Delta IV

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Delta IV

- *Delta IV is an expendable launch system in the Delta rocket family.*
- *The Delta IV is available in five versions: Medium, Medium+ (4,2), Medium+ (5,2), Medium+ (5,4), and Heavy, to cover a range of payload size and weight.*
- *The Delta IV was primarily designed to satisfy the needs of the U.S. military.*

Delta IV is an expendable launch system in the Delta rocket family. The rocket's main components are designed by Boeing's Defense, Space & Security division and built in the United Launch Alliance (ULA) facility in Decatur, Alabama. Final assembly is completed at the launch site by ULA. The rocket was designed to launch payloads into orbit for the United States Air Force Evolved Expendable Launch Vehicle (EELV) program and for the commercial satellite business. The Delta IV is available in five versions: Medium, Medium+ (4,2), Medium+ (5,2), Medium+ (5,4), and Heavy, to cover a range of payload size and weight. The Delta IV was primarily designed to satisfy the needs of the U.S. military.

The rocket is assembled at the Horizontal Integration Facility for launches from SLC-37B at Cape Canaveral and in a similar facility for launches from SLC-6 at Vandenberg Air Force Base.

History

- *The Delta IV entered the space launch market when global capacity was already much higher than demand.*
- *In 2015, ULA stated that a Delta IV Heavy is sold for nearly $400 million.*
- *All of Delta IV's launches, with the exception of its debut launch carrying the Eutelsat W5 commercial communications satellite, were paid for by the US government.*

While the Delta-IV retains the name of the Delta family of rockets, the vehicle was a new design, rather than an evolution of the older Delta boosters. A primary change in the design is that the first stage uses liquid hydrogen fuel, rather than the kerosene fuel of earlier Delta boosters, and thus used a new engine, the Rocketdyne RS-68.

The Delta IV entered the space launch market when global capacity was already much higher than demand. Furthermore, as an unproven design it has had difficulty finding a market in commercial launches, and the cost to launch a Delta IV is higher than that for competing vehicles. In 2003, Boeing pulled the Delta IV from the commercial market, citing low demand and high costs. In 2005, Boeing stated that it sought to return the Delta IV to commercial service.

All of Delta IV's launches, with the exception of its debut launch carrying the Eutelsat W5 commercial communications satellite, were paid for by the US government. In 2015, ULA stated that a Delta IV Heavy is sold for nearly $400 million.

Recent history

- *The United States Air Force (USAF) funds Delta IV engineering, integration, and infrastructure through contracts with Boeing Launch Services (BLS).*
- *The Delta IV will be largely replaced by the Atlas V.*
- *In March 2015, ULA announced plans to phase out all Delta IV launchers except the Delta IV Heavy by 2018.*
- *Chung is suspected of having passed on classified information on designs including the Delta IV rocket.*

The United States Air Force (USAF) funds Delta IV engineering, integration, and infrastructure through contracts with Boeing Launch Services (BLS). On August 8, 2008 the USAF Space and Missile Systems Center increased the "cost plus award fee" contract with BLS for $1.656 billion to extend the period of performance through the end of FY09[update]. In addition a $557.1 million option was added to cover FY10.

Naturalized citizen Dongfan Chung, an engineer working with Boeing, was the first person convicted under the Economic Espionage Act of 1996. Chung is suspected of having passed on classified information on designs including the Delta IV rocket.

In March 2015, ULA announced plans to phase out all Delta IV launchers except the Delta IV Heavy by 2018. The Delta IV will be largely replaced by the Atlas V.

2012 upper stage anomaly

- *By December 2012 ULA had determined the cause of the anomaly to be a fuel leak, and Delta IV launches resumed in May 2013.*
- *While the vehicle had sufficient fuel margins to successfully place the payload, a GPS Block IIF satellite, into its targeted orbit, investigation into the glitch delayed subsequent Delta IV launches and the next Atlas V launch (AV-034) due to commonality between the engines used on both vehicles' upper stages.*

- *After two more successful launches, further investigation led to the delay of Delta flight 365 with the GPS IIF-5 satellite.*

On October 4, 2012, a Delta IV M+ (4,2) experienced an anomaly in the upper stage's RL10-B-2 engine which resulted in lower than expected thrust. While the vehicle had sufficient fuel margins to successfully place the payload, a GPS Block IIF satellite, into its targeted orbit, investigation into the glitch delayed subsequent Delta IV launches and the next Atlas V launch (AV-034) due to commonality between the engines used on both vehicles' upper stages.

By December 2012 ULA had determined the cause of the anomaly to be a fuel leak, and Delta IV launches resumed in May 2013. After two more successful launches, further investigation led to the delay of Delta flight 365 with the GPS IIF-5 satellite. Originally scheduled to launch in October 2013, the vehicle lifted off on February 21, 2014.

Planned successor

- *The Delta IV Heavy and Atlas V are expected to stay in service for a few years after Vulcan's inaugural launch, and the Heavy is expected to be discontinued in the late 2020s.*
- *The Vulcan rocket is planned to replace the Atlas V and Delta IV rockets.*

The Vulcan rocket is planned to replace the Atlas V and Delta IV rockets. Vulcan is projected to enter service by 2021, using the Blue Origin BE-4 methane-fueled rocket engine. The Delta IV Heavy and Atlas V are expected to stay in service for a few years after Vulcan's inaugural launch, and the Heavy is expected to be discontinued in the late 2020s.[citation needed]

Vehicle description

Delta IV first stage

- *The first stage of a Delta IV consists of one, or in the Heavy variety three, Common Booster Cores (CBC) powered by an Aerojet Rocketdyne RS-68 engine, which burns liquid hydrogen and liquid oxygen.*

The first stage of a Delta IV consists of one, or in the Heavy variety three, Common Booster Cores (CBC) powered by an Aerojet Rocketdyne RS-68 engine, which burns liquid hydrogen and liquid oxygen.

In 2002, the RS-68 became the first large liquid-propellant rocket engine designed in the U.S. since the Space Shuttle main engine (SSME) in the 1970s. The primary goal for the RS-68 was to reduce cost versus the SSME. Some sacrifice in chamber pressure and specific impulse was made, hurting efficiency; however, development time, part count, total cost, and assembly labor were reduced to a fraction of the SSME, despite the RS-68's significantly larger size. Typically, the RS-68 runs at 102% rated thrust for the first few minutes of flight, and then throttles down to 58% rated thrust before main engine cutoff. On the Heavy variant, the main CBC's engine throttles down to 58% rated thrust around 50 seconds after liftoff, while the strap-on CBCs remain at 102%. This allows the main CBC to conserve propellant and burn after booster separation. After the strap-on CBCs separate, the main CBC's engine throttles back up to 102% before throttling back down to 58% prior to main engine cutoff.

The RS-68 engine is mounted to the lower thrust structure of the vehicle by a four-legged (quadrapod) thrust frame, and enclosed in a protective composite conical thermal shield. Above the thrust structure is an aluminum isogrid (a grid pattern machined out of the inside of the tank to reduce weight) liquid hydrogen tank, followed by a composite cylinder called the centerbody, an aluminum isogrid liquid oxygen tank, and a forward skirt. Along the back of the CBC is a cable tunnel to hold electrical and signal lines, and a feedline to carry the liquid oxygen to the RS-68 from the tank. The CBC is of a constant, 5-meter (16.4 ft) diameter.

Delta Cryogenic Second Stage

- *The upper stage of the Delta IV, or DCSS, is based on the Delta III upper stage, but with increased propellant capacity.*

The upper stage of the Delta IV, or DCSS, is based on the Delta III upper stage, but with increased propellant capacity. The 4-meter (13.1 ft) version uses lengthened propellant tanks, while the 5-meter version has a 5-meter diameter liquid hydrogen tank and a further lengthened liquid oxygen tank. The second stage is powered by a RL10B2 engine, which features an extendable carbon-carbon nozzle to improve specific impulse. Depending on variant, two different interstages are used to mate the first and second stages. A tapering interstage which narrows down from 5 m to 4 m in diameter is used on 4-meter variants, where a cylindrical interstage is used on 5-meter variants. Both interstages are built from composites.

Guidance, navigation, control and communications

- *The L3 Technologies Redundant Inertial Flight Control Assembly (RIFCA) guidance system used on the Delta IV is common to that carried on the Delta II, although the software is different because of the differences between the Delta II and Delta IV.*

The L3 Technologies Redundant Inertial Flight Control Assembly (RIFCA) guidance system used on the Delta IV is common to that carried on the Delta II, although the software is different because of the differences between the Delta II and Delta IV. The RIFCA features six ring laser gyroscopes and accelerometers each, to provide a higher degree of reliability.

Payload encapsulation

- *The Delta IV is over 62 m (205 ft) tall.*

To encapsulate the satellite payload, a variety of different payload fairings are available. A stretched Delta III 4-meter composite payload fairing is used on 4-meter variants, while an enlarged, 5-meter composite fairing is used on 5-meter variants. A longer fairing version is standard on the Heavy variant, and a Boeing-built Titan IV-derived, 5-meter, aluminum isogrid fairing is also available for the Heavy. The Delta IV is over 62 m (205 ft) tall.

Comparable rockets

Variants

Delta IV Small

- *This would have featured the Delta II second stage, an optional Thiokol Star 48B third stage, and the Delta II payload fairing, all atop a single CBC.*
- *During the Delta IV's development, a Small variant was considered.*

During the Delta IV's development, a Small variant was considered. This would have featured the Delta II second stage, an optional Thiokol Star 48B third stage, and the Delta II payload fairing, all atop a single CBC. The Small variant was dropped by 1999.

Delta IV Medium

- *The Delta IV Medium (Delta 9040) is the most basic Delta IV.*

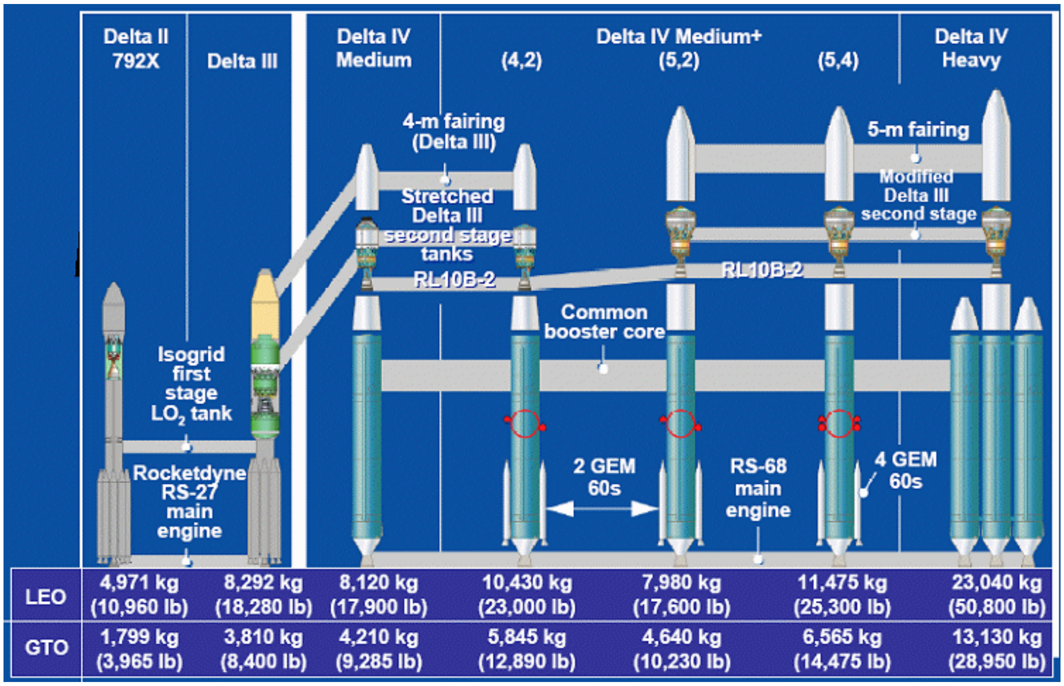
The Delta IV Medium (Delta 9040) is the most basic Delta IV. It features a single CBC and a modified Delta III second stage, with 4-meter liquid hydrogen and liquid oxygen tanks and a 4-meter payload fairing. The Delta IV Medium is capable of launching 4,200 kg to geosynchronous transfer orbit (GTO). The GTO orbit is 1804 m/s away from GEO. The mass of fairing and payload attach fittings have been subtracted from the gross performance.

The Delta IV Medium+ (4,2) (Delta 9240) is similar to the Medium, but uses two Orbital ATK-built 1.5-m (60-in) diameter solid rocket booster Graphite-Epoxy Motors (GEM-60s) strap-on boosters to increase payload capacity to 6,150 kg to GTO.

The Delta IV Medium+ (5,2) (Delta 9250) is similar to the Medium+ (4,2), but has a 5-m–diameter payload fairing for larger payloads and a modified second stage with a 5-meter liquid hydrogen tank and stretched liquid oxygen tank. Because of the extra weight of the larger payload fairing and second stage, the Medium+ (5,2) can launch 5,072 kg to GTO.

The Delta IV Medium+ (5,4) (Delta 9450) is similar to the Medium+ (5,2), but uses four GEM-60s instead of two, enabling it to lift 6,882 kg to GTO.

Delta IV Heavy launching



Delta IV evolution

Delta IV Heavy

- *The Delta IV Heavy also features a stretched 5-meter composite payload fairing.*
- *The Delta IV Heavy (Delta 9250H) is similar to the Medium+ (5,2), except that it uses two additional CBCs instead of using GEMs.*

The Delta IV Heavy (Delta 9250H) is similar to the Medium+ (5,2), except that it uses two additional CBCs instead of using GEMs. These are strap-on boosters which are separated earlier in the flight than the center CBC. The Delta IV Heavy also features a stretched 5-meter composite payload fairing. An aluminum trisector (three-part) fairing derived from the Titan IV fairing is also available. This was first used on the DSP-23 flight.

RS-68A upgrade

- *The possibility of a higher performance Delta IV was indicated in a 2006 RAND Corporation study of national security launch requirements out to 2020, which noted that a single National Reconnaissance Office (NRO) payload would require an increase in the lift capability of the Delta IV Heavy.*
- *The Delta IV Heavy will still require non-standard CBCs for the core and boosters.*

The possibility of a higher performance Delta IV was indicated in a 2006 RAND Corporation study of national security launch requirements out to 2020, which noted that a single National Reconnaissance Office (NRO) payload would require an increase in the lift capability of the Delta IV Heavy. This was achieved using the higher-performance RS-68A engine, and launched on June 29, 2012. ULA phased out the baseline RS-68 engine with the launch of Delta flight 371 on March 25, 2015. All future launches will use the RS-68A, with the engine's higher thrust allowing use of a single CBC design for all Delta IV Medium and M+ versions. This upgrade reduces cost and increases flexibility, since any standardized CBC can be configured for zero, two, or four solid boosters; this CBC will necessitate a slight performance loss for most medium configurations. The Delta IV Heavy will still require non-standard CBCs for the core and boosters.

RS-68A

RS-68

*Masses include Payload Attach Fitting weighing from 240 kg to 1,221 kg depending on payload.

Proposed variants

- *A possible upgrade to the Delta IV family is the creation of new variants by the addition of extra solid motors.*
- *Orion was intended to fly on the Ares I launch vehicle, then the Space Launch System after Ares I was cancelled.*
- *At one point NASA planned to use Delta IV or Atlas V to launch the proposed Orbital Space Plane, which eventually became the Crew Exploration Vehicle and then the Orion.*

Possible future upgrades for the Delta IV include adding extra strap-on solid motors, higher-thrust main engines, lighter materials, higher-thrust second stages, more (up to six) strap-on CBCs, and a cryogenic propellant cross feed from strap on boosters to the common core.

At one point NASA planned to use Delta IV or Atlas V to launch the proposed Orbital Space Plane, which eventually became the Crew Exploration Vehicle and then the Orion. Orion was intended to fly on the Ares I launch vehicle, then the Space Launch System after Ares I was cancelled.

In 2009 The Aerospace Corporation reported on NASA results of a study to determine the feasibility of modifying Delta IV to be human-rated for use in NASA human spaceflight missions. According to Aviation Week the study, "found that a Delta IV heavy [...] could meet NASA's requirements for getting humans to low Earth orbit."

A possible upgrade to the Delta IV family is the creation of new variants by the addition of extra solid motors. One such modification, the Medium+(4,4), would pair the four GEM-60s of the M+(5,4) with the upper stage and fairing of the (4,2). This would theoretically provide a GTO payload of 7,500 kg (16,600 lb) and an LEO payload of 14,800 kg (32,700 lb). This is the simplest variant to implement and is available within 36 months of the first order. Two other possible versions, the Medium+(5,6) and (5,8), would add two or four extra GEM-60s to the (5,4) variant, respectively. These would provide significantly higher performance (up to 9,200 kg/20,200 lb to GTO for the M+(5,8)) but would require more extensive modifications to the vehicle, such as adding the extra attach points and changes to cope with the different flight loads. They would also require pad and infrastructure changes. The Medium+(5,6) and (5,8) could be available within 48 months of the first order.

First Delta IV Heavy with three CBCs prior to launch

Launch sites

- *The vehicle is mounted to the Launch Table by a Launch Mate Unit (LMU), which is attached to the vehicle by bolts that sever at launch.*
- *Delta IV launches occur from either of two rocket launch sites.*
- *The horizontal rocket assembly of the Delta IV are similar to the ones with the assembly of Soyuz launch vehicles; they are also assembled horizontally, unlike the Space Shuttles, the past Saturn launch vehicles and the upcoming Space Launch System, where they are assembled and rolled out to the launch pad entirely vertically.*

Delta IV launches occur from either of two rocket launch sites. Launches on the East coast of the United States, Space Launch Complex 37 (SLC-37) at the Cape Canaveral Air Force

Station. On the West coast, polar-orbit and high-inclination launches use Vandenberg Air Force Base's Space Launch Complex 6 (SLC-6) pad.

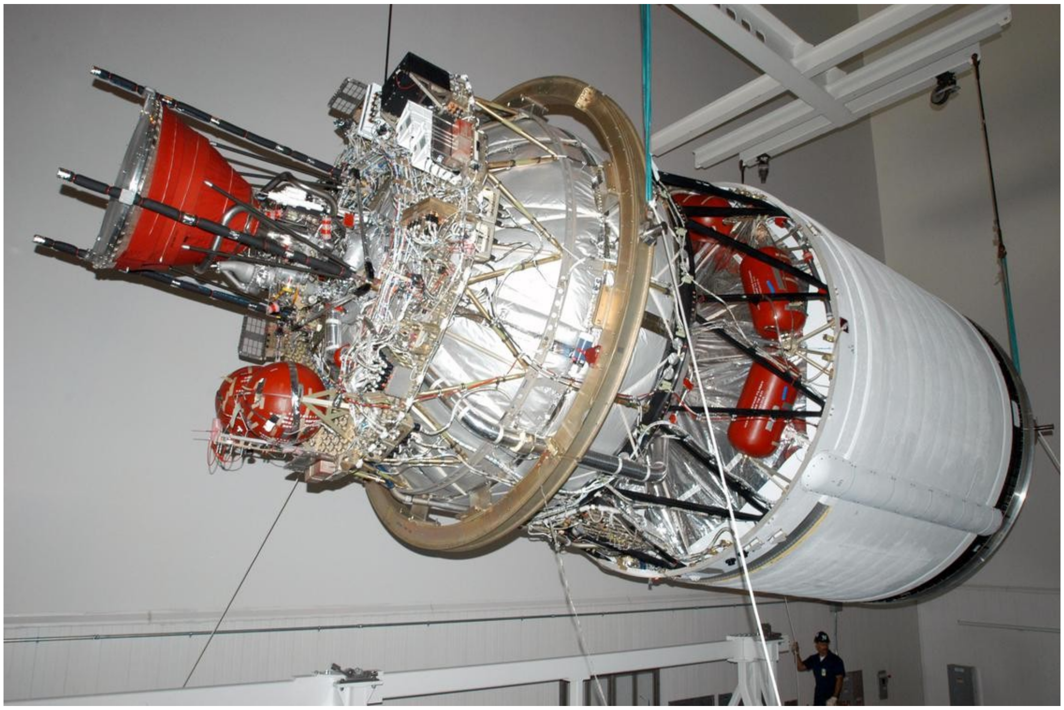
Launch facilities at both sites are similar. At the pad is a Mobile Service Tower (MST), which provides service access to the rocket and protection from the weather. There is a crane at the top of the MST, which allows the payload and GEM-60 solid motors to be attached to the vehicle. The MST is rolled away from the rocket several hours before launch. At Vandenberg, the launch pad also has a Mobile Assembly Shelter (MAS), which completely encloses the vehicle; at CCAFS, the vehicle is partly exposed near its bottom.

Beside the vehicle is a Fixed Umbilical Tower (FUT), which has two (VAFB) or three (CCAFS) swing arms. These arms carry electrical, hydraulic, environmental control, and other support functions to the vehicle through umbilical lines. The swing arms retract at T-0 seconds to prevent them from hitting the vehicle.

Under the vehicle is a Launch Table, with six Tail Service Masts (TSMs), two for each CBC. The Launch Table supports the vehicle on the pad, and the TSMs provide further support and fueling functions for the CBCs. The vehicle is mounted to the Launch Table by a Launch Mate Unit (LMU), which is attached to the vehicle by bolts that sever at launch. Behind the Launch Table is a Fixed Pad Erector (FPE), which uses two long-stroke hydraulic pistons to raise the vehicle to the vertical position after being rolled to the pad from the Horizontal Integration Facility (HIF). Beneath the Launch Table is a flame duct, which deflects the rocket's exhaust away from the rocket or facilities.

The Horizontal Integration Facility (HIF) is situated some distance from the pad. It is a large building that allows the Delta IV CBCs and second stages to be mated and tested before they are moved to the pad. The horizontal rocket assembly of the Delta IV are similar to the ones with the assembly of Soyuz launch vehicles; they are also assembled horizontally, unlike the Space Shuttles, the past Saturn launch vehicles and the upcoming Space Launch System, where they are assembled and rolled out to the launch pad entirely vertically.

Movement of the Delta IVs among the various facilities at the pad is facilitated by Elevating Platform Transporters (EPTs). These rubber-tired vehicles can be powered by either diesel engines or electric power. Diesel EPTs are used for moving the vehicles from the HIF to the pad, while electric EPTs are used in the HIF, where precision of movement is important.



Delta IV 4-Meter Second Stage

Vehicle processing

- *Finally, on launch day, the MST is rolled away from the vehicle, and the vehicle is ready for launch.*
- *They are then loaded onto the M/V Delta Mariner, a roll-on/roll-off cargo vessel, and shipped to either launch pad.*
- *Delta IV CBCs are assembled at ULA's factory in Decatur, Alabama.*

Delta IV CBCs are assembled at ULA's factory in Decatur, Alabama. They are then loaded onto the M/V Delta Mariner, a roll-on/roll-off cargo vessel, and shipped to either launch pad. There, they are offloaded and rolled into a Horizontal Integration Facility (HIF), where they are mated with the second stages, which were shipped separately to the pad on the Delta Mariner. Also, in the HIF, the three CBCs of Heavy variant are mated to each other.

Various tests are performed, and then the vehicle is rolled horizontally to the pad, where the Fixed Pad Erector (FPE) is used to raise the vehicle to the vertical position, inside the MST. At this time, the GEM-60 solid motors, if any are required, are rolled to the pad and attached to the vehicle. After further testing, the payload (which has already been enclosed in its fairing) is transported to the pad, hoisted into the MST by a crane, and attached to the vehicle. Finally, on launch day, the MST is rolled away from the vehicle, and the vehicle is ready for launch.

Delta IV launches

- *For future launches, see List of Thor and Delta launches (2010–2019).*

This list was last updated on March 16, 2019. For future launches, see List of Thor and Delta launches (2010–2019).

GOES-N launch on a Medium+ (4,2)

A unique aerial view of NROL-22 launch from SLC-6

Notable past launches

- *The first payload launched with a Delta IV was the Eutelsat W5 communications satellite.*
- *NROL-32 was a "heavy" launch, carrying a satellite for NRO.*
- *This was also the first Delta IV launch contracted by the United Launch Alliance, a joint venture between Boeing and Lockheed Martin.*
- *It was the first Delta IV Heavy mission to be launched out of Vandenberg.*

The first payload launched with a Delta IV was the Eutelsat W5 communications satellite. The launch vehicle was a Medium+ (4,2) variant, launched from Cape Canaveral. It carried the communications satellite into geostationary transfer orbit (GTO) on November 20, 2002.

Heavy Demo was the first launch of the Heavy variant in December 2004 after significant delays due to bad weather. Due to cavitation in the propellant lines, sensors registered depletion of propellant. The strap-on, and later core CBC engines shut down prematurely, even though sufficient propellant remained to continue the burn as scheduled. The second stage attempted to compensate for the under-burn, until it ran out of propellant. This flight was a test launch carrying a payload of:

DemoSat – 6020 kg; an aluminum cylinder filled with 60 brass rods – planned to be carried to GEO; however due to the sensor faults, the satellite did not reach this orbit.

NanoSat-2, carried to low Earth orbit (LEO) – a set of two very small satellites of 24 and 21 kg, nicknamed Sparky and Ralphie – planned to orbit for one day. Given the under-burn, the two most likely did not reach a stable orbit.

NROL-22 was the first Delta IV launched from SLC-6 at Vandenberg Air Force Base (VAFB). It was launched aboard a Medium+ (4,2) in June 2006 carrying a classified satellite for the U.S. National Reconnaissance Office (NRO).

DSP-23 was the first launch of a valuable payload aboard a Heavy vehicle. This was also the first Delta IV launch contracted by the United Launch Alliance, a joint venture between Boeing and Lockheed Martin. The main payload was the 23rd and final Defense Support Program missile-warning satellite, DSP-23. Launch from Cape Canaveral occurred on November 10, 2007.

NROL-26 was the first "heavy" EELV launch for the NRO. It carried USA 202, a classified reconnaissance satellite, on a Delta IV Heavy that lifted off January 18, 2009.

NROL-32 was a "heavy" launch, carrying a satellite for NRO. The payload is speculated to be the largest satellite sent into space. The rocket lifted off on November 21, 2010; the launch was delayed from October 19.

NROL-49 lifted off from Vandenberg AFB on January 20, 2011. It was the first Delta IV Heavy mission to be launched out of Vandenberg. This mission was for the NRO and its details are classified.

A Delta IV Heavy launched the Orion spacecraft on an uncrewed test flight, EFT-1, on December 5, 2014. The launch was originally planned for December 4, but high winds and valve issues caused the launch to be rescheduled for December 5.

Planned launches

- *The second GPS Block IIIA satellite will be launched using a Medium+ (4,2) rocket in the spring of 2019.*

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See also

- *List of launch vehicles*
- *Expendable launch system*
- *Comparison of orbital launch systems*

Comparison of orbital launchers families

Comparison of orbital launch systems

Advanced Cryogenic Evolved Stage

Expendable launch system

List of launch vehicles

References

External links

- *First Vandenberg Delta IV Heavy launch video via EducatedEarth.*
- *Boeing's Delta IV Heavy Gets Ready for its Close-Up, Space News, 2004-12-06.*
- *Comparison of Delta IV Heavy with Space Shuttle*
- *Boeing's Delta IV Rocket page*
- *Delta IV information on Gunter's Space page*
- *Delta IV Launch Vehicle page on United Launch Alliance site*
- *Delta IV page on Astronautix.com*

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Boeing's Delta IV Rocket page

Delta IV information on Gunter's Space page

Boeing press kit for Heavy Demo launch, 2005

Comparison of Delta IV Heavy with Space Shuttle

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