Chapter 9

U.S. SPACE LAUNCH SYSTEMS

Space systems can be divided into two categories: the launch vehicle and the payload. The launch vehicle, commonly called the booster, propels the spacecraft and its associated payload into space. Typically for military missions, a specific payload is always flown on a specific booster. For example, the Global Positioning System (GPS) satellites are always launched on a Delta II launch vehicle. The same is true for most of our military payloads.

US SPACE LAUNCH SYSTEM DEVELOPMENT

Legacy Boosters

Delta

Delta rockets are a family of medium lift class vehicles by which a variety of satellites have been launched as part of U.S. and international space programs. It was originally designed as an interim launch vehicle consisting of a Thor Intermediate Range Ballistic Missile (IRBM) first stage and Vanguard second and third stages. Continued improvements allow the Delta to inject *over* 4,000 pounds into a geosynchronous transfer orbit (GTO).

The National Aeronautics and Space Administration (NASA) placed the original contract with the Douglas Aircraft Company in April 1959. The early three-stage vehicle had a length of 85.4 feet, a first stage diameter of eight feet and a lift-off weight of 113,500 pounds. The modified Thor first stage had a thrust of about 170,000 pounds. On 13 May 1960, the first Delta failed to achieve orbit, but subsequent vehicles proved to be highly reliable.

Built by McDonnell Douglas (which merged with Boeing in August 1997), The Delta II entered the Air Force inventory in February 1988. The vehicle was developed after the Air Force decided to return to a mixed fleet of expendable launch vehicles following the Challenger disaster and other launch failures.

The first Delta II was successfully launched on 14 February 1989. The Delta II 6925 carried nine GPS satellites into orbit. The Delta II model 7925, the current version of this venerable launch vehicle, boosted the remainder of the original GPS constellation and is currently used to launch the new Block 2R version of GPS.

The Delta II's first stage is 12 feet longer than previous Deltas, bringing the total vehicle height to 130.6 feet. The payload fairing (shroud covering the third stage and the satellite) was widened from eight to 9.5 feet to hold the GPS satellite. The nine solid-rocket motors (SRM) that ring the first stage contain a more powerful propellant mixture than previously used.

Delta 7925 began boosting GPS satellites in November 1990. The Delta 7925 added new solid rocket motors with cases made of a composite material called graphite-epoxy. The motor cases built by Hercules Aerospace are lighter, but as strong as the steel cases they replaced. The new motors are six feet longer and provide much greater thrust. The main-engine nozzle on the first stage was also enlarged to give a greater expansion ratio for improved performance.

The Delta program has had a history of successful domestic/foreign military and commercial launches. The Delta has accomplished many firsts over its lifetime: it was the first vehicle to launch an international satellite (Telstar I in 1962); the first geosynchronous orbiting satellite (Syncom II in 1963) and the first commercial communication satellite (COMSAT I in 1965).

Atlas

The Atlas (**Fig. 9-1**) was produced in the 1950s as the first U.S. intercontinental ballistic missile to counter the threat posed by the Soviet development of large ballistic missiles. An Atlas booster carried U.S. astronaut John Glenn into orbit under the first U.S. manned program, Project Mercury.

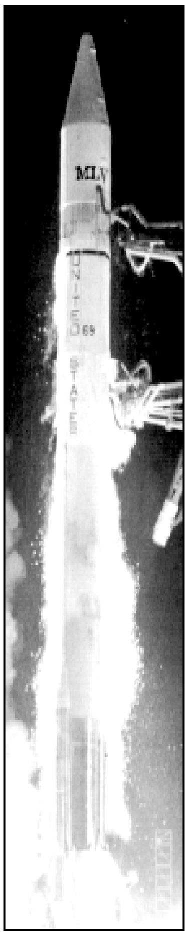


Fig. 9-1. ATLAS I

Its design profited from the thermonuclear break-through of 1954, which led to warheads of lighter weight. Atlas rockets also played a prominent role in the U.S. space program. The Atlas ICBM stood 82.5 feet high and had a diameter of 10 feet. The lift-off weight was about 266,000 pounds, with a range exceeding 9,000 miles.

Attached to the base of the Atlas structure was a gimbal-mounted Rocket-dyne LR-105 engine of 57,000 lb thrust, which operated together with two 1,000 lb thrust swiveling motors used for roll control.

Two Rocketdyne LR-89 boost engines burned at takeoff with the central sustainer. Each of these 165,000 lb-thrust engines operated for about 145 seconds before separating (half-stage). The central Atlas engine continued to burn for a total of about 270 seconds. All the engines drew their liquid oxygen-kerosene (RP-1) propellants from common tanks in the sustainer. Guidance depended on an inertial system that deflected the main engines in conjunction with the two roll jets.

The first Atlas launches were at Cape Canaveral in 1957, but only the third launch on 2 August 1958 was a complete success, traveling about 2,500 miles downrange. The operational Atlas D was flight-tested from the Pacific Test Range in California, between April and August of 1959. Improved versions, Atlas E and F, were test launched in 1960 and 1961, respectively. Some operational missiles were contained in coffin-like shelters (Atlas E) from which they were raised to a vertical position for launch. The increasing vulnerability of launch sites to Soviet ICBMs led to the construction of an underground silo in which the Atlas F was fueled, serviced and elevated to the surface for launching.

In its role as a space launch vehicle, systems are modified for specific space missions. Current Atlas II boosters, provide a medium lift capability for the Fleet Satellite Communications Systems (FLTSATCOM) and the Defense Satellite Communications System (DSCS). The booster generates approximately 340,000 pounds of thrust at liftoff and can place payloads of up to 1,750 pounds into polar orbit. Atlas space launch vehicles were used in all three unmanned lunar exploration programs. Atlas Centaur vehicles also launched Mariner and Pioneer planetary probes.

The Atlas booster has been in use for more than 30 years and remains a key part of the U.S. space program. The first space launch on an Atlas E was in 1974 and the last launch of the “E” series was in March 1995. The E series had been used to launch the military’s Defense Meteorological Satellite Program (DMSP) satellites.

In May 1988, the Air Force chose General Dynamics to develop the Atlas II vehicle, primarily to launch DSCS payloads. This series uses an improved Centaur upper stage, the world's first high-energy propellant stage, to increase its payload capability. Atlas II also has lower-cost electronics, an improved flight computer and longer propellant tanks than Atlas I, which was developed for commercial payloads due to the lull of launch activity caused by several launch failures in the late 1980s. It was used throughout the 1990's primarily for commercial comsats.

Atlas II provides higher performance than the earlier Atlas I by using engines with greater thrust and longer fuel tanks for both stages. The total thrust capability of the Atlas II of approximately 490,000 pounds enables the booster to lift payloads of about 6,100 pounds into geo-synchronous orbit.

On 15 December 1993, the first Atlas IIAS was launched. The rocket can carry 8,000 pounds to a geo-synchronous transfer orbit and up to 18,000 pounds to a low earth orbit. The vehicle uses four Castor 4A solid strap-ons, is 156 feet tall and weighs 524,789 pounds at lift off. Only two of the strap-ons are used at launch. The other two are air-starts about one minute after launch. The launch of the Atlas IIAS completes the development of the original Atlas family.

The division of General Dynamics that builds the Atlas was acquired by Martin Marietta in 1994. They, in turn, merged with Lockheed in 1996 to form the Lockheed-Martin conglomerate.

As of mid-1999, the radically new Atlas III was about to make its inaugural flight. Due to numerous delays stemming from a problem with the upper stage motor, The Atlas III was finally launched on 24 May 1999, flawlessly boosting an Eutelsat communications satellite to geosynchronous orbit. The new model use a Russian designed RD-180 engine with two thrust chambers rather than the traditional one sustainer/two booster configuration of the original Atlases. Engines made by Pratt & Whitney under license will be used for US government launches (by US law) but Russian manufactured engines can be used for commercial payloads. A versatile and upgraded version of the Atlas III dubbed the Atlas V is Lockheed Martin’s entry into the US Air Force Evolved Expendable Launch Vehicle (EELV) program (described later).

Titan II

Deployed as an ICBM from 1963 until 1987, the Titan II (**Fig. 9-2**) is not new to the space launch role. In 1965, modified Titan IIs began supporting NASA's manned Gemini and other unmanned space flights. Fifteen of the 50 existing Titan II ICBMs were refurbished and modified to support future launches.

The two-stage Titan II ICBM stood 103 feet tall with a diameter of 10 feet, and a lift-off weight of about 330,000 pounds. Operationally, the single reentry vehicle usually carried a thermonuclear warhead of five to 10 megatons with a top range of 9,300 miles. The Titan II was in service between 1963 and 1987, with 54 operational missiles. The force comprised three wings of 18 missiles each stored in underground silos at Davis-Mothan AFB, Arizona, McConnell AFB, Kansas and Little Rock AFB, Arkansas.

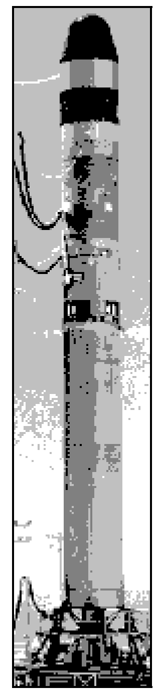


Fig. 9-2. Titan II

Each of the two first-stage Titan II engines develops a thrust of 215,000 pounds. The single second-stage engine develops 100,000 pounds of thrust. Both stages use storable nitrogen tetroxide and aerozine-50 propellants. An inertial system provides guidance commands to the engines. The engines are gimbal-mounted for thrust vector control.

Modified Titan IIs launched Gemini Program astronauts into orbit in 1965 and 1966. Other modified Titans were used to launch Earth satellites and space probes. Heavy payloads were launched by the Titan IIID, which consisted of the two Titan core stages and two strap-on solid propellant boosters. The Titan IIIC consisted of the Titan II central core, a restartable trans-stage with a thrust exceeding 16,000 pounds and two strap-on boosters. The Titan IIIE, which launched two Viking spacecraft to Mars and two

Voyager probes to Jupiter, Saturn, Uranus and Neptune, combined the technology of Titan IIIC with the high-performance Centaur stage. The process of adding larger solid rocket motors (SRMs) to the Titan eventually led to the development of the Titan IV.

Titan IV

Previously known as the Titan 34D-7, Titan IV is the newest and largest expendable booster. The first and second stages of the Titan 34D were stretched and one and one-half segments added to the SRMs. The 16.7-foot-wide payload fairing encloses both the satellite and upper stage. These improvements allow the Titan IV to carry payloads of up to 49,000 lbs to LEO, almost equivalent to the space shuttle's capacity. As the military's heavy lift class booster, it normally launches large payloads weighing up to 12,700 lbs into geo-stationary orbits or up to 38,000 lbs into low earth polar orbits.

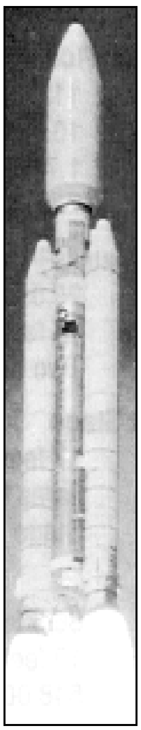


Fig. 9-3. Titan IVB

The flexible vehicle can be launched with one or two optional upper stages for greater and varied carrying capability. In addition, a solid rocket motor upgrade (SRMU) completed testing in 1994 giving the Titan IVB model 25 percent greater lift capability. The first launch using the SRMU occurred successfully in February 1997. The IVB (**Fig. 9-3**) model will the standard U.S. heavy lift vehicle into the next century.

Newer Boosters

Pegasus

Pegasus (**Fig. 9-4**) was developed privately by Orbital Sciences Corporation (OSC). It was first launched into orbit on 5 April 1990 from a B-52 aircraft over the Pacific Ocean.

The triangular-winged rocket is set free at an altitude of 40,000 feet and falls for five seconds. The first stage engine then ignites and flies like a plane during the first-stage burn. It then ascends like a missile in second and third-stage burns.

Pegasus is designed to carry light payloads weighing between 450 and 600 pounds into polar orbit or up to 900 pounds into equatorial orbit. A nominal altitude would be around 280 miles.

The vehicle has three graphite epoxy composite case Hercules motors, a fixed delta platform composite wing and an aft skirt assembly that includes three control fins, an avionics section and a payload faring. A fourth stage can be added to increase payload weight.

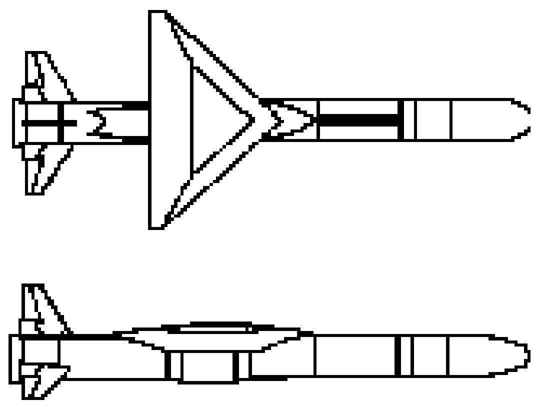


Fig. 9-4. Pegasus

Pegasus weighs about 41,000 pounds at launch. It is 50 feet long and 50 inches in diameter. The XL model uses stretched first and second stages, making it about five feet longer than the standard Pegasus. The first XL launch in July 1994 ended in failure. However, it since has flown successfully over 30 times.

Fig. 9-5. OSC's L-1011 Pegasus Launcher

A new launch platform for the Pegasus was also developed. A modified L-1011 (Fig. 9-5), purchased from Air Canada, debuted in mid-1994.

Taurus

Taurus is being developed by OSC as a four-stage, inertial-guided, solid- propellant launch vehicle. Its configuration is derived from the Pegasus and adds a Peacekeeper (now Castor 120) first stage. The Defense Advanced Research Projects Agency (DARPA) signed a contract with OSC in July 1989 for the initial development of the Taurus.

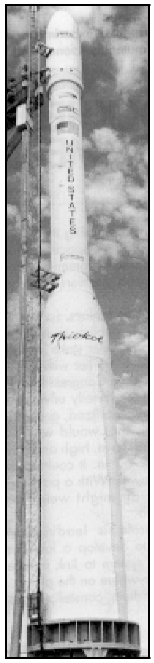


Fig. 9-6. Taurus

The overall length of Taurus is 90 feet and weighs 150,000 pounds at launch. Its maximum diameter (first stage) is 92 inches. The vehicle, shown in **Figure 9-6**, is designed to carry 3,000 pounds into a low polar orbit, up to 3,700 pounds for a due East launch, and up to 950 lbs to geosynchronous transfer orbit .

The first Taurus launch occurred at Vandenberg AFB, California on 13 March 1994. Taurus can be launched from both the Eastern and Western Ranges and has a mobile capability. It is designed to respond rapidly to launch needs and can be ready for launch within eight days. The launch site is a concrete pad with a slim gantry based on its design to be a simple "mobile" launch platform.

Athena I and II

Lockheed announced its new series of expendable launch vehicles in May 1993. First known as the Lockheed Launch Vehicle (LLV) then called the Lockheed-Martin Launch Vehicle (LMLV), this family of rockets are designed to carry light to medium sized payloads to low Earth orbit.

The LMLV has three primary configurations based on the integration of two types of solid rocket motors, Thiokol Corporation's Castor 120 and United Technologies' Orbus 21D.

Fig. 9-7. ATHENA

The smallest of the three rocket versions, Athena 1 (**Fig. 9-7)** can carry a payload of up to 1,750 pounds to LEO. The first launch of this version was from Vandenberg in August 1995 and ended in failure. A launch of NASA's Lewis scientific satellite in 1997 was successful. Launches are also possible from Cape Canaveral.

The Athena II uses Castor 120 booster for both first and second stages and stands 100 feet tall. When additional performance is needed, the rocket can be configured inot the third version by fitting it with Thiokol's Castor-4 solid rocket strap-on boosters

Originally, Lockheed-Martin planned on up to 10 launches/year, but the actual launch rate has been much lower, presumably due to a lower than expected demand for LEO satellite launch services. The advertised launch cost is $14 million, making this booster something of a bargain. The last Athena launch was in 2001 from the Kodiak launch site in Alaska.

Delta III

A new intermediate-class launcher, the Delta III was developed without government support by Boeing Corporation for a commercial Heavy-medium lift payloads. Hughes Aircraft Company (now part of Boeing), a commercial satellite builder, bought ten Delta III launches in 1995 to give Boeing a customer base for the rocket and bring down the cost of launch.

Fig. 9-8. Delta III Launch

Delta III will boost 8,400 pounds to GTO, more than twice what the Delta II can lift. The rocket (**Fig. 9-8**) will have a new cryogenic upper stage and larger fairing.

The first two launches ended in failure. The first was auto-destructed when the vehicle lost control and the second was due to a failure in the second stage. A third attempt, this time a demonstration launch with a dummy payload aboard was successfully launched on 23 August 2000. The Delta III is being phased out in favor of the Delta IV, the Boeing entry into the USAF's EELV competition.

Delta MED-LITE Services Program

Boeing-Orbital Sciences Corporation (OSC) teaming arrangement is providing with NASA for the Medium Light Expendable Launch Vehicle Services program to fill the gap between the small launch vehicle market and the medium-class market. Med-Lite's objective is to support the Mars Surveyor and Discovery programs. Under this program, NASA picked various versions of Boeing's Delta II for 5 to 14 launches of small scientific payloads beginning in 1998.

OSC's Taurus is also included in the MED-LITE program and is launching smaller payloads. A modified Delta II with only three or four strap-ons will handle the heavier payloads in this class.

Evolved Expendable Launch Vehicles

Typical launch costs hover around $10,000 per pound of payload placed in orbit. Recognizing the need for a new, less expensive generation of expendable launchers, the Air Force began its Evolved Expendable Launch Vehicle program in 1995. The goal of the program was to provide more affordable and reliable access to space, saving at least 25 percent and as much as 50 percent over the cost of the "heritage" systems of Delta, Atlas and Titan rockets. In essence, the Air Force is buying launch services, not launch vehicles.

Two competing booster designs emerged from the program, but both will be used rather than allowing a potential single point of failure. Boeing's design is called the Delta IV, and Lockheed Martin's is the Atlas V. With the new standardized launch vehicle families, a single launch pad design, design reliability of 98 percent and completely standardized set up and launch procedures and equipment, the Air Force hopes to realize significant savings over heritage systems. The projected savings through the expected end of the program in 2020 could amount to $5 to 10 billion. The launch services contracted so far cover the period from 2002 to 2006 and a total of 28 launches, with Boeing receiving a contract for 22 launches for $1.7 billion, while Lockheed Martin's contract is for six launches for $500 million. A recent dip in demand for satellite launches, however, is keeping the unit prices on the EELVs higher than originally projected since fewer are being produced.

Delta IV

Boeing's version of the EELV is the Delta IV. Its first launch was on November 20, 2002, when it lofted a European EUTELSAT commercial communications satellite into a geosynchronous transfer orbit. The Delta IV design is based on a modular common booster core (**Fig. 9-9**)-using the liquid hydrogen-liquid oxygen RS-68 engine, which produces 650,000 pounds of thrust. A single common booster core is used for medium lift applications, but can be configured with up to four strap-on solid rocket booster to lift from 9,200 to 14,500 lbs to a geosynchronous transfer orbit (GTO). The Delta IV launches from pad 37 at Cape Canaveral Air Force Station. The booster with its payload fairing stands from 200-225 feet tall. For heavy lift applications, two full-sized common booster cores can be strapped onto a center common booster core to allow up to 29,000 lbs to GTO or 45,200 lbs to LEO.

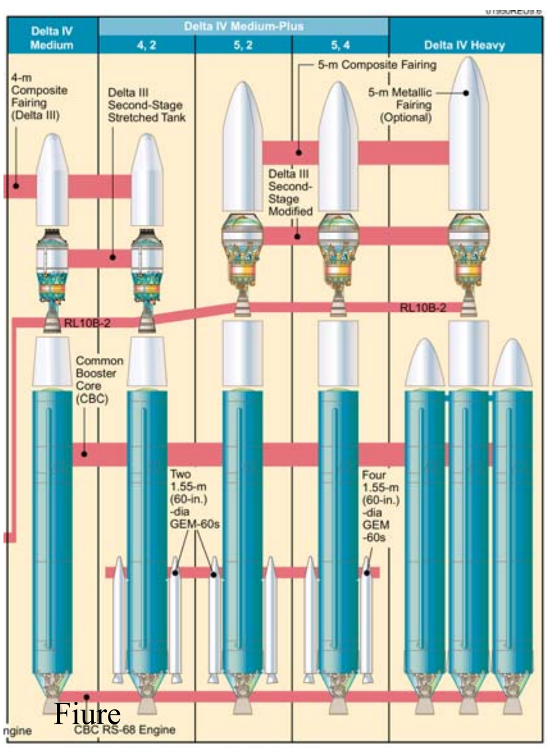


Figure 9-9
Delta IV Configurations

Atlas V

Lockheed Martin's entry into the Air Force's EELV competition is the Atlas V (Fig. 9-10). The decision by the USAF to retain two EELV lines resulted in some launches for the Atlas V but not as many as the Delta IV model. The first Atlas V launch was on August 21, 2002 when it successfully boosted a new European commercial communications satellite into GTO. It will launch medium/heavy to heavy payloads into earth orbit from pad 41 at Cape Canaveral Air Force Station. A planned pad on the west coast is on currently on hold as it may not be immediately needed.

Figure 9-10
Atlas V

Like the Atlas III, the Atlas V core uses the Russian RD-180 engine and will be augmented for heavy payloads with two strap-on boosters. The RD-180 engine is rated at 861,000 lbs of thrust at liftoff. The Atlas V can lift 20,000 lb to LEO or 10,900 lb to GTO. .The booster stands 191 feet tall and is 12.5 feet in diameter.

Manned Boosters

Space Transportation System

The Space Transportation System (STS), also known as the Space Shuttle (**Fig. 9-11**) is a reusable spacecraft designed to be launched into orbit by rockets and then to return to the Earth's surface by gliding down and landing on a runway. The Shuttle was selected in the early 1970s as the principal space launcher and carrier vehicle to be developed by NASA. It was planned as a replacement for the more expensive, expendable booster rockets used since the late 1950s for launching major commercial and governmental satellites. Together with launch facilities, mission control and supporting centers, and a tracking and data relay satellite system, it would complete NASA's new Space Transportation System.

Although the shuttle launched a few military payloads in its early days, such as the Defense Support Program satellite, the USAF abandoned it as a launch vehicle after the Challenger disaster. However, it could conceivably be used for military missions again if the decision were made to do so.

After various delays, the program commenced in the early 1980s. Despite several problems, the craft demonstrated its versatility in a series of missions until the fatal disaster during the launch of the Challenger on January 28, 1986 forced a long delay. The program resumed in late 1988 and the modifications to the shuttle affected neither the basic design of the craft nor its overall dimensions.

The three main components of the Space Shuttle are the orbiter, the external tank and the solid rocket boosters. The Shuttle weighs 4.5 million pounds at launch and stands 184.2 feet tall and can carry up to 55,000 pounds of cargo to LEO on one mission.

The orbiter, 78 feet across the wing tips and 122.2 feet long, is the portion resembling a delta-winged jet fighter. It is a rocket stage during launch, a spaceship in orbit and a hypersonic glider on reentry and landing. A three-deck crew compartment and an attitude thruster module are in the nose, the mid-body is the cargo hold or payload bay (15 ft wide and 60 ft long) and the tail holds the three main engines plus maneuvering engine pods.

Each engine, burning hydrogen and oxygen, produces up to 394,000 pounds of thrust. The external tank, actually an oxygen tank and a hydrogen tank joined by a load-bearing intertank, is the structural backbone of the Shuttle. Measuring 27.56 feet wide and 154.2 feet tall, it carries 1,520,000 pounds of liquefied propellants for the main engines. The shuttle's main engines produce over 27 million horsepower and empties the external tank in about eight and one-half minutes.

Two solid rocket boosters, each slightly over 12 feet wide and 149 feet tall, provide the Shuttle with a lift to the upper atmosphere so the main engines can work more efficiently. Each produces an average thrust of 3.3 million pounds. The propellant in the solid rocket motors consists of ammonium perchlorate, aluminum powder, iron oxide and a binding agent. Total thrust of the vehicle at liftoff (two solid motors and three liquid engines) is 7.78 million pounds.

The Shuttle's main engines are ignited, the booster rockets are ignited about six seconds before lift-off at T-6 seconds and the hold-down bolts are released at T-0. The Shuttle lifts off vertically about 2.5 seconds later with all five engines operating. As soon as it clears the gantry, it rolls and pitches to fly with the orbiter upside down, as the craft's design puts the thrust vector off-center.

At T+2 minutes 12 seconds, the boosters burn out and are jettisoned from the external tank at an altitude of approximately 26-27 statute miles. The boosters then parachute into the sea for recovery, refurbishing and reuse. Meanwhile, the Shuttle continues on under the power of the main engines. Just short of orbital velocity, the engines are shut down (T+8 min 32 sec) and the tank is jettisoned (T+8 min 50 sec). The tank burns up as it reenters the atmosphere.

Once the vehicle is in space, it maneuvers using two different systems, the Orbital Maneuvering System (OMS) and the Reaction Control System (RSC). The orbiter's own OMS engines act as the third stage that puts the craft into orbit.

The OMS uses two bipropellant, 6,000 pound thrust rocket engines mounted in pods on the aft end of the orbiter fuselage. The hypergolic propellants consist of monomethylhydrazine and nitrogen tetroxide, with about 21,600 pounds of propellant stored within the orbiter in titanium tanks. The OMS is used for orbit insertion or transfer, orbit circulation, rendezvous and deorbit.

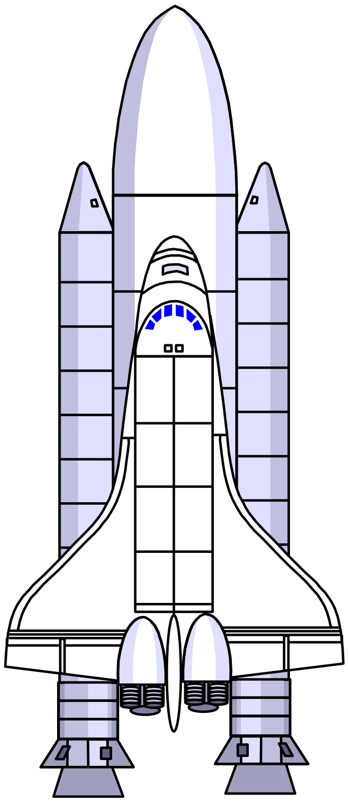


Fig. 9-11. Space Transportation System (STS)

The RCS uses 38 bi-propellant liquid rocket engines and six bipropellant liquid rocket vernier thrusters. Fourteen of the engines are on the orbiter's nose, together with two verniers. The remaining engines and verniers are split equally between the two OMS pods of the aft end of the orbiter fuselage. The RCS used the same type propellants as the OMS, but carries 2,413 pounds of fuel in separate tanks. There is a system to transfer fuel to and from the RCS to the OMS. The RCS is used to maneuver in space during rendezvous and deorbit maneuvers.

The vehicle is normally manned by a crew of four (minimum two, maximum eight except as noted): the commander, pilot, mission specialist and payload specialist. In an emergency ten people can fit in the orbiter. The interior of the orbiter is pressurized, allowing the astronauts to operate in a short-sleeve environment without spacesuits. Passengers can fly on the shuttle without extensive astronaut training because of the relatively light 3G acceleration during launch and the pressurized cabin. The self-contained crew module is supported within the fuselage by four attachment points, the entire module being welded to create the pressure tight vessel. The module has a fuselage side hatch for access, a hatch into the airlock from the mid-section and a hatch from the airlock into the payload bay. As previously mentioned, the crew module is divided into three levels. The upper flight deck has seats for the mission and payload specialists, the commander, and the pilot. There are dual flight controls and the controls for the Remote Manipulator System (RMS) which extracts payloads from the Shuttle's cargo bay. The mid-level deck has additional seating, a galley, electronics bays and crew sleeping and comfort facilities. The lowest level houses environmental equipment and storage.

At the end of the orbital mission, the orbiter is protected from the heat of reentry by heat-resistant ceramic tiles. As dynamic pressure from the air increases, control of the vehicle switches from the RCS to aerodynamic surfaces and the orbiter glides to a landing.

Proposed Boosters

Operationally Responsive Spacelift Initiative

The Air Force began the Operationally Responsive Spacelift initiative in 2003. The goal of the program is to pave the way for reusable rockets that could be launched at a low cost on short notice. As part of a one year analysis of alternatives study which began March 1, 2003, teams are investigating a variety of space planes, air-launched boosters, and fully reusable as well as expendable or partly-reusable spacelifters. The study is closely linked to NASA's Next Generation Launch Technology program, the follow-on to their recently scaled-back Space Launch Initiative. A multi-staged system could be in place by 2014, depending on funding. Also, a low-cost expendable upper stage booster and an orbital transfer vehicle capable of handling spacecraft servicing would be developed. The goal is to have a system that can launch within hours to days as opposed the weeks to months of preparation required by current boosters. Payloads could include the Common Aero Vehicle (CAV, an reentry vehicle which can deliver a variety of munitions to a ground target) or microsatellites.

Scorpius-Sprite

One possible contender for an Operationally Responsive Spacelift job is Micorcosm's Sprite Mini-Lift Launch vehicle **(Fig 9-12)**. Research for the ongoing Scorpius-Sprite program is funded by the Air Force and the Missile Defense Agency, and NASA as well as Microcosm's own research and development funds.

Scorpius, the sub-orbital research vehicle, has already flown and will be scaled up to become the fully orbital Sprite. The Sprite will be
53 feet tall and consist of six 42-inch diameter pods around a central core giving it an an overall diameter of 11.2 feet. It will be a three stage launcher with six 20,000 lb thrust engines followed by a second stage single 20,000 lb engine. The third stage will produce 2,500 lbs of thrust and place a 700 lb payload in a 100 NM low Earth orbit for $1.8 million. A primary goal is to simplify launch operations so that liftoff occurs only 8 hours after the vehicle is brought to the pad.

Figure 9-12
Sprite

RASCAL

The Responsive Access, Small Cargo, Affordable Launch (RASCAL) program will design and develop a low cost orbital insertion capability for dedicated micro-size satellite payloads. The concept is to develop a responsive, routine, small payload delivery system capable of providing flexible access to space using a combination of reusable and low cost expendable vehicle elements.

Specifically, the RASCAL system will be comprised of a reusable airplane-like first stage vehicle called the reusable launch vehicle and a second stage expendable rocket vehicle. The RASCAL demonstration objectives are to place satellites and commodity payloads, between 110 and 280 lbs (50 and 130 kilograms) in weight, into low earth orbit at any time, any inclination with launch efficiency of $9,100 per pound ($20,000 per kilogram) or less. While the cost goal is commensurate with current large payload launch systems, the operational system, through production economies of scale, will be more than a factor of three less than current capabilities for the dedicated micro payload size. This capability will enable cost effective use of on-orbit replacement and re-supply and provide a means for rapid launch of orbital assets for changing national security needs.

With recent advances in design tools and simulations, this program will prudently reduce design margins and trade-off system reliability to maximize cost effectiveness. This program will also leverage advancements in autonomous range safety, first-stage guidance and predictive vehicle health diagnosis, management and reporting to lower the recurring costs of space launch.

FALCON

The FALCON program objectives are to develop and demonstrate technologies that will enable both near-term and far-term capability to execute time-critical, global reach missions. Near-term capability will be accomplished via development of a rocket boosted, expendable munitions delivery system that delivers its payload to the target by executing unpowered boost-glide maneuvers at hypersonic speed. This concept called the Common Aero Vehicle (CAV) would be capable of delivering up to 1,000 pounds of munitions to a target 3,000 nautical miles downrange. An Operational Responsive Spacelift (ORS) booster vehicle will place CAV at the required altitude and velocity. The FALCON program will develop a low cost rocket booster to meet these requirements and demonstrate this capability in a series of flight tests culminating with the launch of an operable CAV-like payload. Far-term capability is envisioned to entail a reusable, hypersonic aircraft capable of delivering 12,000 pounds of payload to a target 9,000 nautical miles from CONUS in less than two hours. Many of the technologies required by CAV are also applicable to this vision vehicle concept such as high lift-to-drag technologies, high temperature materials, thermal protection systems, and periodic guidance, navigation, and control. Initiated under the Space Vehicle Technologies program, and leveraging technology developed under the Hypersonics program, FALCON will build on these technologies to address the implications of powered hypersonic flight and reusability required to enable this far-term capability. The FALCON program addresses many high priority mission areas and applications such as global presence, space control, and space lift.

CURRENT LAUNCH SYSTEM CHARACTERISTICS

Table 9-1. Delta II

Delta II

The Delta II is a two- or three-stage booster. Stages one and two use liquid propellant while stage three uses solid propellant. The booster is configured with nine solid rocket strap-ons surrounding the first stage. The current 7925 model uses lighter and longer strap-ons for increased impulse and greater payload capacity.

- **Delta II 7925**

Stage	Thrust (lbs)	Length (ft)
I	236,984	85.4
II (7925)	9,645	9.3
III (7925)	5,098	6.7

Total Length: 121 feet
Diameter: 8 ft
Fairing Diameters: 8, 9.5 or 10 ft
Payload: 4,120 lbs to GTO
6,985 lbs to polar
11,330 lbs to LEO

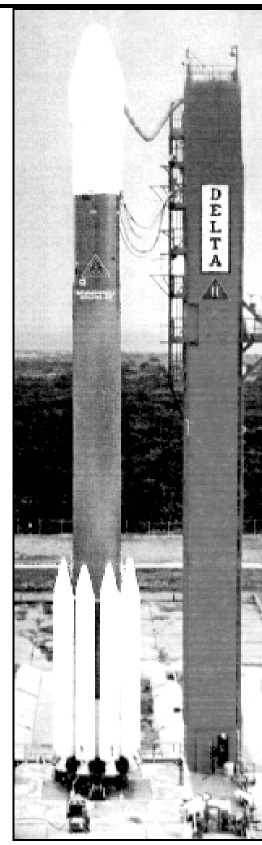
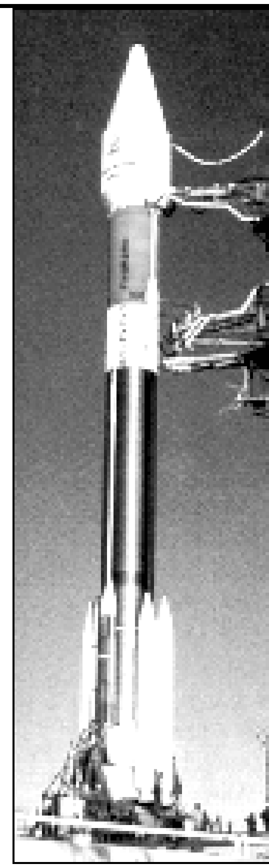


Table 9-2. Atlas II, IIAS, III

Atlas II, IIAS



The Atlas is a stage and one-half liquid propellant booster. It has continually been upgraded since its original late-1950's design as the nation's first ICBM. The Atlas is a medium/heavy lift booster used extensively by the commercial market and for USAF payloads such as the DSCS III satellites.

- **Atlas II**

Engine:	Thrust (lbs)
Booster:	206,950 each (2)
Sustainer:	60,474
Length:	149.6 ft
Diameter:	10 ft
Payload:	14,916 to LEO
	6,094 to GTO

- **Atlas IIAS**

Engine:	Thrust (lbs)
Booster:	207,110 each (2)
Sustainer:	60,525
Strap-ons:	97,500 each (4)
Length:	156 ft
Diameter:	10 ft
Payload:	18,000 to LEO
	8,000 to GTO

- **Atlas III**

Engine:	861,075 lbs thrust
Length:	173.2 ft
Diameter:	10 ft
Payload:	19,050 lb to LEO
	8,940 lb to GTO

Table 9-3. Titan II SLV

Titan II SLV

The Titan II SLV is a former ICBM modified to launch space payloads. Changes to the ICBM include payload interface modifications and the addition of an attitude control system. It is very capable of putting medium/heavy payloads into low earth orbit. It is primarily used by the USAF for launching DMSP satellites into low earth, sun synchronous orbits.

Stage	Thrust (lbs)	Length(ft)
I	430,000	70
II	100,040	40
Payload fairing:	N/A	20 - 25

Diameter: 10 ft
Payload: 6985 to LEO
2300 to GTO

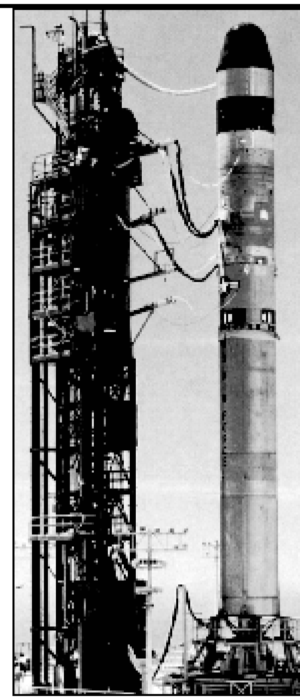


Table 9-4. Titan IVB

Titan IVB

The Titan IV is designed to place heavy payloads into orbit using the Centaur-G or Inertial Upper Stage (IUS) upper stage.

Stage	Thrust (lbs)	Length (ft)
I	551,200	86.5
II	106,150	32.6
SRM	1,600,000 ea. (2)	112.9
SRMU	1,700,000 ea. (2)	112.4
Payload fairing:	N/A	up to 84.0

- Diameter: 10 ft (payload - 16.7 ft)

Payload to GEO: 12,700 lbs

Payload to Polar: 38,000 lbs

Payload to LEO: 49,000 lbs

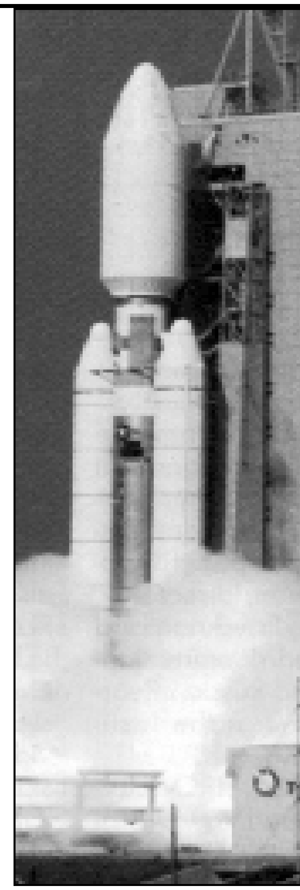


Table 9-5. STS

Space Shuttle

The Space Shuttle is the only US manned space vehicle.

	Thrust (lbs)
SRB's (ea)	3,300,000 lbs.
Orbiter (3ea)	393,800 lbs.

Orbiter Dimensions:

Length: 122ft
Wingspan: 78ft.

Payload to GEO (lbs.):

46-55,000 lbs. (28^{o} incl)
32,500-40,900 lbs. (57^{o} incl)

Table 9-6. Pegasus

Pegasus

The only air-launched space vehicle in the world. Primarily launches small experimental/scientific payload to LEO from 1B L-1011 carrier aircraft.

Pegasus XL:

Length: 55.18 ft.

Payload:

440 lbs. To GTO (w/fourth stage)
600 lbs. To 287 mi. polar
900 lbs. To 287 mi equatorial

Table 9-7. Delta IV

Background Information

First Launch: October 9, 2002

Launch Site: CCAFS, Space Launch Complex-37

Capability: Up to 45,200 lb to LEO; 29,100 lb to GTO

History: Delta IV developed as part of the USAF Evolved Expendable Launch Vehicle (EELV) program

Description·Five variants built around the Common Booster Core (CBC)

- Stage 1: The CBC sub-assembly includes and interstage, liquid oxygen tank, liquid hydrogen tank, engine section, and nose cones for the Delta IV-H. The three Delta IV-M+ configurations use either two or four Alliant graphite-epoxy motors attached to the CBC. Delta IV-H uses two additional CBCs as strap-on liquid rocket boosters. The CBC is powered by a newly developed Rocketdyne RS-68 engine which has a 21.5:1 expansion ratio and produces 650,000 lbs of thrust at sea level.
- Stage 2: There are two second-stage configurations. A 4-m version used on Delta IV-M and Delta IV-M+(4,2) and a 5-m version used on other Delta IV configurations. The second stage is powered by a Pratt & Whitney RL10B-2 cryogenic engine. The 4-m version produces thrust of 24,750 lbs, the 5-m produces thrust of 60,000 lbs.
- Payload fairings: 4-m and 5-m composite bisector fairings based on the Delta III fairings. 5-m trisector fairing which is a modified version of the Titan IV isogrid fairing.

Table 9-8. Atlas V

Atlas V

Background Information

First Launch: 20 Aug 02
Launch Site: LC-41, CCAFS
Capability:20,000 lb to LEO; 10,900 lb to GTO
Description·Two stage booster.

- Stage 1 utilizes one Russian designed RD-180 booster engine with two chambers burning LOX/RP-1 fed from stage 1 tanks, generating a total of 861,075 lb of thrust at sea level, 933,034 lbs of thrust in vacuum.
- RD-180 engine provides throttling capability (75% - 85% max) and gimbaled chambers for 3-axis control.
- Stage 2 (Centaur) has a one or dual engine version using Pratt & Whitney RL10A-4-2 turbopump-fed engines that burn LH2/LOX and produce 24,750 lb of thrust each.

Profile:

Length:	191.2 ft	Launch Weight:	733,304 lb
Diameter:	12.5 ft	Liftoff Thrust:	860,200 lb
Payload Fairing:		40 ft x 13.8 ft (Large); 43 x 13.8 ft (Extended)	

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