announced plans to develop its MICHELLE-B vehicle.

The following chronology summarizes many key events related to the reusable launch vehicle industry in 1999:

- *January*- Successful tests at the X-33 launch site validated a new, laser-guided vehicle positioning system which will help Lockheed Martin meet its goal for rapid turnaround of future RLVs between flights.
- *January 15*- Successful testing completed on the first powerpack for the X-33's linear aerospike engine.
- *January 18*- Kistler Aerospace Corp. delays the inaugural flight of its K-1 reusable launch vehicle until early 2000. Kistler cited funding concerns brought on by conditions in the bond market as the reasoning behind the decision.
- *February*- An industry-led study, the "Space Transportation Architecture Study," concluded that replacing the current U.S. space shuttle fleet with a new generation of RLVs could reduce the cost and improve the safety of travelling to space.
- *March 1*- Rotary Rocket unveiled its $2.8 million, full-size atmospheric test vehicle at Mojave, California.
- *March 17*- Northrop Grumman, seeking a larger role in Kistler Aerospace Corp.'s K-1 program, agreed to adjust its 1998 financial results and write off a $30 million investment in the K-1 program.
- *April 30*- Orbital Sciences Corp. rolled-out the A-1 X-34 vehicle, the first in a series of three X-34 vehicles for NASA.
- *May*- Richard Branson, British billionaire, established Virgin Galactic Airways for space tourism flights.
- *June*- X-PRIZE entrant Burt Rutan of Scaled Composites flew the first stage of Proteus non-stop from Bangor, Maine to Le Bourget, France.
- *June 10*- X-PRIZE entrant Steven Bennett of the Starchaser Foundation unveiled a full-size mockup of his Thunderbird craft at Blackburn Rovers Field in England.
- *June 29*- The A1 X-34 completed its initial captive-carry test while affixed to the bottom of an L-1011 carrier aircraft from NASA's Dryden Flight Research Center.

- *July 4*- A 1/3 scale model of X-PRIZE entrant Bristol Spaceplane "Ascender" passenger spaceplane was displayed at the "Tomorrow's World Live" exhibition held at the Earl's Court 1 Exhibition Centre in West London.
- *July 5*- Rotary Rocket Co. stated that it intended to use a derivative of NASA's developmental Fastrac engine to power its Roton vehicles representing a major change from previous plans to develop the main engine on its own. Several Fastrac-derived engines will be clustered together to generate the thrust necessary for the Roton.
- *July 14*- NASA and Boeing Co. signed a $173 million cooperative agreement to develop the X-37 vehicle.
- *August 9*- Marshall Space Flight Center awarded Summa Technology Inc. a manufacturing and operations contract for the Fastrac engine to be used in the X-34.
- *August 24*- Orbital Sciences Corp. announced that engineers from Orbital and NASA's Dryden Flight Research Center will upgrade A-1 X-34's first airframe. Following a series of tow tests on the ground at Dryden, the A-1 X-34 will be used to conduct unpowered test flights from Orbital's L-1011 carrier aircraft.
- *August 25*- Kistler Aerospace Corp. announced that its current plans call for test flights of the K-1 within the next 10 months.
- *September*- The first series of hot fires were conducted on the X-33 linear aerospike engine at Stennis Space Center.
- *September 13*- Space Access LLC announced that it will pursue special government certification for its planned SA-1 reusable spaceplane. This action will allow Space Access to officially classify the SA-1 as a commercial airplane.
- *September 29*- Lockheed Martin indicated that it plans to use an external payload bay on the VentureStar vehicle instead of the internal payload bay now used on the X-33.
- *October*- CEOs from Kelly Space and Technology, Kistler Aerospace, Pioneer Rocketplane, Rotary Rocket Co. and Space Access LLC testified before Congress at a House Science Committee hearing on commercial spaceplanes.
- *October 5*- NASA concluded X-34 captive carry flight tests for 1999. These flight tests allowed NASA to gather information on the X-34's aerodynamics and helped qualify the Lockheed Martin L-1011 airplane as a reliable launcher.
- *October 12*- Rotary Rocket Co. completed its initial translational flight of the Roton atmospheric test vehicle, reaching an altitude of 22.5 meters during the four-minute flight.
- *October 13*- NASA stated that it is considering creating a prize of $10 million to $20 million to spur development of new launchers.
- *November 3*- The outer skin of the X-33's hydrogen tank was fractured during pressurization tests at Marshall Space Flight Center.
- *November 5*- COSMOPOLIS XXI of Moscow, Russia and TGV Rockets, Inc. of Maryland registered to compete for the X-PRIZE bringing the total number of entrants to 17.

Overview of Development Programs

This report divides RLV programs into four categories: United States Commercial Programs, United States Government Programs, International Concepts, and X PRIZE Competitors.

United States Commercial Programs include vehicles under development that will perform both payload launch and human passenger/crew missions. Most of the concepts in this section are being developed by small private companies with plans to launch satellites into low Earth orbit, resupply the International Space Station, or provide flights for space tourists.

United States Government Programs include testbed vehicles and other programs intended to advance the state-of-the-art technologies for advanced space transportation concepts such as RLVs. The focus of the U.S. government RLV program is on NASA's X-vehicles. However, the USAF also has plans to explore the development of a spaceplane.

International Concepts include proposed vehicles from non-U.S. government and commercial organizations. The governments of Japan and India are proceeding with long-range plans for RLV development, while Bristol Spaceplanes Ltd. in Great Britain is developing commercial vehicle concepts.

X PRIZE Competitors are presented separately from the other commercial vehicles because of the unique nature of their intended mission. The X PRIZE competition will award a $10 million prize to the first entrant that proves it can carry at least three people to a 100-km altitude and repeat the flight within two weeks. X PRIZE vehicles are specifically designed to accomplish this mission, although some X PRIZE vehicles plan follow-on vehicles for commercial satellite launch missions. Two entrants, Kelly Space and Technology and Pioneer Rocketplane, are focused primarily on satellite launch missions and therefore have been included in the United States Commercial Programs section.

In addition to the programs described in detail in this report, there are three additional RLV concepts under consideration for development, but for which limited information is available. In March 1998, Platforms International Corporation, a developer of software for crewless aerial vehicles, proposed the Spaceray, a spaceplane capable of carrying an expendable booster for satellite launches. Platforms International has entered into a strategic partnership agreement with "some of the leading aerospace companies in Russia" for the development of the Spaceray system.[1] In another program, the Russian aerospace company Molniya is reportedly developing the Molniya Multipurpose Aerospace System (MAKS), which consists of a spaceplane that would be air-launched from the back of an AN-124 transport aircraft. The MAKS would be able to carry 9,000 kg to orbit.[2] Finally, Universal Space Lines is planning on developing a fully-reusable TSTO vehicle called the SpaceClipper, which will be designed primarily for space tourism and transportation missions. The vehicle design is based on the Clipper Graham/DC-X program originally funded and tested by the Ballistic Missile Defense Organization (BMDO).[3]

United States Commercial Programs

The private sector is developing a variety of RLV concepts with plans to begin commercial launch operations within the next few years. The vehicles described in this section are in various stages of development.

Vehicle: Astroliner (shown above)

Developer: Kelly Space and Technology

First launch: 2002

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

Possible launch sites: Vandenberg AFB, CA; White Sands Missile Range, NM.

Markets served: Launch of LEO constellation satellites.

Astroliner – Kelly Space and Technology

Kelly Space & Technology (KST) is developing the Astroliner vehicle based on its patented tow-launch technique. The Astroliner will be towed into the air by a modified Boeing 747 aircraft to an altitude of 6 km where the 38-meter long RLV will be released and proceed on a sub-orbital trajectory under its own power. Astroliner will then use expendable upper stages to inject payloads into orbit.

The Astroliner will be powered by a reusable rocket engine, such as Rockwell Rocketdyne Division's aerospike or RS-27, NPO's RD-180 or RD-120, or a multiple engine configuration. Its large fuselage cross-section allows the KST launch vehicle to select a propulsion unit from a wide range of available systems. Once the final concept for the aircraft is adopted, the engine that fits best the mission, design, size, power and safety parameters will be selected.

Following separation from the tow aircraft, the Astroliner ignites its rocket engine(s) and climbs to an altitude of 125 km and a speed of Mach 6.5. The nose of the vehicle then opens to release the upper stages and payload. The Astroliner then reenters the atmosphere and returns to land at a conventional airfield under the guidance of its two-pilot crew.[4] The Astroliner design also features wing-mounted jet engines for powered descent and landing.

The Astroliner will use expendable upper stages, solid or liquid depending upon mission requirements, to carry payloads into orbit. Other, more powerful upper stages, such as the Star 75, Pratt and Whitney's Orbus 21, will be used for launching LEO payloads of up to 4,550 kg.[5] The Astroliner has a suborbital payload capacity of 31,600 kg.

KST has received a United States patent for its tow-launch concept. KST claims that the tow-launch method allows vehicles to lift off with heavier payloads than an air-dropped vehicle and allows the elimination of some of the infrastructure required for vertical launch vehicles. KST also claims that it will offer launch prices of about $15 to $25 million and reduced launch insurance rates for Astroliner payloads.[6]

From December 1997 to February 1998, KST successfully conducted the Eclipse Experimental Demonstration (EXD) tests in cooperation with NASA and the USAF. These tests demonstrated the Eclipse tow-launch technique using a modified QF-106 and a C-141A tow aircraft. KST also received a matching grant from the state of California to conduct research associated with the EXD program. In all, six flight demonstrations were conducted.[7] Current plans call for the first launch of the Astroliner in 2002; however, the schedule is contingent upon successfully raising additional capital.[8]

K-1 – Kistler Aerospace Corporation

Vehicle: K-1

Developer: Kistler Aerospace Corp.

First launch: TBD

Number of stages: 2

Possible launch sites: Woomera, Australia; Nevada Test Site, NM.

Markets served: Deployment of LEO satellites.

Kistler Aerospace Corporation is developing the K-1 reusable launch vehicle for commercial launches of LEO payloads. The K-1 design was developed in 1995 and 1996 as a two-stage-to-orbit (TSTO) vehicle that will have a payload capacity of 10,000 pounds to a standard LEO and will offer launch prices of about $17 million per launch.[9]

The K-1 will launch vertically like conventional ELVs but will use a unique combination of parachutes and air bags to recover its two stages. The vehicle is designed to operate with a small complement of ground personnel and will be transported to the launch site and erected with a mobile transporter. The K-1 vehicle will measure about 36.9 meters high, with a launch mass of 382,300 kg.[10]

Kistler's K-1 vehicle 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 series engines. These engines include the core of the NK-33 engines originally built in the 1960s for the Russian moon mission program. 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). The Orbital Vehicle also carries LOX/ethanol thrusters for orbital maneuvering and attitude control. Following payload separation, the Orbital Vehicle continues on orbit for about 24 hours, after which the LOX/ethanol orbital maneuvering system performs a de-orbit burn. After atmospheric re-entry, the Orbital Vehicle flies a guided re-entry path to a landing area near the launch site and deploys parachutes and air bags for touchdown.

Kistler's subcontractors are producing the major components of the vehicle, and several major milestones have been achieved. The K-1 vehicle is 75% complete, as measured by weight. Northrop Grumman Corporation has been contracted to provide the vehicle structure and has completed 21 of the 23 major structural panels for the K-1,[11] while Aerojet has undertaken test firings of the modified AJ26 engines.[12] Lockheed Martin Michoud has completed the liquid oxygen tanks. The parachute and airbag systems for the first stage have undergone a series of drop tests, and final vehicle assembly commenced in May 1998.

Kistler is planning to operate the K-1 vehicle from two launch sites, one in Woomera, Australia and one at the Nevada Test Site. Kistler received authorization from the Australian government to begin construction of launch facilities at Spaceport Woomera in April 1998 and held a groundbreaking ceremony at the site in June 1998. The launch pad designs are complete, and Kistler will conduct its initial flight tests and commercial operations from Woomera. In October 1998, Kistler finalized a deal with the Nevada Test Site Development Corporation (NTSDC) to permit Kistler to occupy a segment of the Nevada Test Site (NTS) for its launch operations.[13] Kistler is in pre-application processing with the FAA for permission to conduct launches from the NTS, with both stages returning to Earth at the NTS as well.

Pathfinder – Pioneer Rocketplane

The Pathfinder (not to be confused with the Future X pathfinder program discussed in the U.S. Government Programs section) tracks its heritage to a military spaceplane concept.[14] The "Black Horse" spaceplane was promoted within the United States Air Force in the early 1990s. Pioneer Rocketplane renamed the vehicle "Pathfinder" and proposed it as a potential design for NASA's X-34 program.

Although the Pathfinder was not selected for the X-34, the company elected to continue Pathfinder development. In June 1997, Pioneer Rocketplane was awarded one of four $2 million NASA Low Cost Boost Technology Program contracts to develop detailed preliminary designs and conduct wind-tunnel tests for concepts to launch small satellites. The Low Cost Boost Technology program was later canceled.

Pathfinder is a spaceplane operated by a crew of two and is powered by both air-breathing jet engines and LOX/kerosene rocket engines. The 23-meter long vehicle takes off horizontally using turbofan jet engines. When it reaches an altitude of 6 km, the Pathfinder meets a tanker aircraft that transfers about 59,000 kg of liquid oxygen to the Pathfinder's LOX tanks in a method identical to air-to-air refueling. After disconnecting from the tanker, the spaceplane ignites its RD-120 rocket engine and climbs to an altitude of 112 km at a speed of Mach 15. Once out of the atmosphere, the Pathfinder can open its cargo bay doors and release its payload with a conventional liquid rocket upper stage. The payload is then carried into orbit as the spaceplane re-enters the atmosphere. After deceleration to subsonic speeds, the Pathfinder re-starts its jet engines and lands horizontally.[15] The Pathfinder's maximum payload capacity to a space station orbit is 2,300 kg.

Vehicle: Pathfinder

Developer: Pioneer Rocketplane

First launch: TBD

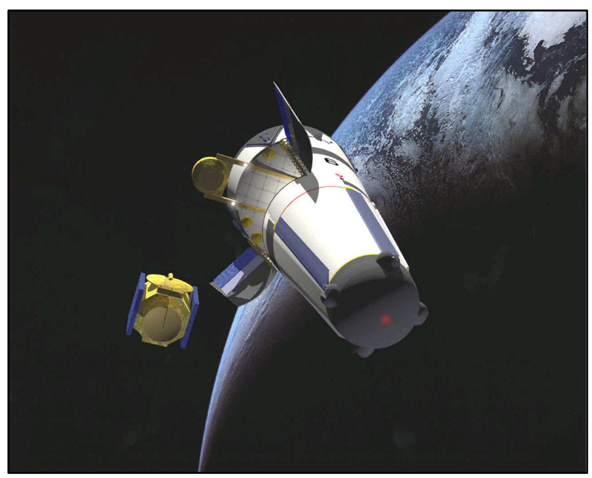
Number of stages: 2

Possible launch sites: Vandenberg AFB, CA.

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

The Pathfinder vehicle uses primarily existing technology and components. The propulsion system uses proven jet and rocket engines (two GE F404 turbofan engines and one kerosene/oxygen-burning RD-120 rocket engine), and the avionics systems are derived from existing military aircraft. In September 1998, Pioneer Rocketplane announced that it had completed a system design review and concluded that all components and systems fit together properly. In May 1999, Pioneer was also awarded a $40,000 grant by the State of California to conduct a study on the possibility for Pathfinder to launch from the California coast.

Roton C-9 – Rotary Rocket Company



The Roton C-9 is under development by Rotary Rocket Company to provide launches of satellites to low Earth orbit. The SSTO Roton C-9 vehicle is designed for vertical takeoff and landing. The 19.5-meter high Roton C-9 is powered by a cluster of several engines derived from the Fastrac engine developed by NASA.[16] The cargo compartment is positioned in the middle of the vehicle between the LOX tank (in the nose) and the kerosene tank (above the engine). Following ascension to LEO, the Roton C-9 deploys a payload and performs a de-orbit burn. The vehicle can remain on-orbit for up to 72 hours.

Vehicle: Roton C-9

Developer: Rotary Rocket Company

First launch: 2000

Number of stages: 1

Possible launch sites: TBA

Markets served: Deployment of LEO constellations and replacement satellites.

The Roton C-9 is cone-shaped with the rotor blades folded flat against the exterior. The vehicle uses the rotor blades to control the vehicle descent after atmospheric re-entry. Each blade is powered by small hydrogen peroxide/methanol rocket motors on the blade tips that power the rotor.

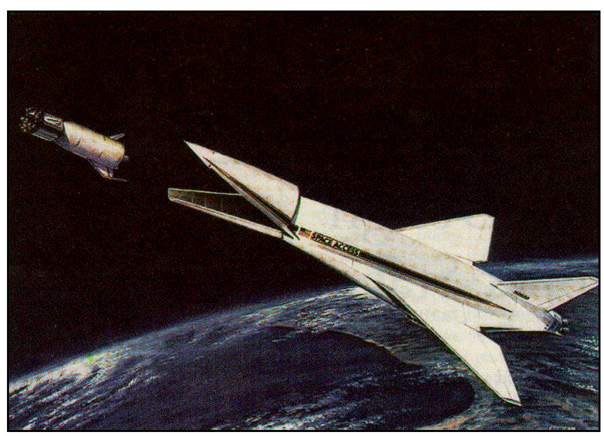
The Roton touches down vertically under the control of its two-person crew. The vehicle is designed to be serviced by a small team of ground personnel, and Rotary Rocket is targeting turnaround times between flights of 24 hours or less.[17] The Roton also has been designed to be able to return to Earth with the cargo bay fully loaded.

Rotary Rocket Company developed and tested many of its systems throughout 1998, including the rotor blade-tip engines and the rotor assembly. In addition, the company began construction of its manufacturing and flight operations facility in June 1998 at the Mojave Civilian Test Flight Center, and completed the construction in January 1999.[18]

During 1998, Rotary Rocket Company tested some of the systems for the proprietary RocketJet engine. The RocketJet engine was originally intended as the powerplant for the Roton C-9 vehicle. But, in June 1999, Rotary Rocket elected to proceed with development using the Fastrac engine variant in order to “permit the Roton development program to be concluded more rapidly [19] Development of the RocketJet engine was deferred.

In 1999, construction of the Roton Atmospheric Test Vehicle (ATV) was completed and flight testing began. The ATV is a full-scale prototype vehicle without the main propulsion system, designed to perform approach and landing tests. During July through October 1999, the ATV completed four test flights demonstrating the vehicle control characteristics needed for the Roton landing profile, including hovering and low altitude forward movement.

SA-1 – Space Access LLC



Vehicle: SA-1

Developer: Space Access LLC

First launch: 2001

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

Possible launch sites: Homestead AFB, FL; Orlando Airport, FL; Tampa Airport, FL.

Markets served: Launch of LEO and GTO payloads.

The SA-1 has been proposed to conduct satellite launches by Space Access LLC. The concept consists of an unpiloted spaceplane that uses a hybrid propulsion system and one or two rocket-powered upper stages to deliver a full range of payloads to LEO or GTO.

The spaceplane vehicle, or “aerospacecraft,” is approximately the size of a Boeing 747 aircraft. Its propulsion system is based on a ramjet engine design that was developed in the 1960s by the USAF. Space Access has developed a proprietary modification to the engines that will allow the ramjet to operate at both subsonic and supersonic speeds (ramjets normally only operate above Mach 2).[20] One of the company’s subcontractors, Kaiser Marquardt, has reportedly tested elements of the propulsion system,[21] and Space Access has worked with the Air Force Research Laboratory

(AFRL) since September 1995 to study the "ejector" ramjet propulsion system and the design of the aerospacecraft. As of March 1998, Space Access had wind-tunnel tested the ejector ramjet engine at all of the altitude and speed points of the SA-1's planned flight profile.[22]

The SA-1 vehicle will take off horizontally, using a mixture of air and liquid hydrogen to power its ejector ramjet engines. The aerospacecraft then climbs to 45 km, at a speed of Mach 8. When it reaches the limits of the atmosphere and its ramjets loose power, the SA-1 switches power sources and uses a liquid rocket to reach its final altitude of 90 km at Mach 9. The vehicle then releases an upper stage carrying the payload from its nose area. For LEO missions, the SA-1 carries a single upper stage that features a lifting-body design and autonomously de-orbits and lands horizontally. For missions to GTO, the SA-1 carries two such upper stages.[23]

The SA-1 vehicle will be able to launch payloads up to 5,200 kg to GTO. Space Access intends to pursue GEO launches as its primary market, but the SA-1 will have significant LEO capability as well. Space Access also plans to introduce capability that would allow it to undertake resupply missions to the International Space Station.[24]

In 1999, after working with NASA on the Space Transportation Architecture Study, Space Access decided to study development of a crewed version of the second stage, which would give the SA-1 the capability to provide human access to space. Space Access hopes that the SA-1 could become an alternative or replacement to the Space Shuttle.[25]

Space Access plans to test a one-third-scale demonstrator vehicle with the ejector ramjet and other key systems. Development plans call for testing of a full-size vehicle in 2001 with launch operations commencing in 2005.[26]

Space Cruiser System – Vela Technology Development

Vehicle: Space Cruiser System

Developer: Vela Technology Development, AeroAstro LLC

First launch: 2001

Number of stages: 2

Possible launch sites: Commercial airports.

Markets served: Sub-orbital space tourism flights.

The Space Cruiser System (SCS) vehicle is currently being marketed for space tourism flights beginning in December 2001 by Space Adventures of Arlington, Virginia which acquired the Seattle-based Zegrahm Space Voyage in November 1999. The SCS vehicle is being designed and developed by Virginia-based Vela Technology Development, Inc. to carry six passengers on a sub-orbital flight reaching an altitude of just over 100 km.[27]

SCS is a two-stage horizontal-takeoff-and-landing design that employs both airbreathing and rocket engines. The first stage booster, or "Sky Lifter," will be piloted by a two-member crew and will be powered by two JT8D/F100-class jet engines.

The Sky Lifter is designed as a conventional jet aircraft with a 30-meter delta wing and will a dry mass of approximately 10,000 kg. The Space Cruiser second stage spaceplane will be carried underneath the Sky Lifter. The Space Cruiser will measure 18.3 meters from nose to tail and will weight about 11,800 kg with fuel and passengers. The two stages will climb together to about 15 km where the Space Cruiser, carrying two crewmembers and six passengers, separates and will climb to 100 km using its three nitrous oxide/propane-fueled rocket engines. During re-entry into the atmosphere, the Space Cruiser will fire retro-rockets to slow the vehicle's descent and then will activate two JT15D-class turbo-jet engines to return to a landing site.[28]

All preliminary testing has been successfully completed and Vela Technology is awaiting funding to proceed to the next phase of the development and construction. A first test flight is anticipated to take place in late 2001. Vela Technology Development and Space Adventures have received over 60 requests for reservations ($5,000 deposit and $1,000 a month) since they started marketing operations in October 1997 and are planning a first voyage for 2003.

Vela Technology Development intends to build two sets of operational vehicles and plans to initially operate two launches per week. In November 1997, Vela named AeroAstro LLC as the prime contractor for the SCS system.[29]

VentureStar™ Lockheed Martin Corporation

VentureStar™ is Lockheed Martin's potential commercial follow-on to the X-33 vehicle being developed for NASA's RLV program (an overview of the X-33 is provided in the next section).

The VentureStar vehicle will be similar in design to the X-33 but twice the size and about eight times the launch mass. VentureStar will be powered by seven linear aerospike engines. Although original plans for the VentureStar called for an internal payload bay similar to the X-33, the design was modified during 1999 to shift to an external payload bay.[30]

Vehicle: VentureStar™

Developer: VentureStar LLC, Lockheed Martin Skunk Works

First launch: 2004

Number of stages: 1

Possible launch sites: 15 states are bidding to have a VentureStar launch site.

Markets served: Launch of heavy-class LEO payloads.

Lockheed Martin plans to target the commercial satellite launch market with VentureStar. The company hopes to operate the vehicle at a flight rate of at least 40 launches per year, leading to launch costs of approximately $1,000 per pound. NASA and Lockheed Martin are also studying the accommodation of crew missions on VentureStar. One option is to launch VentureStar as a cargo-only craft initially, with crew-capable modules phased-in later.[31]

Development of VentureStar is underway in parallel with the X-33. Although fielding the VentureStar vehicle is contingent on the results of the X-33 program and on raising an expected $5 billion in funding, Lockheed Martin established VentureStar LLC to manage the ongoing development of the vehicle concept.[32]

Lockheed Martin plans to contract for the use of two spaceport facilities for VentureStar operations. In July 1998, Lockheed Martin provided its spaceport requirements for the VentureStar to interested parties, with fifteen states responding to the qualifications.

United States Government Programs

In the 1990s, NASA and the Department of Defense have been committed to progress in RLV development. The DC-X (later the DC-XA and Clipper Graham) was funded by the military in the early 1990s and later by NASA. This vehicle demonstrated RLV materials and operations and paved the way for the current NASA X-vehicle prototype development programs. The U.S. military is continuing its RLV study involving military spaceplane concepts.

Recognizing the commercial value in the development of RLV technologies, NASA successfully negotiated two government-industry partnerships in 1994 to finance and administer current X-vehicle projects. The X-33 is a vehicle being developed by a Lockheed Martin-NASA partnership, and the X-34 is being developed by Orbital Sciences and NASA. Five years later, in 1999, NASA negotiated a third major government-industry partnership with Boeing to develop the X-37.

In 1998, NASA devised a budgetary platform referred to as Future-X to award further contracts to industry for RLV technology development. The Future X initiative defined two development programs: trailblazer and pathfinder. In general, a trailblazer program is devoted to a single demonstrator vehicle that tests integrated vehicle systems. A trailblazer class vehicle is funded in excess of $300 million. A pathfinder program includes development of several specific RLV technologies and smaller X-vehicle projects to demonstrate pathfinder technologies.

In keeping with the spirit of this initiative, NASA created the Pathfinder program office in May 1999 to manage the X-34 and the newly awarded X-37 projects. These two vehicles are small testbed demonstrators designed to validate RLV technologies. The only trailblazer-class vehicle under development, the X-33, is managed by a separate NASA program office.

In addition to the trailblazer and pathfinder vehicles, NASA is also leading the development of a crew return/transfer vehicle called the X-38. The European Space Agency is NASA's partner for the X-38 program. The fifth vehicle, the X-40A, is being loaned to NASA for its X-37 project by the Air Force. In return, the Air Force has become a partner in the project and will be testing military RLV technologies.

Space Shuttle

NASA's Space Shuttle is the world's first reusable launch vehicle and has been used for all U.S. human spaceflight programs since 1981. Although the Space Shuttles have launched several commercial and military satellite payloads during their initial years of service, commercial payloads have been effectively banned from the shuttles since the explosion of the *Challenger* orbiter in 1986.

The Space Shuttle consists of a reusable delta-wing spaceplane called an orbiter; two solid-propellant rocket boosters, which are recovered and reused; and an expendable external tank containing liquid propellants for the orbiter's three main engines. The Space Shuttle carries astronauts to orbit to perform a wide variety of missions such as spacecraft deployment and recovery, research in pressurized modules in the cargo bay, repair, and International Space Station support.[33]

Vehicle: Space Shuttle

Developer: Rockwell International, Lockheed Martin, Thiokol. Operated by United Space Alliance (USA).

First launch: 1981

Number of stages: 2

Possible launch sites: Kennedy Space Center, FL.

Markets served: Heavy LEO payloads and human spaceflight.

In October 1996, United Space Alliance (USA), a joint venture of Lockheed Martin and Boeing, took over day-to-day operations of the Space Shuttle fleet under a six-year contract with NASA. In October 1999, USA acquired USBI Co., gaining responsibility for the assembly, test, and refurbishment of the Space Shuttle's solid rocket boosters.[34] The move to a private contractor may allow for a reduction in program costs through elimination of program redundancies and the potential enhancement of Space Shuttle safety, reliability, and capability.[35]

Current plans call for the Space Shuttle fleet to remain in service until at least 2012.[36] In order to continue operations, a two-phased program to develop upgrades for the fleet is in place. Phase one upgrades are designed to enhance safety or vehicle performance for International Space Station missions; examples include improved main engine turbopumps/main combustion chambers, and a lightweight aluminum-lithium external tank. As of the end of 1999, all Phase one upgrades are complete or very near completion. Phase two upgrades are low-cost, high-value incremental enhancements; examples include a micro-meteoroid and orbital debris (MMOD) protection system, and the replacement of launch control room systems.[37] Additional long range performance and safety upgrades are also under consideration, including the use of liquid-fueled fly-back booster rockets, five-segment solid rocket boosters, and the addition of a crew escape module.

X-33

The X-33 program was initiated to develop a testbed for integrated RLV technologies, paving the way for full-scale development of a SSTO RLV that would be contracted for government and private sector use.[38] The X-33 is targeted to reach high hypersonic speeds and demonstrate SSTO and autonomous operations capabilities. NASA has set goals of a routine seven-hour turnaround time and a 3.5-hour emergency flight turnaround time. NASA hopes the program will lead to the development of RLVs that will reduce the cost of space launches by an order of magnitude within ten years.

Vehicle: X-33

Developer: Lockheed Martin

First launch: 2000

Number of stages: 1

Possible launch sites: Edwards Air Force Base, CA.

Markets served: Testbed for RLV technologies and operations.

In April 1995, NASA signed cooperative agreements with Lockheed Martin, McDonnell Douglas, and Rockwell International to develop concept designs for the X-33 program. On July 2, 1996, NASA selected Lockheed Martin's aeroballistic rocket design. Government funding has been appropriated through the end of 2000 and a funding cap has been set at $941 million.[39]

Lockheed Martin's design is a SSTO vehicle that relies on a lifting body rather than wings. The X-33 will measure about 21 meters in length, with a dry mass of about 34,000 kg.[40] The X-33 will be powered by two linear aerospike engines under development by Boeing's Rocketdyne division. These engines do not use conventional cone-shaped exhaust nozzles but allow the exhaust flow to adjust to changes in atmospheric pressure.

Major progress has been achieved on two of three critical technologies for the vehicle. The thermal protection system was declared "ready for flight" after extensive testing at the end of 1998. The first aerospike engine, the centerpiece for the vehicle propulsion system, completed assembly and began testing in the fall of 1999. In addition, the X-33's avionics bay was installed by September 1999, and the launch umbilicals have been installed.[41] Kennedy Space Center also validated a new laser-guided vehicle positioning system for the X-33.[42]

The flight test facility at Edwards Air Force Base in California was completed in November 1998. The X-33 rotating launch platform at Edwards Air Force Base was validated with a 70,000 pound simulator in February 1999. In addition, the translating shelter, ground electrical supplies, and storage systems were activated.[43] The 15 test flights of the X-33 will be conducted from the launch site on the eastern portion of Edwards Air Force Base to landing sites at Michael Army Air Field in Utah and Malmstrom Air Force Base near Great Falls, Montana.

Testing on the third of the critical technologies, lightweight fuel tanks, has focused on the composite hydrogen fuel tanks. On November 3, 1999, after the conclusion of a pressurization test at Marshall Space Flight Center, damage was discovered on the tank's right wall. NASA and Lockheed Martin formed a failure investigation board to evaluate the damage. Until the board makes its conclusions, it is unclear whether the fuel tank will need to be repaired, remanufactured or redesigned. The flight date of the vehicle has been delayed once already due to damages to the fuel tank during its manufacturing process.[44]

X-34

Vehicle: X-34

Developer: Orbital Sciences Corporation

First launch: 2000

Number of stages: 1

Possible launch sites: Edwards Air Force Base, CA; Kennedy Space Center, FL.

Markets served: Testbed for RLV technologies and operations.

In 1994 NASA began the X-34 program to develop an RLV for payloads of about 1,100 kg. After first awarding a contract to a team of Orbital Sciences and Rockwell International in 1995, NASA canceled the contract and redesigned the X-34 program to use a smaller vehicle to demonstrate key technologies. Following a competition that included nine entries, NASA awarded Orbital Sciences a $60 million contract in June 1996 to design, develop, and test the X-34. The contract value was increased to $85 million in December 1998 when NASA decided to exercise its option for a second phase of 25 additional X-34 flights.[45] In May 1999, management of the X-34 project shifted to the Pathfinder program office.

The X-34 is designed to be a sub-orbital technology testbed. The goals of the X-34 are to achieve a maximum speed of Mach 8 and to reach altitudes of up to 80 km. The program also aims to reduce launch costs and nominal turnaround times by using a ground and support team of twelve to launch twice within a two-week timeframe.[46] Flight testing will focus on RLV operations such as a surge capability of 24-hour turnaround, landing in adverse weather conditions, and safe abort procedures. New technology demonstrations will include composite primary and secondary airframe structures; cryogenic insulation and propulsion system elements; advanced thermal protection systems and materials; and low cost avionics, including differential global positioning and inertial navigation systems. Operations technologies such as integrated vehicle health-monitoring and automated checkout systems also will be validated.[47]

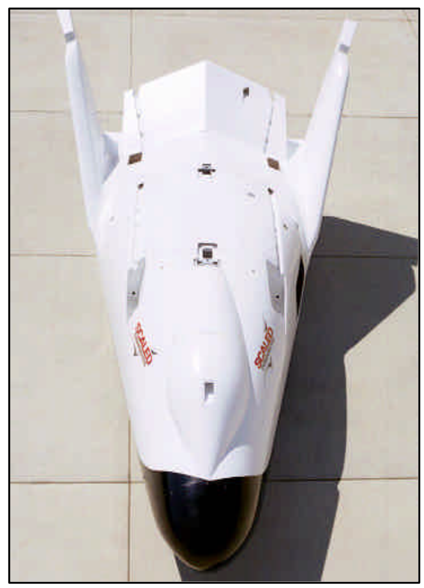
The X-34 design features a cylindrical body with delta wings. The vehicle will measure 17.7 meters in length and will have a dry mass of 19,500 kg. The vehicle will be launched from an

L-1011 carrier aircraft. The primary engine is a new LOX/kerosene rocket engine known as Fastrac, that is being designed, developed, and provided by NASA under a separate program. In August 1999, NASA, having concluded the development of the engine, awarded a contract to Summa Technology Inc. to manufacture three Fastrac engines for the X-34 program. The contract also calls for Summa to develop possible commercial uses of the Fastrac engine.[48]

NASA's contract with Orbital Sciences includes the development of three vehicles. The first vehicle, designated A-1A, is an unpowered flight vehicle and it is expected to perform test flights in Spring 2000. The next two vehicles, the A2 and A3, are both powered vehicles. The A2 will be flown at speeds of up Mach 4.5 and demonstrate crosswind landings and flight through rain. The A3 will be flown at Mach 8 at an altitude of 250,000 with additional carry-on experiments.[49]

During 1999, the program was setback an estimated six months with the unexpected announcement by the Air Force to prohibit launches from Holloman Air Force Base. NASA and Orbital are now planning on moving to Edwards Air Force Base for the first series of test launches of the A-1A.[50] The second series will be conducted from Kennedy Space Center and will use the A2 and A3 vehicles.

X-38/Crew Return Vehicle



The X-38 is a technology demonstration vehicle project of the Johnson Space Center and Dryden Flight Research Center. The X-38 is a prototype for a crew return vehicle (CRV) that will be attached to the International Space Station. The CRV will provide a means of returning to Earth if an emergency requiring immediate evacuation of the Space Station arises, if an astronaut has a medical emergency requiring immediate treatment on Earth, or if the Space Shuttle fleet is grounded and the astronauts must return to Earth.

Plans for a CRV have been under consideration since the Space Station was first proposed. Proposals for CRVs have taken on many different forms. NASA and ESA are currently working together on a concept to satisfy their Space Station crew transport needs. Rather than focusing solely on an emergency return vehicle, ESA wants to develop a vehicle capable of both launching and returning crew members to and from the station.

Vehicle: X-38/CRV

Developer: JSC, Dryden Flight Research Center, Scaled Composites

First launch: 2000

Number of stages: 1 (at least 2 for launch)

Possible launch sites: KSC, Kourou.

Markets served: Prototype for ISS crew return.

CRV development is expected to cost almost $1 billion.[51] Multinational participation remained strong in 1998 as the French company Dassault provided critical design support, and Dutch, German, and Spanish companies produced key components.[52] In 1999, however, ESA declined to allocate funding directly for the CRV program, and instead offered ESA governments the chance to contribute individually.[53]

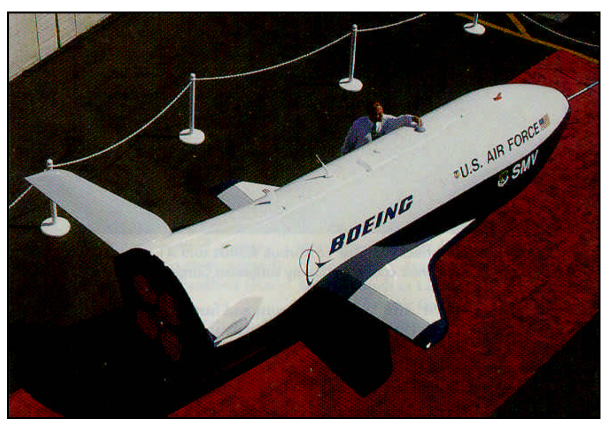
The X-38 employs a lifting body design based on a 1970s-vintage X-aircraft. Rather than landing in an unassisted glide like the Space Shuttle, the X-38 will deploy a steerable parafoil that will allow the vehicle to maneuver to a landing site. The parafoil is as large as the wing area of a Boeing 747 aircraft.

Four X-38 vehicles are planned, including three atmospheric prototypes and one orbital test vehicle. Two X-38 atmospheric prototypes (Vehicle 131 and Vehicle 132) have been constructed by Scaled Composites, with parafoils supplied by Pioneer Aerospace. Avionics and control systems were incorporated into the test vehicles, and the orbital test vehicle (Vehicle 201) is currently being constructed at the Johnson Space Center.

ESA and NASA have agreed to develop a design that is compatible for launch atop an ELV such as Ariane 5.[54] This decision required that the designs of the third prototype and the orbital test vehicle be modified to be able to withstand the structural pressures of launch. While the CRV design has no space maneuvering propulsion system, an orbital transfer vehicle could be used to move it into position at the Space Station, allowing it to carry crews both to and from the Station.

Vehicle 131 conducted free-flight tests on March 12, 1998 and February 6, 1999, during which the vehicle was dropped from the wing of a B-52 and returned to the ground using its parafoil. Following the completion of its testing, the vehicle was returned to Scaled Composites to be retrofitted to the redesigned aerodynamic shape. Vehicle 132 conducted free-flight tests in March and July 1999. The third prototype is intended to become the primary atmospheric test vehicle after the turn of the century. The orbital test vehicle is scheduled for launch on the Space Shuttle in 2001.[55]

X-40A/Military Spaceplane



In August 1996, the USAF Space Command (AFSPC) approved a "concept of operations" for a spaceplane demonstrator to satisfy USAF space operations needs in the future. An Integrated Concept Team (ICT) was established to develop designs for a multimission vehicle that could perform a variety of orbital and sub-orbital military missions, such as placing small satellites in low-Earth orbit, conducting surveillance, disabling adversaries' space vehicles, releasing weapons (within the atmosphere) against terrestrial targets, serving as a time-critical communications relay platform, or delivering cargo.[56]

Following a year of study, the AFSPC followed the ICT's recommendation to establish a central spaceplane program office to coordinate the program. Spaceplane research efforts have been funded through "add-on" funds originally appropriated in 1996.[57] Through this program, the Air Force is developing a two-stage spaceplane concept. The concept consists of a reusable "mini-spaceplane," or Space Maneuver Vehicle (SMV) that is carried to hypersonic speeds by a sub-orbital reusable first stage. The SMV is released and accelerates to orbit, where it will be designed to maneuver in space and remain on-orbit for perhaps as long as one year.

Vehicle: Military Spaceplane

Developers: Boeing, Lockheed Martin

First launch: TBA (SMV tests conducted in 1997)

Number of stages: 2

Possible launch sites: TBA

Markets served: Military payload delivery to LEO; Special missions such as satellite orbital transfer.

The SMV is under development by Boeing Phantom Works, and a 90-percent scale unpowered testbed, also known as the X-40A, was rolled out in September 1997 under a $5.2 million contract awarded in October 1996 by the USAF's Wright Laboratory.[58] The first flight of the X-40A took place on August 11, 1998, when it was carried aloft by helicopter and released, making a landing controlled by the vehicle's on-board systems.

The current focus of this program has shifted as the USAF has teamed with NASA to begin the X-37 program (see next section). The USAF has loaned the X-40A test article to NASA and has provided some funding for continued testing. To move the X-37 program forward while the X-37 test article is under construction, the X-40A will be used to test the avionics for the similarly-designed X-37.

X-37

On July 14, 1999, NASA and Boeing signed a cooperative agreement to develop a Future X Pathfinder vehicle designated X-37. The X-37 is the first NASA X vehicle that is designed to operate in both orbital and reentry phases of flight, and it will be the fastest of the vehicles designed to reach speeds of up to Mach 25. The $173 million program will be funded over three years in a cost-sharing arrangement that is approximately 50/50 between industry and government. In addition, the USAF agreed to contribute $16.1 million towards the government share in order to test additional technologies for military spacecraft. The Air Force also agreed to loan the X-40A test vehicle to the X-37 program to test X-37 avionics.[59]

Currently in the design phase at Boeing's Phantom Works, the X-37 is scheduled to enter development in January 2000. Designed to be a 120 percent-scale derivative of the X-40A, the

X-37 will be 27.5 feet long and will have a wingspan of 15 feet. The X-37 will have a 7-foot long and 4-foot wide experiment bay, an advanced thermal protection system, a rocket engine, and several other spacecraft systems. Hydrogen peroxide and JP-8 will fuel an AR-2/3 rocket engine that can produce 7,000 pounds of thrust.[60]

Vehicle: X-37

Developers: Boeing

First launch: September 2002

Number of stages: 1 stage deployed by Shuttle

Possible launch sites: KSC

Markets served: Testbed for RLV technologies and operations.

Assembly and integration will be conducted at Boeing's production facilities in Palmdale and Seal Beach, CA. Meanwhile, the X-37 program will oversee a series of atmospheric flight tests of the X-40A vehicle to test the avionics of the X-37. The program is planning to use helicopters for the series of X-40A captive-carry tests. Roll-out of the X-37 vehicle is planned for fall of 2001, at which time the X-37 will be moved to Edwards Air Force Base for ground and test flights. The X-37 will be carried under a B-52 aircraft to a suborbital altitude where it will be dropped for atmospheric test flights. The first orbital launch is scheduled for September 2002 on a Space Shuttle from Kennedy Space Center.[61]

Once deployed, the X-37 will remain on-orbit for up to 2 days on the first mission and up to 21 days on the second mission. Once on-orbit, the X-37 will test space vehicle technologies, including a solar array system developed by the Air Force. The vehicle will reenter the Earth's atmosphere and land autonomously on a conventional runway.[62] The project is only currently funded for two flights. However, the X-37 will be capable of 20 flights and a cumulative on-orbit duration of 420 days.[63]

International Concepts

International public and private organizations are designing RLVs to satisfy government and commercial launch needs. As with the U.S. commercial vehicles in the previous section, these vehicles are in various stages of development.

AVATAR – Defense Research Development Organization (India)

In May of 1998, India's Defense Research Development Organization (DRDO) announced the initial funding of the design of a small reusable spaceplane.[64] The Aerobic Vehicle for Advanced Trans-Atmospheric Research (AVATAR) is planned to be the size of a jet fighter/bomber and would be capable of delivering 500 kg to 1,000 kg to orbit.

Vehicle: AVATAR

Developer: Defense Research Development Organization (India)

First launch: TBA

Number of stages: 1

Possible launch sites: TBA

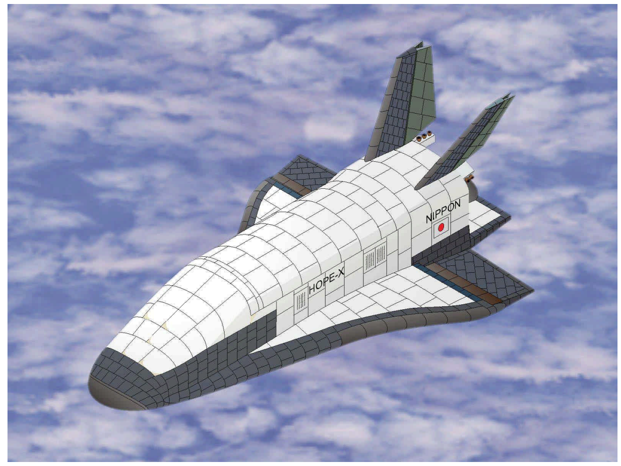
Markets served: Satellite deployment.

The initial development budget is only $5 million, but project supporters claim that the vehicle can be built in ten years with total funding of under $2 billion. Designers admit, however, that international assistance would most likely be required for the project to reach its goal. In addition to the DRDO team working on the conceptual design, development of technology components is being undertaken by academic institutions in India as well.[65]

The AVATAR would take off horizontally using ramjet engines that burn air and hydrogen. Once at a cruising altitude, the vehicle would use scramjet propulsion to accelerate to Mach 7. During these cruising phases, an on-board system will collect air from which liquid oxygen will be separated. The liquid oxygen collected then would be used in the final flight phase, when the rocket engine burns the collected liquid oxygen and the carried hydrogen to attain orbit. Both the scramjet engine concept and the liquid oxygen collection process have already undergone successful tests at DRDO and at the Indian Institute of Science. DRDO has approved further testing of the liquid oxygen process and assigned a team to conduct a detailed review of the vehicle's design.

National Space Development Agency of Japan

The National Space Development Agency of Japan (NASDA) began studying the development of a small crewless space shuttle in 1987. The original parameters called for a 20,000 kg vehicle that would be lifted by the H-2 booster and would land by remote control in Japan or Australia.



Vehicle: HOPE-X

Developer: NASDA

First launch: TBA

Number of stages: 2 (when the Hope-X is considered the second stage)

Possible launch sites: Tanegashima, Japan.

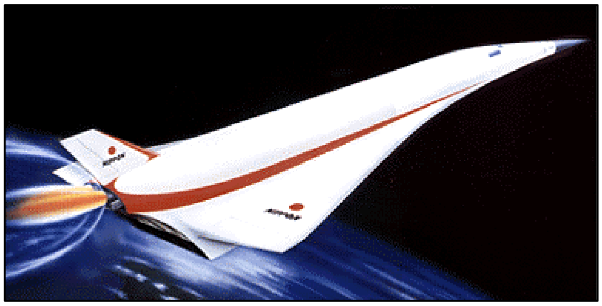
Markets served: Technology demonstration.

To this end, NASDA and the National Aerospace Laboratory (NAL) have been developing the H-II Orbiting Plane Experimental (Hope-X). Hope-X will be the end result of a series of experiments: the Orbital Re-entry Experiment (OREX) completed in 1994, the Hypersonic Flight Experiment (HYFLEX) and the Automatic Landing Experiment (ALFLEX) both completed in 1996, and finally the High Speed Flight Demonstration (HSFD) which is planned for early 2002.[66]

The current design for the Hope-X shows a 49-square meter delta wing and two vertical tails on its 13.4 meter-long fuselage. The main structure will be made of a conventional aluminum alloy strengthened with ceramic tiles and flexible thermal insulation.[67] The Hope-X will be launched by the H-2A rocket and will enter low earth orbit and climb to an altitude of 200 km powered by its own Orbital Maneuvering System after separation. After one revolution, it will de-orbit and re-enter into the atmosphere where the reaction control system will control the flight path and attitude until the vehicle lands as a traditional airplane on an island in the Pacific Ocean. The mission should be completed in approximately two hours.[68]

Budget constraints have forced NASDA to postpone Hope-X's first launch originally planned for 2001. The current estimate for a first launch is 2004 but the final date has yet to be determined. The primary mission of the Hope-X program is to establish the technologies for an advanced reentry vehicle system.[69]

Single-Stage-To-Orbit Spaceplane – National Aerospace Laboratory (Japan)



Vehicle: SSTO Spaceplane

Developer: National Aerospace Laboratory (Japan)

First launch: 2010

Number of stages: 1

Possible launch sites: TBA

Markets served: Launch and recovery of heavy-class LEO payloads.

Japan's long-term reusable launch vehicle goal is the construction of a single-stage-to-orbit (SSTO) spaceplane. The Japanese government modified the HOPE program (see HOPE-X entry) in order to reduce the number of intermediate steps to reach the goal of a fully reusable SSTO vehicle in the long run. Following the recommendation of the Committee on Future Fully Reusable Space Transportation Systems, the design for a SSTO RLV is being explored and refined by the National Aerospace Laboratory.

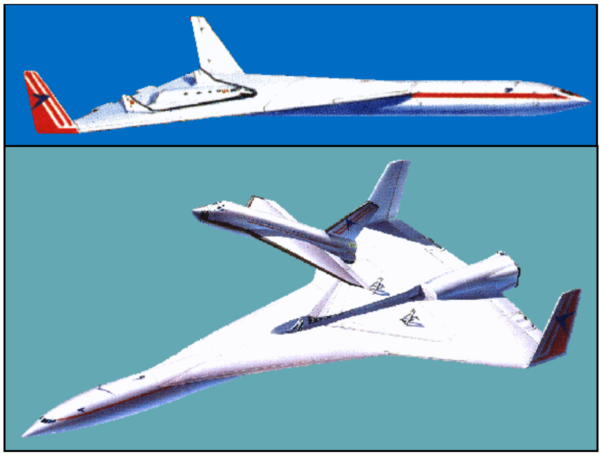
The National Aerospace Laboratory concept calls for the development of a SSTO prototype rocket by 2010 and the final SSTO Spaceplane by 2020.[70] The companies of the Space Plane Committee of the Society of Japanese Aerospace Companies (Mitsubishi, Ishikawa-jima-Harima, Kawasaki, Fuji, and Sumitomo) have all been studying advanced propulsion systems in support of the program. Development of the spaceplane is expected to cost $20 billion.[71] These concepts are still in the early development stages, but they represent the official direction for Japan's RLV development.

The SSTO Spaceplane would take off and land horizontally and carry a crew of four. The vehicle would measure about 50 meters in length, with a mass of about 52 metric tons.

The SSTO Spaceplane would use either air-breathing propulsion for atmospheric flight and multiple rocket engines to achieve orbit or may employ new hybrid engines. Propulsion concepts favored for the spaceplane include liquefied air cycle engines (LACE) and scramjets. LACE engines liquefy air at low altitudes and accumulate oxygen to be used later at higher altitudes. In one design concept, LACE would be used to power the craft to Mach 5 at an altitude of 20 km, where scramjets would be activated to accelerate the vehicle to Mach 20. The LACE engines would then switch to rocket mode to achieve orbit. Engines that combine the aspects of both LACE and scramjets (known as combined cycle engines) may be developed to provide an optimal combination of weight and power.[72]

Development could begin before 2010 if funding becomes available after 2003 and if several flights of the HOPE-X are undertaken. However, "propulsion technology breakthroughs and international cooperation would be necessary if Japan is ever to seriously consider spaceplane development."[73]

Spacecab/Spacebus – Bristol Spaceplanes Ltd. (England)



Vehicle: Spacecab (top)/Spacebus (bottom)

Developer: Bristol Spaceplanes Ltd.

First launch: 2010

Number of stages: 2

Possible launch sites: TBA

Markets served: Orbital space tourism. Launch of small-class LEO payloads. ISS crew transfer. Repair of LEO satellites.

Spacecab and Spacebus are similar concepts promoted by Bristol Spaceplanes Limited (BSL) of Bristol, England. BSL is headed by David Ashford, an advocate of space tourism for many years and has entered its Ascender vehicle in the X PRIZE competition.

The Spacecab would be a prototype two-stage spaceplane. The first stage would consist of a supersonic aircraft similar to the Aerospatiale/British Aerospace-built Concorde but equipped with four air-breathing and two rocket engines, allowing acceleration to Mach 4. Upon reaching Mach 4, the second stage reusable orbiter would separate from the top of the first stage and use rocket power to reach orbit. The orbiter would be similar in size and design to the Ascender vehicle but would be capable of carrying a crew of two with either six passengers or 750 kg of cargo. Both the booster and the orbiter would land horizontally.[74]

Spacebus is an enlarged version of the Spacecab. The Spacebus booster would have a length of approximately 88 meters and a mass of 130,000 kg, while the orbiter would be 34 meters long with a mass of 19,900 kg. The Spacebus booster would have greater power and accelerate to Mach 6 for orbiter separation. The orbiter would be capable of carrying 50 passengers.[75]

According to BSL, Spacecab can be built using existing technology, and the development cost and timetable of the prototype of each stage should be comparable with that of the prototype of an advanced aircraft. The prototype could be used for early operational flights to and from orbit and could launch small satellites and ferry crews and passengers to and from space. BSL completed a feasibility study of the Spacecab and Spacecab demonstrator vehicles for ESA in 1994, but ESA has not acted to develop the concept any further.[76]

X PRIZE® Competitors

The X PRIZE

In the spirit of the early 20th century aviation prizes, such as the Orteig prize that Charles Lindbergh won for crossing the Atlantic in 1927, the X PRIZE Foundation was established in 1994 as an educational, non-profit corporation dedicated to inspiring private, entrepreneurial advancements in space travel. The St. Louis-based X PRIZE Foundation is offering a $10 million prize to the first team able to launch a vehicle capable of carrying three people to a 100-km sub-orbital altitude and repeating the flight within two weeks (only one person and ballast for two others are required to actually make the flights). The X PRIZE is offered to help speed along development of space vehicle concepts that will reduce the cost of access to space and to allow human spaceflight to become routine.

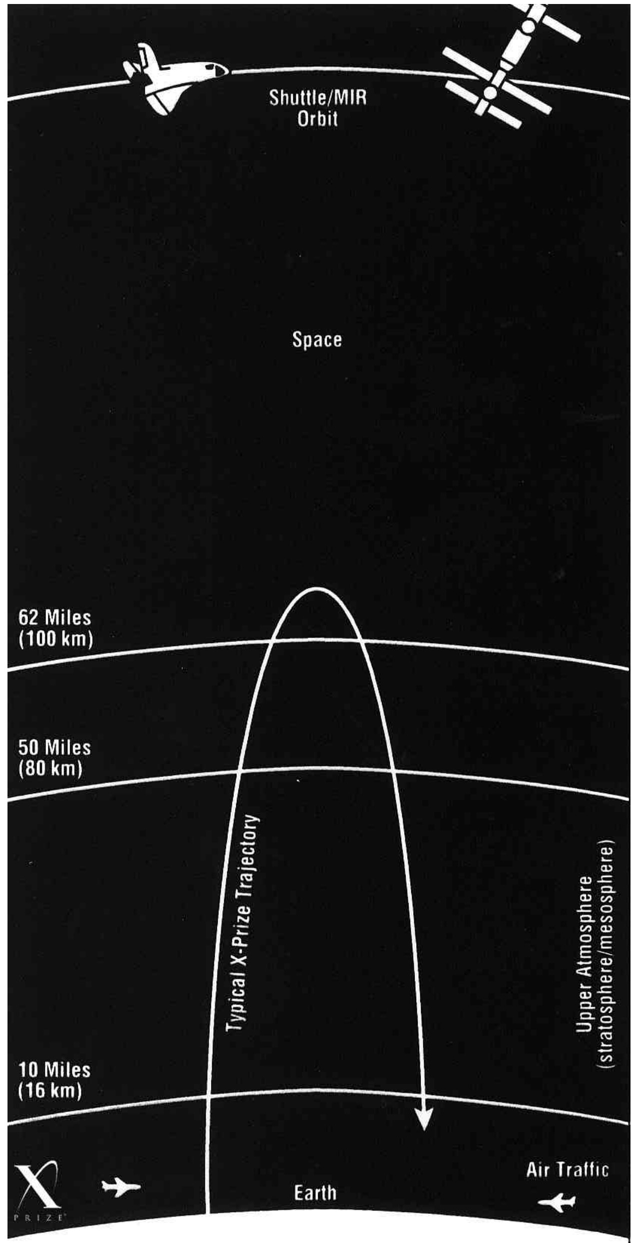


Figure 1: Typical X PRIZE℠ Trajectory

The X PRIZE competition currently has 17 entrants from five countries offering a variety of different RLV concepts. The commercial vehicles under development for the X PRIZE competition are uniquely designed for sub-orbital space tourism operations carrying about three to six passengers. These designs use many different takeoff, landing, and design concepts, but all plan to use existing technology to accomplish their goals.

In May 1998, the Foundation unveiled the X PRIZE trophy, which was put on display at the National Air and Space Museum in Washington DC. During the course of 1999, the X-Prize trophy was on loan to the Seattle Museum of Flight. It is expected that the trophy will next be displayed in San Diego, continuing its tour around the nation.

During 1999, the X PRIZE Foundation made progress in attracting sponsors and new entrants.[77] The foundation worked with several non-US groups to encourage greater international participation in the competition. One of these non-US groups, Cosmopolis XXI of Moscow, Russia, became the latest X-PRIZE entrant. This year's other X-PRIZE entrant was TGV Rockets of Bethesda, Maryland.

Table 2: Summary of X PRIZE Vehicles

Program	Developer	Vehicle Type
Ascender	David Ashford, Bristol Spaceplanes Limited	Spaceplane powered by two conventional jet engines and a liquid-fueled rocket engine. The vehicle will take off and land horizontally.
Astroliner	Kelly Space and Technology	See the Astroliner entry for information.
Cosmos Mariner	Dynamica Research	Spaceplane powered by two air-breathing engines and one rocket engine. The vehicle will launch and land horizontally.
Gauchito	Pablo De Leon and Associates	Two-stage vehicle that will launch vertically. The first stage booster and the second stage passenger capsule return to Earth using parachutes.
Green Arrow	Graham Dorrington	Cylinder-shaped rocket using liquid-fueled rocket engines. The vehicle will launch vertically and land vertically using parachutes and air bags.
Lucky Seven	Mickey Badgero	Cone-shaped vehicle powered by rocket engines. The vehicle will launch vertically and land using a parafoil.
Mayflower (CAC-1)	Advent Launch Services	Cylinder-shaped glider powered by liquid-fueled rocket engines. The vehicle will launch vertically from water and land horizontally in water.
MICHELLE-B	TGV Rockets	The vehicle will launch vertically and land vertically using ascent engines in a deep throttle mode.
PA-X2	Rick Fleeter, AeroAstro Inc.	Cylinder-shaped vehicle using a liquid-fueled engine. The vehicle will launch vertically and land horizontally using a steerable parafoil.
Pathfinder	Pioneer Rocketplane	See the Pathfinder entry for information.
Proteus	Burt Rutan, Scaled Composites	Two-stage vehicle consisting of the conventional turbo-fan powered Proteus aircraft and a rocket-powered second stage.
The Space Tourist	John Bloomer, Discraft Corporation	Disc-shaped vehicle powered by air-breathing "blastwave-pulsejets." The vehicle will take off and land horizontally.
Thunderbird	Steven M. Bennett, Starchaser Foundation	Cylinder-shaped rocket using air-breathing engines and liquid fueled rocket engines. The vehicle will launch and land vertically.
X Van	Pan Aero, Inc., Third Millennium Aerospace	Pan Aero has publicized two designs for the X Van. The entry may be a two-stage-to orbit system comprised of a booster stage and orbiter stage, or a single-stage system flying a sub-orbital trajectory.
unnamed	William Good, Earth Space Transport System Corporation	No information on this entry has been released.
unnamed	Cosmopolis XXI	Cylinder-shaped rocket which is launched off of carrier aircraft "Geophisika". The vehicle will take off vertically and land horizontally.

Several of the X PRIZE entrants also took steps forward in developing their vehicles during 1999. In June, Burt Rutan flew the first stage of Proteus at the Paris Air Show. The flight, which initiated in Mojave, California, took the aircraft across the country to Bangor, Maine. From Bangor, Rutan took Proteus on a 12-hour journey nonstop to Le Bourget, France. Also in June, Steven Bennett, founder of the Starchaser Foundation, unveiled a full size mock-up of his Thunderbird craft to a crowd at Blackburn Rovers Field in England. During July, a 1/3 scale model of Bristol Spaceplanes' "Ascender" passenger spaceplane was displayed at the "Tomorrow's World Live" exhibition held in London.

Several of the competitors have commercial plans for their vehicles after the X PRIZE. In addition to the already discussed plans of Pioneer Rocketplane and Kelly Space and Technology, Scaled Composites' Proteus aircraft is planned for use for missions such as atmospheric research, reconnaissance, microsatellite launch, and as a telecommunications platform over metropolitan areas.[78] The Mayflower and the Ascender are planned for continued use as commercial space tourism platforms. The X Van and the Cosmos Mariner are proposed for both satellite launch and space tourism missions.

Vehicle	First launch	Manufacturer/ Developer (website)	Number of stages	Powerplants	Performance	Launch method	Recovery method	Launch Contracts	Government funding	Potential Markets Served	Subcontractors	Commercial Investors	Possible launch sites
Commercial Programs													
Astroliner	2002	Kelly Space and Technology (www.kellyspace.com)	3	Engines under consideration include: GenCorp Aerojet's NK-33, Rockwell Rocketdyne Division's Aerospike and RS-27, or NPO's RD-180; Upper stages under consideration include Thiokol's Star 71, and Pratt & Whitney Orbus 21	4,700 kg to 300 km 28.5 deg. LEO 3,950 kg to 300 km 86 deg. LEO 3,400 kg to 1700 km 28.5 deg. LEO 2,700 kg to 1700 km 86 deg. LEO 2,072 kg to GTO	air-launched	horizontal landing	yes	no	Launch of LEO constellation satellites and GTO payloads	ACTA, Aircraft Technical Services, GenCorp Aerojet, AeroLaunch Systems Corporation, Altair, Frontier Engineering, Menasco, Modern Technologies Corp., Oceaneering Space Systems, Pioneer Aerospace, Thiokol, Tracor, TRW, Universal Space Lines	Motorola has signed $89 million contract with KST for ten launches of twenty Iridium satellites	Vandenberg AFB, CA; White Sands Missile Range, NM
K-1	TBD	Kistler Aerospace Corporation (www.kistleraerospace. com)	2	First stage: 3 GenCorp Aerojet AJ-26 kerosene/ LOX engines Second stage: 1 GenCorp Aeroject AJ-60 kerosene/ LOX engine	Standard Payload Module: 4,000 kg to 400 km 45 deg. LEO 2,100 kg to 1,000 km 45 deg. LEO 2,250 kg to 400 km 98 deg. LEO Extended Payload Module: 3,700 kg to 400 km 45 deg. LEO 1,900 kg to 1000 km 45 deg. LEO 2,000 kg to 400 km 98 deg. LEO	vertical launch	parachutes and air bags (both stages)	yes	no	Launch of LEO satellites	GenCorp Aerojet, Northrop Grumman Corporation, Lockheed Martin Michoud Space Systems, Draper Laboratories, Honeywell (formerly AlliedSignal Aerospace), Irvin Aerospace, Inc., Oceaneering Thermal Systems	Kistler Aerospace has raised more than $500 million in private capital, and continues to seek commercial financing to complete the K-1. Northrop Grumman has invested $30 million, with options for additional investment. Space Systems/Loral has signed a contract worth in excess of $100 million with Kistler Aerospace for ten launches.	Woomera, Australia; Nevada Test Site, NV
Pathfinder	2001	Pioneer Rocketplane (www.rocketplane.com)	2	2 Pratt and Whitney F100 air-breathing engines, 1 RD-120 LOX/kerosene engine	2,100 kg to 200 km Equatorial 1,600 kg to 200 km Polar 1,900 kg to 1,000 km Equatorial 1,450 kg to 1,000 km Polar	horizontal takeoff	horizontal landing	no	yes	Launch of LEO constellation satellites	Scaled Composites, ARB Rockets Incorporated		Vandenberg AFB, CA
Roton C-9	2000	Rotary Rocket Company (www.rotaryrocket.com)	1	Cluster of several engines derived from the Fastrac design	3,600 kg to 275 km 35 deg. LEO 2,700 kg to 370 km 90 deg. LEO 3,150 kg to 550 km 35 deg. LEO 2,250 kg to 550 km 90 deg. LEO	vertical launch	vertical landing	no	no	Launch of LEO constellation satellites	Scaled Composites, Advanced Rotorcraft Technologies, Deskin Research Corp., Hypersonics Inc., Aerotherm Corp., Altus Associates, Luna Corp., Guidance Dynamics Corporation, Howard & Houston Engineering, Inc., LAPCAD, National Technical Systems		Mojave Civilian Test Flight Center, CA
SA-1	2005	Space Access LLC	2 (LEO) 3 (GTO)	Ejector LOX/hydrogen ramjets for each stage	5,200 kg to GTO	horizontal takeoff	horizontal landing	no	no	Launch of medium-class LEO and GTO payloads. Launch of ISS resupply missions or human spaceflight	Kaiser Marquardt, undisclosed "major aerospace firms"		Homestead AFB, FL; Orlando Airport, FL; Tampa Airport, FL
Space Cruiser System (SCS)	2001	Vela Technology Development, Inc. Space Adventures (www.spaceadventures. com)	2	Lower stage: 2 JT8D/F100-class turbo-jet engines Upper stage: 3 Nitrous Oxide/Propane, pressure fed, rocket engines, two JT15D-class turbo-jet engines	6 passengers and 2 crew to 100 km sub-orbital	horizontal takeoff	horizontal landing	yes	no	Sub-orbital space tourism; Sub-orbital microgravity and other experiments; Aerospace training	AeroAstro		Commercial airports capable of servicing business jets
VentureStar	2004	Lockheed Martin (www.lmco.com)	1	7 RS-2200 linear aerospike engines	22,700 kg to LEO	vertical launch	horizontal landing	no	yes	VentureStar launch of heavy-class LEO payloads			15 states are bidding to have a VentureStar site
United States Government Programs													
Space Shuttle	1981	Rockwell, Rocketdyne, Lockheed Martin (www.boeing.com) (www.lmco.com)	2	3 Rocketdyne LOX/hydrogen Space Shuttle Main Engines	24,950 kg to 204 km 28 deg. LEO 18,600 kg to 204 km 57 deg. LEO	vertical launch	horizontal landing	yes	yes	Sience missions, experimental payloads, human spaceflight, launch and in-orbit rtreival and repair of spacecraft			Kennedy Space Center, FL
X-33	2000	Lockheed Martin (www.lmco.com)	1	2 J-2S linear aerospike engines	Mach 13.8 at 91 km	vertical launch	horizontal landing	no	yes	Testbed for RLV technologies and operations	LM Space Operations, LM Manned Space Systems, LM Astronautics, LM Engineering and Sciences, Sanders, Rocketdyne, Rohr, AlliedSignal, Alliant Techsystems, Sverdrup, Boeing Rocketdyne		Edwards AFB, CA
X-34	2000	Orbital Sciences Corporation (www.orbital.com)	1	One kerosene/LOX Fastrac engine or One Russian-built NK-39 engine (possible if funding becomes available)	Mach 8 at 76 km (vehicle A3) 181kg payload allocation	air-launched	horizontal landing	no	yes	Sub-orbital demonstration of RLV technology	AlliedSignal, Oceaneering Incorporated, Draper Laboratories, Summa Technology Inc.		Edwards AFB, CA; Kennedy Space Center, FL
X-38/Crew Return Vehicle	2001	Scaled Composites	TBA	X-38: none CRV: Expendable Deorbit Propulsion Stage (DPS)	CRV: Emergency International Space Station crew return capability	on-board Space Shuttle	horizontal landing	no	yes	Prototype for International Space Station crew return operations	Pioneer Aerospcace, SSE Inc.		Kennedy Space Center, FL; Kourou, French Guyana
X-40A/Military Spaceplane	TBA	Boeing Phantom Works (www.boeing.com)	2	Hypersonic first stage: similar design to X-33 or Clipper Graham Space Maneuver Vehicle (SMV) second stage: TBA	450 kg to LEO	vertical launch	horizontal or vertical landing	no	yes	Military payload delivery or special missions such as satellite orbital transfer or satellite neutralization			TBA
X-37	2001	Boeing Phantom Works (www.boeing.com)	2	TBA		vertical launch	horizontal landing	no	yes	Demonstration of launch, orbit, reentry, and landing phases of RLV flight			Kennedy Space Center, FL
International Concepts													
AVATAR (India)	TBA	Defense Research Development Organization	1	Powered by turbofan ramjet engines, airbreathing propulsion engines for atmospheric flight	1/2 metric ton to one metric ton to LEO	vertical launch	horizontal landing	no	yes	Launch of LEO payloads; Security services: intelligence, surveillance, and reconnaissance			TBA
HOPE-X (Japan)	2004	National Space Development Agency of Japan (www.nasda.go.jp)	3	Thrusters utilizing nitrogen tetroxide and either monomethelhydrazine or hydrazine	3,000 kg to space station orbit 1,000 kg to 200 km orbit	vertical launch with H 2A booster	horizontal landing	no	yes	Technology demonstration	Fuji Heavy Industries, Kawasaki Heavy Industries, Mitsubishi Corp.		Tanegashima, Japan
Single-Stage-To-Orbit Spaceplane (Japan)	2010	National Aerospace Laboratory (www.nasda.go.jp)	1	Multiple liquid propellant engines Airbreathing engines for atmospheric flight	10,000 kg to 500 km 28.5 deg. LEO	horizontal takeoff	horizontal landing	no	yes	Launch and recovery of LEO payloads			TBA
Spacecab/ Spacebus (England)	2010	Bristol Spaceplanes Limited	2	Lower stage: combination of air-breathing and rocket engines Upper stage: six RL-10 or HM7 class engines	Spacecab: 6 passengers/space station crew 750 kg to LEO	horizontal takeoff	horizontal landing	no	no	Orbital space tourism; Launch of small-class LEO payloads; ISS crew transfer; Repair of satellites in LEO			TBA

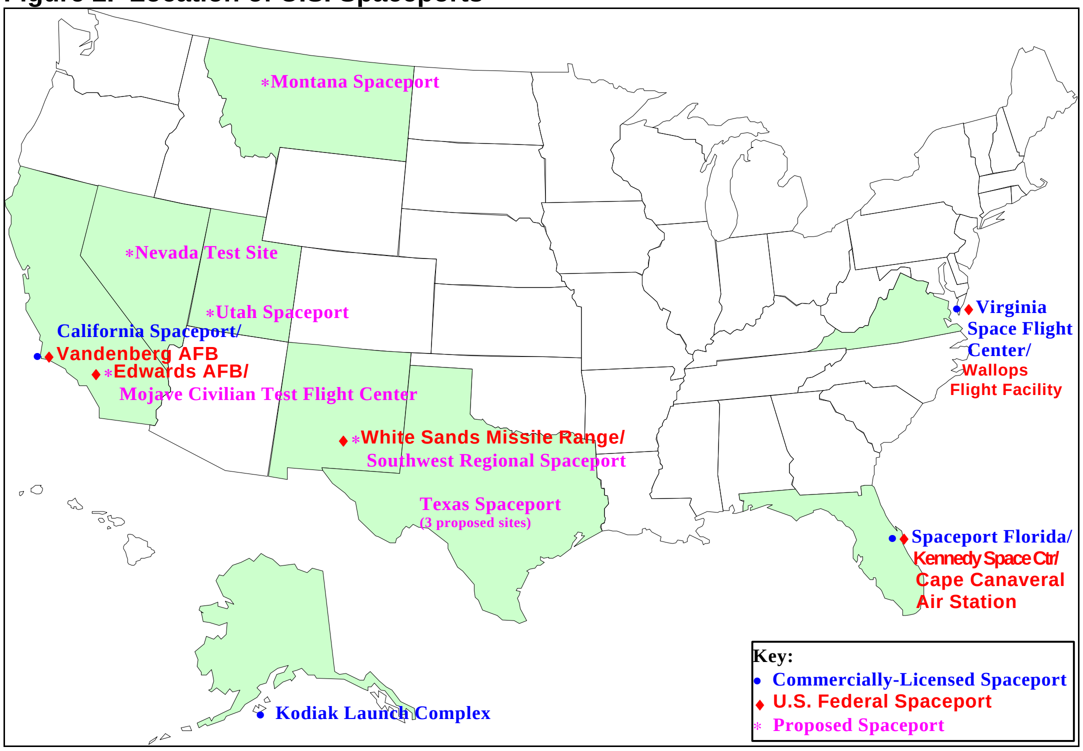
Spaceports

The United States government has, since the 1950s, built, operated, and maintained a space launch infrastructure for launching satellites into space. Much of the demand for and use of these launch sites has traditionally come from U.S. military and civil government agencies. Beginning in the early 1980s, a number of the government-operated launch sites began providing support for commercial launch activities as well, with NASA acting as the primary intermediary for providing launch services to satellite operators. Following the Challenger accident, a White House decision in August 1986 allowed launch customers to solicit bids directly from the launch vehicle builders who would, in turn, lease launch facilities from NASA or the USAF. This decision, coupled with the 1984 U.S. Commercial Space Launch Act and its 1988 amendments, did much to foster commercial launch business, which continues to grow to this day.

Today, commercialization of the U.S. launch infrastructure is evident, with commercially-operated launch facilities making significant progress toward realization. In January 1998, the very first launch from a U.S. commercial launch site took place at Spaceport Florida. Also, many states are encouraging the development of Spaceports through a variety of monetary grants and legislative activity.

This section describes existing and emerging launch sites, otherwise known as Spaceports, and it is divided into three parts: Commercially-Licensed Spaceports, U.S. Federal Spaceports, and Proposed Spaceports. A map showing the location of these Spaceports is provided below, and a table is included at the end, which summarizes the major characteristics of each Spaceport.

Figure 2. Location of U.S. Spaceports



Commercially-Licensed Spaceports

In order to conduct a commercial space launch or operate a commercial launch site in the U.S., it is necessary to obtain a license from the United States government. The Federal Aviation Administration's Associate Administrator for Commercial Space Transportation (AST) performs this function. While the vast majority of licensed launch activities occur from U.S. Federal Ranges (described in the next section), many future launch activities are expected to occur from private or State-operated launch sites. Since September, 1996, AST has licensed the operation of four non-Federal launch sites including the California Spaceport at Vandenberg Air Force Base, Kodiak Launch Complex in Alaska, Spaceport Florida at Cape Canaveral Air Station, and the Virginia Space Flight Center at Wallops Island (see Table 3). The first launch from a non-Federal range licensed by AST was that of NASA's Lunar Prospector aboard a Lockheed Martin Athena-2 rocket on January 6, 1998, from Spaceport Florida.

Table 3. Launch Site Operator Licenses Issued

License	Operator / Launch Site	Location	Original Effective Date	Expiration Date
LSO 96-001	Spaceport Systems International / California Spaceport	VAFB	19 Sep 1996	19 Sep 2001
LSO 97-002	Spaceport Florida Flight Authority / Spaceport Florida	CCAS	22 May 1997	22 May 2002
LSO 97-003	VA Commercial Space Flight Authority / Virginia Space Flight Center	WFF	19 Dec 1997	19 Dec 2002
LSO 97-004	Alaska Aerospace Development Corporation / Kodiak Island	KLC	24 Sep 1998	24 Sep 2003

California Spaceport, Lompoc, California

The California Spaceport is a commercially operated launch services company. It is operated and managed by Spaceport Systems International, L.P. (SSI), a limited partnership between ITT Federal Services Corporation and California Commercial Spaceport, Inc.

The California Spaceport was the first commercial launch site to be licensed by the Associate Administrator for Commercial Space Transportation (September 19, 1996). From its position on Vandenberg Air Force Base (SSI has signed a 25 year lease with VAFB), the launch can support a variety of mission profiles to low polar orbit inclinations, with possible launch azimuths ranging from 220° to 150°.

Construction at California Spaceport's launch complex began in 1995. Today, the concrete flame ducts, communication, electrical, and water infrastructure are in place. When complete, California Spaceport's new launch complex will be equipped to accommodate several configurations of small launch vehicles, based on either the Castor 120 or the Minuteman solid motor first stages. SSI also has plans to provide facilities to service launch vehicles using a variety of liquid and cryogenic fuels. Additionally, the completed launch complex will provide two Stack & Checkout Facilities for preparing launch vehicles. Rail-mounted mobile launch platforms will transport the stacked vehicle and payload to the launch site.

The focus of the California Spaceport's payload processing services was originally on the refurbishment of the Payload Preparation Room, which was a cleanroom facility designed to process three Space Shuttle payloads simultaneously. The Payload Preparation Room, located near Space Launch Complex 6 (SLC-6), is now leased by SSI as their Integrated Processing Facility. SSI will be a provider of payload processing services and orbital launch support services for both commercial and government users. California Spaceport provided payload processing services for the NASA Lewis satellite and has contracts to provide payload processing for two Earth Observation System (EOS) satellites.

California Spaceport is planning to support the launch of an orbital payload under the Air Force's Orbital/Sub-orbital Program intended to use surplus ballistic missile assets to deploy government payloads. The Minotaur launch vehicle, a modified Minuteman II first and second stage with an Orbital Sciences Corporation Pegasus upper stage, will deploy JAWSAT, a joint project by the Air Force Academy and Weber State University. This launch originally planned for late 1999, was delayed until January 2000.

Kodiak Launch Complex, Kodiak Island, Alaska

In January 1998, after obtaining a commercial launch site license from the FAA, the Alaska Aerospace Development Corporation began building a commercial spaceport at Narrow Cape on Kodiak Island, about 250-miles south of Anchorage and 25 miles southwest of the City of Kodiak. The Kodiak Launch Complex (KLC) is located on a 3,100 acre site, divided among four areas: 1) the Launch Control and Management Center, 2) the Payload Processing Facility which will include a class-100,000 cleanroom and a 40-foot by 60-foot airlock and a 40-foot by 60-foot processing bay, 3) the Integration and Processing Facility/Spacecraft Assemblies Transfer Facility, and 4) the Launch Pad and Service Structure .

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. Also under consideration is the use of Wallops Flight Facility's mobile tracking stations.

Kodiak Island provides a wide launch azimuth and unobstructed downrange flight path. KLC's planned markets are telecommunications, remote sensing, and space science payloads of up to 8,000 pounds into low Earth polar and Molniya orbits as well as RLVs. The first launch from Kodiak was a suborbital vehicle (Ait-1) built by Orbital Sciences for the Air Force in 1998. A second suborbital vehicle (Ait-2) was launched in September 1999.

Upon completion, the Kodiak Launch Complex will be the only commercial launch range in the United States not co-located with a federal facility. No firm orbital launch customers have yet been found for the Kodiak site.

Spaceport Florida, Cocoa Beach, Florida

The Spaceport Florida Authority (SFA) was established in 1989 by the state of Florida to facilitate the development of the state's space related industry. A commercial license from the FAA Associate Administrator for Commercial Space Transportation was awarded to the Spaceport Florida Authority on May 22, 1997. The SFA facility consists of about 70 acres of land owned by the U.S. Air Force and operated by the U.S. Navy's Strategic Systems Program Office.

The cornerstone of SFA's efforts was refurbishing Launch Complex 46, an old Trident missile launch site at Cape Canaveral Air Station, to accommodate small commercial launch vehicles. The philosophy behind developing Launch Complex 46 was not to tailor a facility for a single launch system, but rather to build a public transportation infrastructure for several competing launch systems. SFA's Launch Complex 46 can accommodate a variety of launch vehicle configurations, and payload lift capabilities up to 4,000 pounds to LEO are possible. In the future, the complex could even accommodate lift capabilities in excess of 4,900 pounds to LEO. Launches to LEO, GEO, and interplanetary trajectories can be conducted from this site.

As Spaceport Florida is located on the Cape Canaveral Air Station, this commercial launch site can offer extensive support services by relying on existing range infrastructure. Payload processing facilities, including cleanroom environments are available from off-site commercial providers, in addition to range tracking and telemetry equipment required to conduct launch operations.

Currently, the launch complex is configured to launch vehicles that use the Castor 120 or similar solid motors as a first stage; examples include Lockheed Martin's Athena launch vehicle and

Orbital Sciences Corporation's Taurus vehicle. Infrastructure can support launch vehicles with a maximum height of 120 feet and diameters ranging from 50 to 120 inches. The first launch from Launch Complex 46 was of the Lockheed Martin Athena 2 launch vehicle, which deployed the Lunar Prospector mission for NASA in January 1998.

The next major effort by the SFA is to convert former Titan 1, Titan 2, and suborbital pads to service a variety of small launch vehicles for both orbital and suborbital launches. SFA has also recently upgraded Launch Complex 20, which includes three launch pads, a launch control blockhouse, and an on-site facility for small payload preparation and storage. The SFA hopes to take advantage of these facilities to provide a rapid response capability for the LEO communications satellite replacement market or for scientific payloads. By refurbishing the blockhouse, the SFA hopes to offer a multi-user launch control and data monitoring system that will serve several types of vehicle and payload systems.

Virginia Space Flight Center, Wallops Island, Virginia

The Virginia Space Flight Center (VSFC) is operated by the Virginia Commercial Space Flight Authority in cooperation with NASA at the Wallops Flight Facility on Wallops Island, Virginia.

The origins of this commercial launch site began at Virginia's Old Dominion University in 1992 when the Center for Commercial Space Infrastructure was created to establish commercial space research and operations facilities in the state of Virginia. The Center worked in cooperation with Wallops Flight Facility to develop a commercial launch infrastructure there. Three years later, the Governor of Virginia signed a bill into law creating the Virginia Commercial Space Flight Authority (VCSFA) as a public organization specifically to develop a Virginia commercial launch capability. The Virginia Commercial Space Flight Authority was awarded a commercial launch site operator license by the FAA on December 19, 1997.

The VCSFA is located on Virginia's southeastern Atlantic coast, and it can accommodate a range of orbital inclinations and launch azimuths. Facilities exist to service a variety of solid-fueled vehicles.

Development of the commercial facilities include completion of launch pad LP 0-B, which will consist of a 19,000-square foot pad and a 182-foot service tower, equipped with a 75-ton crane for vehicle and payload handing. Phase I construction of the pad began in early 1998 and was completed by December of that year.[79] Phase I includes the pad, launch mount, and some additional supporting infrastructure. The service tower will be included in subsequent phases. The new pad is designed as a "Universal Launch Pad," capable of supporting a variety of small and medium launch vehicles. The most likely vehicles for the facility are the Lockheed Martin Athena or the Orbital Sciences Corporation Taurus.

In 1997, the VCSFA signed an agreement with NASA to use NASA facilities at Wallops in support of commercial launches under what is known as the NASA/Virginia Commercial Space Flight Authority Reimbursement Space Act Agreement. The 30-year agreement allows the Authority access to the NASA facilities on a cost reimbursement basis.

The Virginia Space Flight Center is not the first commercial venture at Wallops Flight Facility. In 1994, EER Systems of Seabrook, Maryland, built and operated pad LP 0-A, to be used by EER's Conestoga launch vehicle. The Conestoga's first and only attempted launch from this location took place in fall 1995. The launch pad is still owned by EER Systems.

U.S. Federal Spaceports

The U.S. federal ranges have supported commercial launch activity since the mid-1980s. The Eastern range at Cape Canaveral and the Western range at Vandenberg Air Force Base are where the bulk of the nation's government and commercial launches are conducted today. The U.S. government, primarily the Air Force, is preparing to accommodate the continuing increase in the number of commercial launches from the federal launch sites. This will be accomplished through range modernization programs that will upgrade much of the range's support and communications systems. The U.S. Air Force began a complete range modernization program in 1987 and in July 1993. The Range Standardization and Automation program is currently underway and it is a key effort to modernize and upgrade the Eastern range at Cape Canaveral and portions of the Western range at Vandenberg. Launch pad modifications are also continuing in order to accommodate the next generation of the Delta and Atlas launch systems, the Delta 3 and the Atlas 3. Work is also progressing to support the new EELV family of launch vehicles, each being separately developed by Boeing and Lockheed Martin.

Cape Canaveral Air Station/Kennedy Space Center, Cocoa Beach, Florida

Cape Canaveral Air Station (CCAS) and NASA Kennedy Space Center (KSC) are collocated on the "Florida Space Coast." The Cape Canaveral Air Station, dates back to 1949, when the Banana River Naval Air Station was transferred to the Air Force to become a joint service missile range. It became increasingly active and developed with the space race in the 1950's and is the only site (along with the adjacent KSC) ever used for U.S. manned space missions. Today the Air Station encompasses active Delta, Atlas, and Titan launch complexes as well as support and launch facilities for the military, NASA and commercial companies. Because its launch complexes were conceived and built in the 1950's, the Cape can only support 25 to 30 launches a year. The 9 currently operational pads (a total of 40 were built) require an average of 26 to 40 days processing between each launch. In addition to the pads, CCAS provides extensive support facilities, including a Range Operation Control Center, 5 hangars for non-hazardous payload processing, the Shuttle Payload Integration Facility, the Satellite Assembly Building and an Explosive Safe Area.

The only launch complex located on the Kennedy Space Center grounds is dedicated to the Space Shuttle. Pads 39 A&B and their support and processing facilities are all located on Meritt Island, between the Florida mainland and Cape Canaveral. KSC was originally built to support the Apollo program. After the end of the lunar landing program in 1972, Launch Complex (LC) 39 served to launch SkyLab missions, the Apollo-Soyuz program and the Space Shuttle. Support facilities for LC-39 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 (and Florida Spaceport) has been selected as the launch site of three RLVs: the X-34 (in its second phase of powered testing), the X-37, and the X-38/CRV. Primarily to support X-34 operations, but also in the hope of attracting more RLV business, the state of Florida has financed the construction of a climate-controlled hangar and processing facility at KSC.

Edwards Air Force Base, Mojave, California

Edwards Air Force Base in Mojave, California is the home of the NASA Dryden Flight Facility and of the Air Force Flight Test Center.

Edwards AFB was chosen as the initial Space Shuttle landing site. The first two flights by the Shuttle ended with the orbiters landing on Rogers Dry Lake, a natural hardpack riverbed about 44 square miles in size. However, rainfall at Edwards AFB in early 1982 flooded the normally dry lakebed and NASA diverted the landing site of the third mission to White Sands, N.M. Later that year, a 4.5km concrete runway was built at Edwards.

The X-33 Program Office is planning on using 30 acres of land at Edwards AFB as its launch site. The complex, completed in December 1998, consists of an X-33-specific launch pad, the Operation Control Center (OCC) and a movable hangar where the vehicle is housed and serviced in the horizontal position. The OCC, which will serve as a launch monitoring facility and mission control, is situated about a mile away from the launch pad, and it is linked to the data and communication systems at the launch site. Telemetry and tracking functions will be performed using existing Air Force and NASA facilities on Edwards AFB. The X-33 spaceport is also equipped with hydrogen and nitrogen gas tanks, and liquid hydrogen and oxygen tanks capable of holding more than 300,000 gallons of cryogenic materials. A 250-feet-tall water tower will supply 250,000 gallons of water dropped into the concrete flame trench at launch. The deluge system is not only a cooling mechanism, it also serves as a sound suppression system and helps minimize the intensity of the shock-wave rebounding from the trench to the engine.[80]

Edwards Air Force Base is also planned for X-34 high speed and long range testing.

Vandenberg Air Force Base, Lompoc, California

Vandenberg Air Force Base has, until now, been primarily used for the development and testing of ICBMs. It is also used for launching classified satellites and for putting NASA and DOD payloads into polar orbit. Vandenberg AFB has a 4.5 km runway, vertical launch facilities, payload processing facilities, tracking radar, optical tracking and telemetry facilities, a control center, engineering office space, and a range extending from the San Francisco area to the Mexican border and westwards to the Hawaiian Islands.[81]

The 399 square kilometers base houses 53 host organizations and 49 contractor companies in 1,100 buildings. VAFB is actively trying to attract commercial aerospace companies and is supporting the California Spaceport effort.

Vandenberg Air Force Base has been contacted by two RLV manufacturers: Pioneer Rocketplane and Kelly Aerospace. Both have expressed interest in using Vandenberg facilities for testing purposes and possibly as their spaceport once the testing sequence is completed. The existing facilities on base may or may not require modifications depending on the final design of the vehicle tested there. No upgrades or new facilities are currently being planned. Should there be a need for construction, the RLV firms would be responsible for the cost as the government is prohibited from subsidizing commercial space operation. Operations and maintenance costs would also be the responsibility of the RLV operators.

Pioneer Rocketplane has signed an Initial Support Agreement with Vandenberg and obtained a "right-of-entry" to Vandenberg facilities. This permit has, however, expired and Pioneer moved their offices off base.

Kelly Aerospace and Vandenberg are still in the planning phase and have yet to sign an Initial Support Agreement. Kelly Aerospace has expressed its intention to only use Vandenberg AFB facilities for testing purposes and hope to move their operations to privately operated facilities when the Astroliner is operational.[82]

Although there are no definite plans for other RLVs to use Vandenberg AFB, the base is attempting to capture more RLV business and has presented a proposal to VentureStar. It is also being considered as a potential site for the "Military Space Operation Vehicle" in the future.

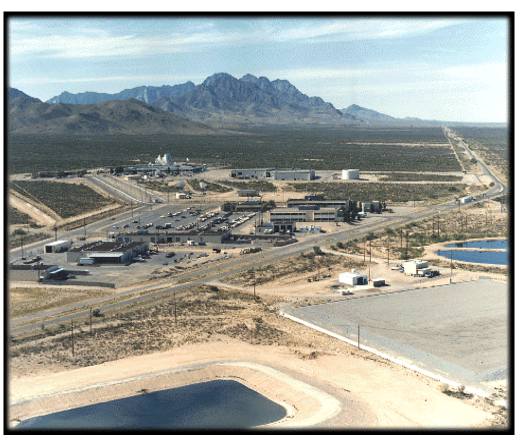
Wallops Flight Facility, Wallops Island, Virginia

NASA has operated a sounding rocket range at Wallops Island since 1945 and conducted its first orbital launch in 1961, when a Scout launch vehicle deployed the Explorer 9 balloon that was used to study atmospheric density. Since that time, several orbital and suborbital missions have been conducted at Wallops for NASA. In 1994, EER Systems completed launch pad LP 0-A, which was built to support its Conestoga launch vehicle. The first and only flight of Conestoga failed to deploy the METEOR recoverable satellite, designed for microgravity experiments, in 1995.

Other orbital launches from Wallops have included flights of Orbital Sciences Corporation's Pegasus air-launched vehicle, the first of which deployed the MSTI 3 satellite in 1996 on a commercially-licensed launch. In April 1996, the Air Force designated Wallops Flight Facility as one of the sites to conduct launches of converted Minuteman II missiles under the Orbital/Sub-orbital Program, along with Kodiak Launch Complex and the California Spaceport.

Although Wallops has not supported any orbital flights since the Conestoga failure in 1995, NASA is committed to maintain the existing infrastructure. Five launch areas, including one for heavy lift sub-orbital rockets and one for classified payloads, two blockhouses, and preparation facilities are operational. The Virginia Space Flight Center is co-located at Wallops.

White Sands Missile Range, Las Cruces, New Mexico



White Sands Missile Range, which includes the NASA White Sands Flight Test Center situated 26 km northeast of Las Cruces, New Mexico, is operated by the U.S. Army and used mainly as a sounding rocket firing base and supports BMDO flight testing. Its 8,100 square kilometers also include the site of the first atomic explosion: Trinity Site.

Also used as a test center for rocket engines and experimental spacecraft, White Sands counts seven engine test stands and precision cleaning facilities including a class 100 clean room for spacecraft parts.

White Sands also provides the third shuttle landing site in the U.S. after Edwards AFB and KSC. The Northrup Strip consists of two 11 km-long gypsum-sand runways. More recently, White Sands was chosen as the site for the first phase of unpowered tests for the X-34 vehicle.

Proposed Spaceports

Montana Spaceport, Great Falls, Montana

The State of Montana is aggressively pursuing the development of its space industry. Under the Department of Commerce, the Montana Space Development Authority has been established to coordinate and lead the state's commercial space efforts. Montana's space strategy involves creating the necessary organizational and educational infrastructure to support state space activities and ultimately constructing and licensing a commercial spaceport.

Montana is proposing to fly reusable launch vehicles from a site near Great Falls, Montana and Malmstrom Air Force Base. Malmstrom has already been selected as a landing site for the X-33 flight test program. Montana has been working with officials from both Lockheed Martin's VentureStar and Rotary Rocket company to bring commercial space launch to the State. Montana Space Development Authority personnel have flown to Washington to meet with FAA's AST division and are in the process of obtaining a commercial spaceport license for the Great Falls site.

Another manifestation of Montana's space effort includes the founding of a Commercial Space Policy Institute at Montana State University's Billings campus. The Institute will examine policy and political issues important to the commercial space industry.

Nevada Test Site, Nye County, Nevada

The Nevada Test Site (NTS), 100 km northwest of Las Vegas, was selected by Kistler Aerospace as a spaceport for the K-1 RLV in addition to their Woomera facility in order to increase scheduling flexibility and widen the range of launch azimuths available for customers. Although it did not have any launch infrastructure as of December 1999, the Nevada Test Site has existing basic infrastructure that can be used as support facilities, such as a paved runway, water, roads, and power.

The Nevada Test Site Development Corporation (NTSDC) obtained an *Economic Development Use* permit in 1997 from the Department of Energy. Shortly after, the NSTDC issued a sub-permit allowing Kistler to operate a launch and recovery operation at the NTS.

In 1999, a task force was formed to facilitate the growth of an aerospace industry in Nevada. The development of Spaceport Nevada is actively supported by the state; NTSDC has participated in discussions with VentureStar and is planning to respond to their request for proposal when it is published.

Southwest Regional Spaceport, White Sands, New Mexico

The State of New Mexico proposes to construct and operate the Southwest Regional Spaceport (SRS) for use by private companies conducting commercial space activities and operations. The SRS is proposed to be located in south central New Mexico. The SRS is expected to provide a full range of support for satellite launches and recoveries, scientific research, and space station support. Vehicles for the proposed spaceport are expected to have the capability to terminate each flight without damage and include the ability to make a fully controlled soft landing under emergency conditions. No spent stages or other components would be dropped during normal flight.

Major components of the proposed SRS include a Spaceport Central Control Facility, an Airfield, a Maintenance and Integration Facility, a launch/recovery complex, a Flight Operations Control Center, and a cryogenic plant.

Texas Spaceport

The State of Texas has enabled the development of a commercial Spaceport(s) for reusable launch vehicles. The most promising sites were determined based on a detailed engineering and business evaluation of many potential sites using criteria which included 56 parameters - the most heavily weighted criteria were public safety (consistent with the FAA Spaceport Guidelines) and environmental compatibility. The three candidate sites are located on the Gulf of Mexico (2) and in the desert area of west Texas (1). The Texas Spaceport site(s) will be selected in cooperation with RLV operators. The Spaceport(s) will be owned and operated by a public-private sector partnership. A state law was enacted in the early 1999 which provides for the Spaceport Authority.

Utah Spaceport, Wah Wah Valley, Utah

The Wah Wah Valley Interlocal Cooperation Entity, proposes to construct and operate a commercial launch site utilizing approximately 70,000 acres of Utah State Trust lands located 30 miles southwest of Milford, Utah. This proposed spaceport’s mission is to provide a cost effective launch and recovery facility for single stage to orbit reusable launch vehicles.

This development of the proposed Wah Wah Valley Spaceport would occur over several years. The proposed project would include the construction of a new 15,000 foot long space vehicle recovery and aircraft runway at an elevation of 5,000 feet above sea level and two space vehicle launch facilities located at 7,600 feet above sea level. Additionally, assembly, testing, processing, and office facilities would be constructed.

Woomera Spaceport (Australia)

Situated 430 km north of Adelaide in South-Central Australia, the Woomera Range was established jointly by the United Kingdom (UK) and Australia in 1946 to test ballistic missiles and sounding rockets. Unfortunately, the plan to make Woomera an international launch site never came to fruition as France chose to build its own site and the UK announced it would no longer use the facilities after 1976.[83]

After twenty years of virtual inactivity and with the support of the South Australian government, Woomera is envisioned to become the first operational commercial RLV spaceport. In 1996, Kistler Aerospace signed an agreement and 25 years lease with the Australian government giving it the right to build and operate an RLV launch complex on Woomera grounds. After a groundbreaking ceremony in July 1998, Kistler had to halt construction because of lack of funds. Kistler, who invested $45 million in its Woomera facility, recently announced that work would start again in January 2000 and that Woomera Spaceport would be operational by 2001.[84]

At present, the Woomera range is little more than an outdated launch site and assembly building and tracking facility. However, Kistler's plans include completely new facilities. Also, the Australian government is hoping that Kistler's efforts will attract other RLV companies in the future and has passed a series of legislative acts in support of space-related foreign investment in the area of Woomera.

Mojave Civilian Test Flight Center, Mojave, California

The Mojave Airport was established in 1935 as a county facility with taxiways and basic support facilities suitable for general aviation. A few years later, the airport was taken over by the Federal Government and turned into a Marine Corps Auxiliary Air Station. In 1961, Kern County re-acquired the facilities and turned the Mojave airport into a civilian flight test center.[85]

In 1998, Rotary Rocket Company moved parts of its Roton manufacturing and testing facilities to Mojave Airport where it had acquired a 2.5-acre lot. In May of that year, Rotary Rocket announced the completion of its

Rotor Test Stand and that they would start assembling and testing hardware on site at Mojave. This was only the first step of a $5.5 million project. The complex including a an engineering "workshop and campus" and a high bay building which is used to house office space as well as to assemble the Roton Atmospheric Test Vehicle (ATV) was completed in early 1999.[86]

On July 23, 1999, the first test flight of the ATV was successfully completed as the Roton flew for 4 minutes and 40 seconds over runway 30 at Mojave Airport. Other stability tests have since then taken place and the first operational flight is planned for 2001.[87]

This document has attempted to capture most, if not all, of the existing and proposed U.S. Spaceports. However, it is possible that there are other proposed Spaceport concepts in existence.

Table 3: RLV Spaceport Summary Information

Spaceport	Location	Spaceport Owner/Operator	Launch Infrastructure at Site	Current Development Status
Commercially Licensed Spaceports				
California Spaceport	Lompoc, California	Spaceport Systems International, L.P.	Existing launch pads, runways, payload processing facilities, telemetry and tracking equipment.	The site is still undergoing upgrades. Currently in place are the concrete flame ducts, communication, electrical, and water infrastructure.
Kodiak Launch Complex	Kodiak Island, Alaska	Alaska Aerospace Development Corporation	Limited infrastructure at this time.	Construction for the launch control and management center, the payload processing facility and the integration and processing facility is in progress.
Spaceport Florida	Cocoa Beach, Florida	Spaceport Florida Authority (SFA)	Two launch complexes including pads and a control center, a small payload preparation facility and an RLV support facility.	SFA has invested over $200 million to upgrade LC 46 and 20, build an RLV support complex adjacent to the Shuttle landing facilities, and develop a new space operation support complex .
Virginia Flight Test Center	Wallops Island, Virginia	Virginia Commercial Space Flight Authority	Launch pad and service tower, payload processing facility, downrange tracking facility.	Pad 0-B was completed in December 1998. VSFC obtained a commercial license from the FAA in 1997.
Federal Spaceports				
Cape Canaveral Air Station/ Kennedy Space Center	Cocoa Beach, Florida	USAF, NASA, Florida Spaceport Authority	Telemetry and tracking facilities, jet and shuttle capable runways, launch pads, hangar, vertical processing facilities and assembly building.	RLV spaceport and processing facilities to be completed in early 2000.
Edwards AFB	Mojave, California	USAF	Telemetry and tracking facilities, jet and shuttle capable runways, X-33 launch pad, operations control center, movable hangar, fuel tanks, water tower.	Site is operational.
Vandenberg AFB	Lompoc, California	USAF	Launch pads, vehicle assembly and processing buildings, payload processing facilities, telemetry and tracking facilities, control center, engineering office space, shuttle-capable runway.	VAFB has started negotiations with several commercial companies. Existing infrastructure is operational. Upgrades may or may not be required depending on vehicle requirements.
Wallops Flight Facility	Wallops Island, Virginia	NASA	Launch pads, blockhouses and processing facilities.	Wallops Flight Facility has not supported any orbital flights since the failure of Conestoga in 1995. NASA is committed to maintain the existing infrastructure.
White Sands Missile Range	White Sands, New Mexico	US Army	Telemetry and tracking facilities, 4.5 km runway. Engine and propulsion testing facilities.	NASA Flight test center is operational. RLV-specific upgrades will probably be required.
Proposed Spaceports				
Montana Spaceport	Great Falls, Montana	Montana Space Development Authority	No infrastructure at this time.	Montana Spaceport is primarily seeking RLV business. The Montana Space Development Authority is in the process of obtaining a commercial spaceport license for the Great Falls site.
Nevada Test Site	Nye County, Nevada	Department of Energy/Nevada Test Site Development Corporation (NTSDC)	No launch infrastructure at this time. Power and basic facilities available.	NTSDC has issued a sub-permit allowing Kistler to operate a launch and recovery operation. NTSDC is actively promoting the site as a spaceport for both RLVs and conventional launchers.
Southwest Regional Spaceport	White Sands, New Mexico	New Mexico Office of Space Commercialization	No infrastructure at this time.	Plans for this site include a Spaceport central control facility, an airfield, a maintenance and integration facility, a launch and recovery complex, a flight operation control center, and a cryogenic plant.
Texas Spaceport	TBD	State of Texas Spaceport Authority	No infrastructure at this time.	The final Texas Spaceport site(s) has not been selected yet.
Utah Spaceport	Wah Wah Valley, Utah	Utah Spaceport Corporation	No infrastructure at this time.	Plans for the proposed Utah Spaceport include a central administrative control facility, an airfield, a maintenance and integration facility for both payloads and craft, launch pads, a flight operation control center, and a propellant storage facility.
Woomera Rocket Range	Woomera, Australia	Woomera Rocket Range/Kistler Woomera	Outdated launch site infrastructure, assembly building, and tracking facility.	Kistler is starting work on new facilities in January of 2000. The Australian government has passed congressional acts to attract aerospace business to the Woomera area.
Mojave Civilian Test Flight Center	Mojave, California	Mojave Airport Authority	Air control tower, runway, rotor test stand, engineering facilities, high bay building.	The infrastructure in place is part of a $5.5 million project.

Acronyms

AADC – Alaska Aerospace Development Corp.
ACRV – Assured Crew Return Vehicle
AFB – Air Force Base
AFRL – Air Force Research Laboratory
AFSPC – United States Air Force Space Command
ALFLEX – Automatic Landing Flight Experiment
AST – Associate Administrator for Commercial Space Transportation (FAA)
ATV – Atmospheric Test Vehicle (Roton); Advanced Technology Vehicle (NASA)
AVATAR –Aerobic Vehicle for Advanced Trans–Atmospheric Research
BMDO – Ballistic Missile Defense Organization
BSL – Bristol Spaceplanes Limited
CATS – Cheap Access to Space
CCAS – Cape Canaveral Air Station
CRV – Crew Return Vehicle
CTV – Crew Transfer Vehicle
DLR – Deutschen Zentrum für Luft– und Raumfahrt (German National Aerospace Research Center/German Space Agency)
DOD – Department of Defense
DRDO – Defense Research Development Organization (India)
EELV – Evolved Expendable Launch Vehicle
ELV – Expendable Launch Vehicle
EOS – Earth Observing System
ESA – European Space Agency
EXD – Eclipse Experimental Demonstration
FAA – Federal Aviation Administration
GEO – Geosynchronous Orbit
GTO – Geosynchronous Transfer Orbit
HOPE-X – H-II Orbiting Plane Experimental
HYFLEX – Hypersonic Flight Experiment
ICBM – Intercontinental Ballistic Missile
ICT – Integrated Concept Team
ISS – International Space Station
JSC – Johnson Space Center
KLC – Kodiak Launch Complex
KSC – Kennedy Space Center
KST – Kelly Space and Technology
LACE – Liquefied Air Cycle Engines
LC – Launch Complex
LEO – Low Earth Orbit
LLC – Limited Liability Corporation
LOX – Liquid Oxygen
LP – Launch Pad
MEO – Medium Earth Orbit
MSFC – Marshall Space Flight Center
NASA – National Aeronautics and Space Administration
NASDA – National Space Development Agency of Japan
NTS – Nevada Test Site
NTSDC – Nevada Test Site Development Corp.
PTV – Propulsion Test Vehicle (Roton)
RFP – Request For Proposal
RLV – Reusable Launch Vehicle
SCS – Space Cruiser System
SFA – Spaceport Florida Authority
SLC – Space Launch Complex
SMV – Space Maneuver Vehicle
SRS – Southwest Regional Spaceport
SSI – Spaceport Systems International
SSPP – (RLV) System Safety Program Plan
SSTO – Single-Stage-to-Orbit
TBA –To Be Announced
TSTO – Two-Stage-to-Orbit
UK – United Kingdom
USAF – United States Air Force
VAFB – Vandenberg Air Force Base
VCSFA – Virginia Commercial Space Flight Authority
VSFC – Virginia Space Flight Center
WFF – Wallops Flight Facility
X-vehicle – Experimental Vehicle

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