Chapter 20

Space-Lift Systems

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Space-launch systems provide access to space—a key to any activity in space. Historically, access to space was primarily a function of national governments. Today, space launch is primarily a commercial enterprise. Historically, specific payloads flew on specific boosters. For example, global positioning system (GPS) satellites launched from Delta II launch vehicles.[1] Today, various payloads can fly on different boosters. This section describes only US launch vehicles. It describes the current inventory of unmanned boosters and manned systems and concludes with a look at future systems.

Unmanned Boosters

Unmanned systems in the current inventory include the Delta II rocket, evolved expendable launch vehicle (Delta IV and Atlas V), Pegasus, Minotaur, Taurus, and the Falcon launch vehicle.

Delta II

The Delta II rocket (fig. 20-1) is part of a family of medium-lift-class vehicles from which a variety of satellites has been launched as part of US and international space programs. It launches from Space Launch Complexes (SLC) 17A and 17B at Cape Canaveral AFS, Florida, and from SLC-2 at Vandenberg AFB, California. The original Delta launch vehicle consisted of a Thor intermediate range ballistic missile (IRBM) first stage and Vanguard second and third stages.[2] Continued improvements allow the Delta II to inject over 4,000 pounds into a geosynchronous transfer orbit (GTO).[3]

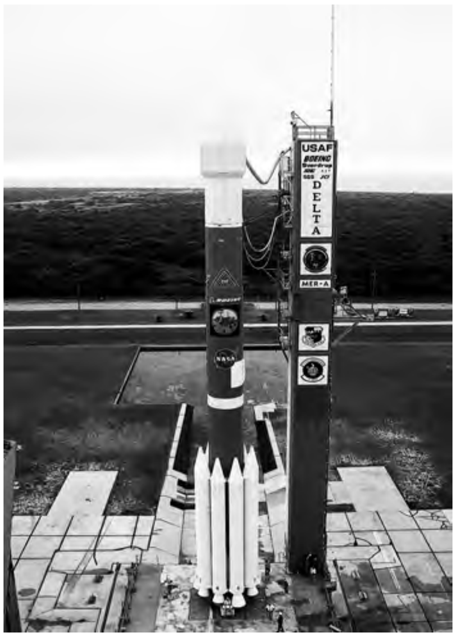

Figure 20-1. Delta II launch. (NASA photo)

The National Aeronautics and Space Administration (NASA) placed the original contract with Douglas Aircraft Company in April 1959.[4] The early three-stage vehicle had a length of 85.4 feet, a first-stage diameter of eight feet, and a liftoff weight of 113,500 pounds.[5] 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.[6]

In 1987, the Air Force entered into a contract with McDonnell Douglas (which merged with Boeing in August 1997) to build the first 18 Delta II rockets.[7] 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 successfully launched on 14 February 1989.[8] The Delta II 6925 carried nine GPS satellites into orbit. The Delta II 7925, the current version of this venerable launch vehicle, boosted the remainder of the original GPS constellation into orbit. It continues service in launching the current Block IIR 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.[9] The payload fairing (shroud covering the third stage and the satellite) was widened from eight to 9.5 feet to hold the GPS satellite.[10] The solid-rocket motors (3, 4, or 9, depending on the configuration) that ring the first stage contain a more powerful propellant mixture than previously used.

Delta 7925 began boosting GPS satellites in November 1990.[11] 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 than the steel cases they replaced, but just as strong. 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.[12]

The Delta program has 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).[13]

The major elements of today's Delta II launch vehicle are the first stage, with its graphite-epoxy motor (GEM) solid strap-on rocket motors, the second stage, an optional third stage with spin table, and the payload fairing. The Delta II launch-vehicle series are the 7300, 7400, and 7900. The Delta II also has a "heavy" configuration that employs larger-diameter GEM-46 solid strap-on rocket motors on the 7900-series vehicle to increase the performance capability. The payload lift capabilities are listed in table 20-1.

Table 20-1. Delta II family

	732X-10	*742X-10*	*792X-10*	*792XH-10*
GTO	900 kg (1,980 lb.)	1,070 kg (2,370 lb.)	1,750 kg (3,850 lb.)	2,120 kg (4,680 lb.)
LEO	2,450 kg (5,410 lb.)	2,380 kg (6,230 lb.)	4,490 kg (9,910 lb.)	5,430 kg (11,970 lb.)

Adapted from United Launch Alliance, "Delta II," http://www.ulalaunch.com/docs/product_sheet/DeltaIIProductCardFinal.pdf (accessed 28 May 2009).

Evolved Expendable Launch Vehicle

The evolved expendable launch vehicle (EELV) is the Air Force's space-lift modernization program. EELV reduces the cost of launching by at least 25 percent over current

Delta, Atlas, and Titan launch systems.[14] Part of these savings results from the government now procuring commercial launch services and turning over responsibility for operations and maintenance of the launch complexes to the contractors. This new space-lift strategy reduced the government's traditional involvement in launch processing while saving a projected $6 billion in launch costs between the years 2002 and 2020. In addition, EELV improves space-launch operability and standardization.

The two primary launch contractors are Boeing (Delta IV) and Lockheed Martin (Atlas V). However, in May 2005 Lockheed Martin and Boeing announced their plans to form a joint venture called United Launch Alliance (ULA), which officially began operations in December 2006. ULA provides reliable and cost-efficient Delta and Atlas launch services solely in support of US government launch requirements.

Delta IV. Boeing's version of the EELV is the Delta IV family of boosters (fig. 20-2), consisting of five vehicle configurations: the Delta IV Medium (Delta IV M), three variants of Delta IV Medium-Plus (Delta IV M+), and the Delta IV Heavy (Delta IV H). Its first launch was in November 2002, when it lofted a European Telecommunications Satellite Organization (EUTELSAT) commercial communications satellite into a geosynchronous transfer orbit.[15] The Delta IV design is based on a modular common booster core using the liquid hydrogen–liquid oxygen RS-68 engine, which produces over 660,000 pounds of thrust.[16] A single common booster core is used for medium-lift applications, but the Delta IV can be configured with up to four strap-on solid-rocket boosters to lift from 9,200 to 14,500 pounds to a GTO.[17] The Delta IV launches from SLC-37 at Cape Canaveral AFS and from SLC-6 at Vandenberg AFB. The booster with its payload fairing stands from 200 to 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 pounds to GTO or 45,200 pounds to LEO.[18] Detailed Delta IV launch payload capabilities are listed in table 20-2.

Figure 20-2. Delta IV launch. (USAF photo)

Atlas V. Lockheed Martin's entry into the Air Force's EELV competition is the Atlas V (fig. 20-3). The Atlas V comes from a family of launch vehicles

Table 20-2. Delta IV family

	Delta IV M	*Delta IV M+ (4, 2)*	*Delta IV M+ (5, 4)*	*Delta IV H*
GTO	4,300 kg (9,840 lb.)	6,030 kg (13,290 lb.)	7,020 kg (15,470 lb.)	12,980 kg (28,620 lb.)
LEO	9,150 kg (20,170 lb.)	12,240 kg (26,980 lb.)	13,360 kg (29,450 lb.)	22,560 kg (49,740 lb.)

Adapted from United Launch Alliance, "Delta IV," http://www.ulalaunch.com/docs/product_sheet/DeltaIVProductCardFinal.pdf (accessed 28 May 2009).

Figure 20-3. Atlas V. (USAF photo)

that made its debut in 1957 as America's first operational intercontinental ballistic missile (ICBM). The Atlas, Atlas II, and Atlas III launch vehicles have logged nearly 600 launches for US government and commercial missions. The decision by the Air Force 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 from SLC-41 at Cape Canaveral AFS was in August 2002, when it successfully boosted a new European commercial communications satellite into GTO.[19] Its first successful West Coast launch occurred in March 2008 from SLC-3E at Vandenberg AFB.

Like the Atlas III, the Atlas V 400 and 500 series share a core that uses Russian RD-180 engines and is augmented for heavy payloads with two strap-on boosters.[20] The RD-180 engine can produce 861,000 pounds of thrust at liftoff.[21] It also uses the common core booster with up to five strap-on solid-rocket boosters. The common core booster is 12.5 feet in diameter by 106.6 feet long and uses 627,105 pounds of liquid oxygen and RP-1 rocket fuel propellants.

Additionally, on Atlas V, Lockheed Martin introduced a 4.57-meter usable diameter Contraves payload fairing in addition to retaining the option to use the heritage Atlas payload fairings. The Contraves fairing is a composite design based on flight-proven hardware. Three configurations will be manufactured to support Atlas V. The short- and medium-length configurations are used on the Atlas V 500 series.

The Centaur upper stage uses a pressure-stabilized propellant tank design and cryogenic propellants. The Centaur stage for Atlas V is stretched 5.5 feet and is powered by either one or two Pratt & Whitney RL10A-4-2 engines, with each engine developing a thrust of 22,300 pounds. Operational and reliability upgrades are enabled with the RL10A-4-2 engine configuration. The inertial navigation unit located on the Centaur provides guidance and navigation for both the Atlas and Centaur and controls both Atlas and Centaur tank pressures and propellant use. The Centaur engines are capable of multiple in-space starts, making possible insertion into low Earth parking orbit, followed by a coast period and then insertion into GTO.

The Atlas V can lift 20,000 pounds to LEO or 10,900 pounds to GTO.[22] The booster stands 191 feet tall and is 12.5 feet in diameter.[23] Detailed payload lift capabilities are listed in table 20-3.

Pegasus. Orbital Sciences Corporation developed Pegasus (fig. 20-4) privately. Its first launch into orbit occurred on 5 April 1990 from a B-52 aircraft over the Pacific Ocean.[24]

The triangular-winged rocket is set free at an altitude of 40,000 feet and falls for five seconds.[25] 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.[26] A nominal altitude would be around 280

Table 20-3. Atlas V family

	401	*431*	*551*	*Heavy*
GTO	4,950 kg (10,900 lb.)	7,800 kg (17,190 lb.)	8,700 kg (19,180 lb.)	13,000 kg (28,660 lb.)
LEO	9,750 kg (21,490 lb.)	13,620 kg (30,020 lb.)	18,500 kg (40,780 lb.)	29,420 kg (64,860 lb.)

Adapted from United Launch Alliance, "Atlas V," http://www.ulalaunch.com/docs/product_sheet/AtlasProductCardFinal.pdf (accessed 28 May 2009).

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.

Pegasus weighs about 41,000 pounds at launch and is 50 feet long and 50 inches in diameter.[27] 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.[28] However, it since has flown successfully over 30 times launching more than 70 satellites.[29]

A new launch platform for the Pegasus was also developed. A modified L-1011 (fig. 20-5), purchased from Air Canada, debuted in mid-1994.[30]

Figure 20-4. Pegasus launch vehicle. (NASA photo)

Figure 20-5. Orbital Sciences Corporation L-1011 Pegasus launcher. (NASA photo)

Figure 20-6. Minotaur I launch. (NASA photo)

Minotaur. The Minotaur program was developed for the Air Force's Orbital/Suborbital Program (OSP) as a low-cost, four-stage space-launch vehicle (SLV). The Minotaur I SLV uses a combination of government-supplied surplus Minuteman II ICBM motors and proven Orbital space-launch technologies (fig. 20-6). The OSP has since expanded to include Minotaur IV and Minotaur V versions utilizing surplus Peacekeeper motor stages.

The Minuteman motors served as the first and second stages of the Minotaur I. Its third and fourth stages, structures, and payload fairing were taken directly from Orbital's existing Pegasus XL rocket. The addition of improved avionics systems, including modular avionics control hardware (MACH), already used on many of Orbital's suborbital launch vehicles, further enhanced the Minotaur I's capabilities.

Minotaur I made its inaugural flight in January 2000, successfully delivering a number of small military and university satellites into orbit and marking the first use of surplus Minuteman boosters in a space launch. Several derivatives of Minotaur were developed or proposed, but only four are in use today:

1. Minotaur I SLV (the original Minotaur) consists of an M55A1 first stage, SR19 second stage, Orion 50XL third stage, Orion 38 fourth stage, and optional hydrazine auxiliary propulsion system (HAPS) fifth stage for velocity trim and multiple payload deployment. The Minotaur I has the capability to launch a 580 kg payload to low Earth orbit (LEO).
2. Minotaur IV SLV uses surplus Peacekeeper motors for its first three stages. It consists of an SR118 first stage, an SR119 second stage, an SR120 third stage, an Orion 38 fourth stage, and an optional HAPS fifth stage. The Minotaur IV SLV has the capability to launch a 1,750 kg payload into LEO.
3. Minotaur IV+ SLV uses the same configuration as the standard Minotaur IV except it replaces the Orion 38 fourth stage with a Star 48V motor for additional performance.
4. Minotaur V uses the same configuration as the Minotaur IV+ with the addition of either a Star 37FM or FMV fifth stage. The Minotaur V can be used for placing small spacecraft on high-energy trajectories, such as GTO, highly elliptical orbit (HEO), and lunar.

Minotaur SLV launches can occur from the California Spaceport (SLC-8) on Vandenberg AFB, from Pad 0B at the Virginia Spaceflight Center on Wallops Island, from the Kodiak Launch Complex in Alaska, and from Spaceport Florida on Cape Canaveral AFS. To date, seven successful Minotaur launches (Minotaur I) have taken place. The first five launches took place from SLC-8 and the last two from Pad 0B. The first Minotaur IV launch is scheduled for late 2009 from the Kodiak Launch Complex.

Taurus. The Taurus rocket launches small satellites into LEO (fig. 20-7). Developed under the sponsorship of the Defense Advanced Research Projects Agency (DARPA), Taurus was designed for easy transportability and rapid setup and launch. Since its debut flight in 1994, Taurus has conducted seven of eight successful missions, launching 12 satellites for commercial, civil, military, and international customers.[31]

Taurus is a ground-based variant of the air-launched Pegasus rocket and is a four-stage, inertially guided, all-solid-propellant vehicle.[32] Two fairing sizes offer flexibility in designing a particular mission, and with the addition of a structural adapter, either can accommodate multiple payloads, resulting in lower launch costs for smaller satellites “sharing” a mission.[33]

A cornerstone of the Taurus program is a simplified integration and test capability that includes horizontal integration of the rocket’s upper stages and off-line encapsulation of the payload within the fairing. The upper stages and the encapsulated cargo are delivered to the launch site, where they are mated. The whole assembly is then stacked on the first stage using a mobile crane.[34]

The Taurus launch system includes a complete set of ground support equipment to ensure the ability to operate from austere sites. Thus far, Taurus has launched from the US government’s Western Range at Vandenberg AFB, but it is also approved for launch from Cape Canaveral AFS, Wallops Flight Facility in Virginia, and Kodiak Launch Complex, Alaska.[35]

The first Taurus launch occurred at Vandenberg AFB on 13 March 1994.[36] It is designed to respond rapidly to launch needs and can be ready for launch within eight

Figure 20-7. Taurus. (DOD photo)

days. The launch site is a concrete pad with a slim gantry based on its design to be a simple "mobile" launch platform.

The overall length of Taurus is 90 feet, and it weighs 150,000 pounds at launch.[37] Its maximum diameter (first stage) is 92 inches.[38] The vehicle, shown in figure 20-7, 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 pounds to geosynchronous transfer orbit.[39]

Falcon Launch Vehicle. The Falcon family of launch vehicles is the newcomer to the launch industry and is produced by Space Exploration Technologies (SpaceX). SpaceX, established in 2002, set out with the goal of providing a more reliable, simpler, lower-cost, and more responsive option for meeting global launch requirements. Starting in March 2006, SpaceX conducted three launches of the Falcon 1, with the fourth flight completing its first successful operational mission in September 2008. Currently,

Figure 20-8. Falcon 1. (Photo courtesy of SpaceX)

SpaceX produces the Falcon 1 (fig. 20-8) and Falcon 9 series of launch vehicles.

The Falcon 1 launch vehicle is a two-stage rocket that uses liquid oxygen and rocket-grade kerosene (RP-1) as propellant. The first stage is reusable and uses a single Merlin 1C engine producing 94,000 pounds-force (lbf.) of thrust. The second stage uses a single SpaceX Kestrel engine with a multiple restart capability and produces 6,900 lbf. of thrust. The Falcon 1 can launch a 480 kg payload to LEO. In mid-2010, the Falcon 1 will be phased out and replaced by the more capable Falcon 1e.

The Falcon 1e is similar to the Falcon 1 but takes advantage of certain technological and weight-saving advances. The Falcon 1e measures over six meters longer and has a thrust of 128,000 lbf. in vacuum, giving it the capability to launch a 900 kg payload into LEO.

The Falcon 9 is also a two-stage rocket that uses liquid oxygen and RP-1 as propellant (fig. 20-9). The Falcon 9 first stage incorporates nine SpaceX Merlin 1C engines, producing a total of 1.1 million lbf. in vacuum. The second stage is a shorter version of the first stage and uses a single Merlin 1C engine. Depending on the launch site, the Falcon 9 can launch up to 10,450 kg to LEO and over 4,500 kg to GTO.

Figure 20-9. Falcon 9. (Photo courtesy of SpaceX)

The Falcon 9 Heavy is similar to the standard Falcon 9, but it includes two additional Falcon 9 first-stage engines used as strap-on boosters. The Falcon 9 Heavy will produce over 3.3 million lbf. in vacuum and place over 29,600 kg into LEO and over 15,000 kg into GTO.

To date, SpaceX has conducted four Falcon 1 launches, all from the US Army's Kwajalein Atoll. The first Falcon 9 launch is currently scheduled for 2009 from SLC-40 at Cape Canaveral AFS.

Manned Boosters—The Space Transportation System

The Space Transportation System (STS), also known as the space shuttle (fig. 20-10), is a reusable spacecraft designed to be launched into orbit by a rocket and then return to the earth's surface by gliding down and landing on a runway.

Figure 20-10. Space Transportation System. (NASA photo)

The shuttle was selected in the early 1970s as the principal space launcher and carrier vehicle to be developed by NASA.[40] It was planned as a replacement for the more expensive, expendable booster rockets used since the late 1950s for launching major commercial and government 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 several military payloads in its early days, such as the Defense Support Program satellite, the Air Force abandoned it as a primary launch vehicle after the *Challenger* disaster.[41] However, it is capable of military missions again if the decision were made to use it that way.

After numerous delays, the shuttle program started operations in the early 1980s. Despite several problems, the spacecraft demonstrated its versatility in a series of missions until the fatal disaster during the *Challenger* launch on 28 January 1986 forced a long delay.[42] The program resumed in late 1988, and the modifications to the shuttle affected neither the basic design of the craft nor its overall dimensions. Again, disaster struck on 1 February 2003 with the loss of *Columbia* on reentry.[43] After the loss of *Columbia*, it was decided that the STS would fly long enough to complete the International Space Station and then be retired by 2010.

The three main components of the space shuttle are the orbiter, the external fuel tank, and the solid-rocket motors. The shuttle weighs 4.5 million pounds at launch, stands 184.2 feet tall, and can carry up to 63,500 pounds of cargo to LEO on one mission.[44] The orbiter, 78 feet across the wing tips and 122.2 feet long, is the portion resembling a delta-winged jet fighter.[45] 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.[46] 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.[47] The shuttle's main engines produce over 37 million horsepower and empty the external tank in about 8.5 minutes.[48]

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.[49] Each produces an average thrust of 3.3 million pounds.[50] 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.[51]

The shuttle's main engines are ignited first, followed by ignition of the booster rockets about six seconds before liftoff. Then the hold-down bolts release the spacecraft to allow it to fly. 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 24 statute miles.[52] The boosters then parachute into the sea for recovery, refurbishing, and reuse. Meanwhile, the shuttle continues under the power of the main engines. Just short of orbital velocity, the engines shut down (T+8 minutes 32 seconds), and the tank is jettisoned (T+8 minutes 50 seconds).[53] 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 (RCS). 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.[54] The hypergolic propellants consist of monomethylhydrazine and nitrogen tetroxide, with about 21,600 pounds of propellant stored within the orbiter in titanium tanks.[55] The OMS is used for orbit insertion or transfer, orbit circulation, rendezvous, and deorbit.

The RCS uses 38 bipropellant liquid-rocket engines and six bipropellant liquid-rocket vernier thrusters.[56] 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 uses the same type of propellants as the OMS but carries the 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.

A crew of four—commander, pilot, mission specialist, and payload specialist—normally operates the vehicle. A crew must have a minimum of two members and may have a maximum of eight except as noted. In an emergency, 10 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. Four attachment points support the self-contained crew module within the fuselage; the entire module is 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. The upper deck also contains 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.

Future Space Lift

The space shuttle program is at a turning point as it moves toward retirement in 2010. Meanwhile, as a result of the NASA Authorization Act of 2005, the United States is transitioning from a country that sends astronauts to orbit the earth to one that sends humans out into the solar system.

Figure 20-11. Ares vehicle. (NASA photo)

Constellation Program

NASA's Constellation Program is building the next generation of spacecraft for human exploration. The Orion crew exploration vehicle will launch on the Ares I rocket (fig. 20-11). The Ares V will launch cargo. Constellation will return humans to the moon by 2020 to set up a lunar outpost in preparation for journeys to Mars.

Orion will be similar in shape to the Apollo spacecraft, but significantly larger. The Apollo-style heat shield is understood to be the best shape for reentering Earth's atmosphere, especially when returning directly from the moon. Orion will be 16.5 feet in diameter and have a mass of about 25 tons. Inside, it will have more than 2.5 times the volume of an Apollo capsule. The larger size will allow Orion to accommodate four crew members on missions to the moon and six on missions to the International Space Station or Mars. Orion is scheduled to fly its first missions to the space station by 2014 and carry out its first sortie to the moon by 2020.

A launch-abort system atop the Orion capsule will be capable of pulling the spacecraft and its crew to safety in the event of an emergency on the launch pad or any time during ascent. Orion's power and propulsion systems will be housed in a service module that will be mounted directly below the capsule, covering the entry heat shield during launch and in-space activities. A spacecraft adapter will connect the Orion capsule and service module to the launch systems.

Orion will be launched into LEO by the Ares I crew launch vehicle. To maximize the crew's safety, Orion and its abort system will be placed at the top of the Ares I rocket. The rest of the two-stage Ares I will be stacked vertically, below the crew vehicle. This design will virtually eliminate the possibility of debris from the booster striking Orion during ascent.

Orion will be able to remain docked to the space station for up to six months, providing a means for the crew to return to Earth at any time. The spacecraft will have the ability to stay in lunar orbit untended for the duration of a lunar visit that could last up to six months. Orion will be capable of carrying pressurized cargo to the space station on unpiloted missions.

For missions to the moon, NASA will use two separate launch vehicles, each derived from a mixture of systems with their heritage rooted in Apollo, space shuttle, and commercial launch-vehicle technology. An Ares V cargo launch vehicle will precede the launch of the crew vehicle, delivering to LEO the Earth departure stage and the lunar module that will carry explorers on the last leg of the journey to the moon's surface. Orion will dock with the lunar module in Earth orbit, and the Earth departure stage will propel both on their journey to the moon. Once in lunar orbit, all four astronauts will use the lunar landing craft to travel to the moon's surface, while the Orion spacecraft stays in lunar orbit. Once the astronauts' lunar mission is complete, they will return to the orbiting Orion vehicle using a lunar ascent module. The crew will use the service-module main engine to break out of lunar orbit and head to Earth. Orion and its crew will reenter the earth's atmosphere using a newly developed thermal protection system. Parachutes will further slow Orion's descent through the atmosphere.

Operationally Responsive Space-Lift Initiative

The Air Force began the operationally responsive space-lift initiative in 2003.[57] 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 that began 1 March 2003, teams are investigating a variety of space planes, air-launched boosters, and fully reusable, as well as expendable or partly reusable, space lifters.[58] 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 multistaged system could be in place by 2014, depending on funding.[59] Also, a low-cost, expendable, upper-stage booster and an orbital transfer vehicle capable of handling spacecraft servicing are planned for development. The goal is to have a system that can launch within hours to days as opposed to the weeks to months of preparation required by current boosters. Payloads could include the common aero vehicle (CAV), a reentry vehicle that can deliver a variety of munitions to a ground target, or microsatellites.

Scorpius-Sprite Program

One possible contender for an operationally responsive space-lift solution is Microcosm's Sprite Mini-Lift launch vehicle. The Air Force, the Missile Defense Agency, and NASA, as well as Microcosm's own research and development funds, fund research for the ongoing Scorpius-Sprite program.[60]

Scorpius, the suborbital research vehicle, has already flown and will be scaled up to become the orbital Sprite. The Sprite will be 53 feet tall and consist of six 42-inch-diameter pods around a central core, giving it an overall diameter of 11.2 feet.[61] It will be a three-stage launcher with six 20,000-pound-thrust engines followed by a second-stage single 20,000-pound engine.[62] The third stage will produce 2,500 pounds of thrust and place a 700-pound payload in a 100-nautical-mile (nm) low Earth orbit for $1.8 million.[63] A primary goal is to simplify launch operations so that liftoff occurs within eight hours of bringing the vehicle to the pad.

Force Application and Launch from CONUS

The Force Application and Launch from CONUS (FALCON) program objectives are to develop and demonstrate technologies that will enable both near-term and far-term capabilities to execute time-critical, global-reach missions. A 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, will be capable of delivering up to 1,000 pounds of munitions to a target 3,000 nm downrange.[64] An operationally responsive space-lift booster vehicle will place the 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.

The vision for a far-term capability entails a reusable, hypersonic aircraft capable of delivering 12,000 pounds of payload to a target 9,000 nm from CONUS in less than two hours.[65] Many of the technologies required by CAV are also applicable to this 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 the 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.

Notes

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