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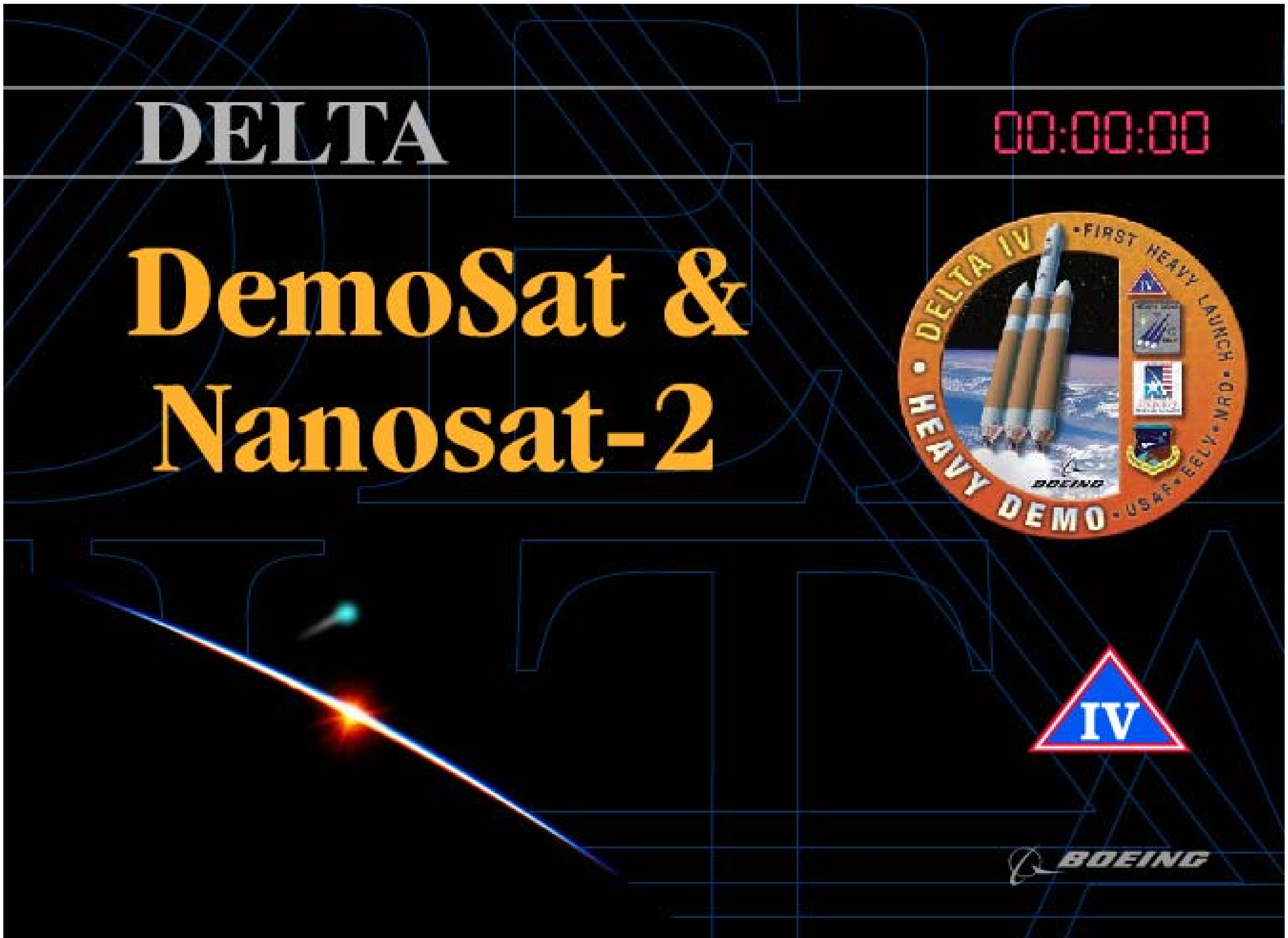

Delta IV Heavy Demonstration Flight Media Kit

This site requires a JavaScript-enabled browser and uses Flash for both animation a
of the Boeing Web Site, you will need to download and install the latest version of t
the Delta IV EELV Delta IV Heavy Demonstration Flight site.

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- Delta IV Video
- Mission Information
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Heavy Demo Mission Fact Sheet

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DemoSat & Nanosat-2

Delta Launch Vehicle Programs

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Heavy Demo Objectives

The Delta IV Heavy configuration can deploy large payloads to GTO, polar, sun-synchronous, planetary/escape and, as it will in its first mission, direct insertion into geosynchronous Earth orbit (GEO).

In a typical GTO mission, the mission includes the first-stage burn, one burn of the second stage, a short coast in a parking orbit, followed by a second burn of the second stage to establish an elliptical orbit of ~185 km x 35,788 km (100 nmi x 19,324 nmi) at a 27.0-deg inclination, followed by spacecraft separation. Following the acquisition of the spacecraft as the spacecraft nears apogee altitude, or the orbit location on the ellipse farthest away from the Earth, the propulsion system of the spacecraft performs a series of burns and maneuvers to circularize and remove inclination from the orbit.

For the first launch of the Delta IV Heavy, the mission requirement is to deploy the DemoSat directly into GEO. The direct insertion of the DemoSat to GEO will demonstrate Delta IV capability to directly insert a payload to GEO to ensure that future missions can be deployed to GEO.

For this GEO mission, the sequence will duplicate the typical GTO sequence up to spacecraft separation. In the GEO mission the payload remains attached to the second stage in the elliptical transfer orbit and performs a long-duration coast, just over 5 hr for the DemoSat launch. As the second stage and DemoSat near apogee, a third burn of the second stage occurs to establish a near-circular orbit at geosynchronous altitude, followed by spacecraft separation. This additional maneuver performed by the Delta IV second stage is normally preformed by the spacecraft. By using the second stage to circularize the orbit, the spacecraft saves station-keeping propellant and increases its on-orbit lifetime.

A typical GEO is 35,786 km (19,323 nmi) circular at 0.0 deg. The Delta IV Heavy will deploy DemoSat into a circular orbit of 36,342 km (19,623 nmi) at 10.0 deg to avoid any contact with a functioning satellite.

The capability and flexibility of the Delta launch vehicle family ensures that Boeing can meet the current and future needs of our launch service customers far into the 21st century.

Nanosat Objectives

In addition to the DemoSat, the Delta IV Heavy demonstration mission will fly an auxiliary payload for the Department of Defense Space Test Program (STP). The STP provides spaceflight for research and development payloads approved by the DoD Space Experiments Review Board. The payload, Nanosat-2, is sponsored by the Air Force Research Laboratory and consists of a small constellation of two nanosatellites built by university students. The first payload, "Ralphie," was built by students from the University of Colorado, Boulder, and is named for the school's mascot, a real buffalo named Ralphie. The second payload, "Sparky," was built by students from Arizona State University in Phoenix, and is likewise named for the school's mascot, Sparky the Sun Devil. The two payloads weigh 54 lb and 47 lb, respectively.

The objectives of the two Nanosat-2 payloads are to demonstrate miniaturized component and collaborative formation flying of nanosat technologies, and to demonstrate a standard deployment system for future government small-satellite missions. Originally designed for launch on the Space Shuttle, the Nanosat-2's initial configuration consisted of three individual payloads, but payload environments and the short integration schedule forced the removal of one of the Nanosats.

Nanosat-2 is attached to the side of the DemoSat during launch and ascent. After SECO-1, a separation signal is sent from the Delta IV, and 983 sec after launch, both payloads power on and separate from the DemoSat. The on-orbit lifetime of Nanosat-2 is estimated to be 0.5 to 2 days.

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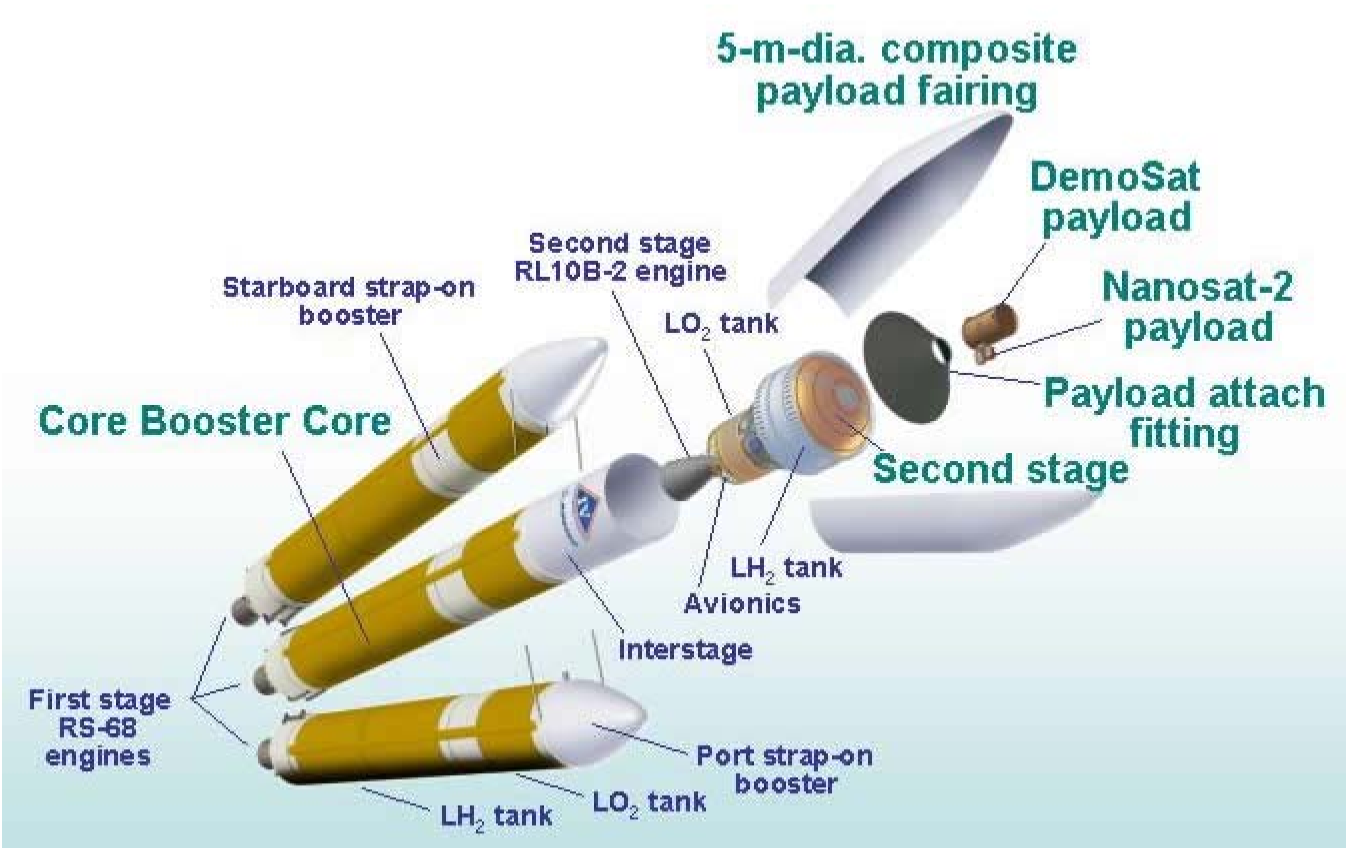
Vehicle Overview

Click on the highlighted text to read more.

Common Booster Core | Fairing | Payload Attach Fitting | Cryogenic 2nd Stage | DemoSat | NanoSat-2



Common Booster Core

The Delta IV CBC design is optimized for balanced performance over a wide range of payloads using the high-performance RS-68 main engine powered by liquid hydrogen (LH_2) and liquid oxygen (LO_2). The RS-68 is throttleable to serve various mission profiles operating at 102% and 58% thrust level. Two separate 5-m-dia. LO_2 and LH_2 tanks provide the majority of the first stage structure. These two tanks are integrated with a composite cylinder, called the centerbody. At the forward end of the CBC, another composite cylinder, the interstage, provides the interface between the CBC and the cryogenic second stage. For the port and starboard strap-on CBCs of the Heavy configuration, Boeing replaces the interstage structure with a composite nosecone. For 4-m second stage configurations, the interstage is tapered to integrate the 4-m-dia. second stage.

At the aft end of the CBC, an engine section provides the thrust structure and thermal shield that integrates the RS-68 main engine to the CBC. The RS-68 requirements were balanced to enable operational thrust at lower chamber pressures. This design trade increases engine reliability, while reducing complexity. Compared with the SSME, the RS-68 has an 80% reduction is unique part count. Even with lower performance than comparable LO_2/LH_2 engines, the RS-68 develops a world record 2,949 kN (663,000 lb) of sea-level thrust with a specific impulse (Isp) of 407.55 seconds at maximum power level.

Payload Fairing

The 5-m-diameter payload fairing (PLF) encapsulates the spacecraft and provides a benign environment during flight. Design features of the 5-m PLF include composite blended cone/cylinder structure, biconic separation and separation system, access doors, and an acoustic attenuation system. The 76.2-mm-thick acoustic absorption blankets are provided in the cylinder section as well as the lower section of the nose cone. The acoustic blankets are vented through a mesh filter that controls particulates to a negligible contamination level.

The separation system for all of our fairings is a non-contaminating thrusting joint separation system patented by Boeing. Fairing separation is accomplished when pyrotechnics at the aft ends of each joint are detonated. The assembly in each cylinder rail retains the detonating-fuse gases to prevent contamination of the payload during the separation event. This type of thrusting joint has been subjected to more than 300 ground tests and has flown more than 200 missions with no failures or spacecraft contamination.

A separation augmentation spring system is added to the composite fairings to reduce fairing pitch rate and increase center-of-gravity velocity to provide clearance at fairing jettison. The springs in this system are preloaded and installed on the aft frame after mating to the second stage. Boeing has proven 100% mission success in over 400 PLFs to date.

Payload Attach Fitting

Boeing offers a variety of payload attach fittings (PAFs) that provide the mechanical and electrical interfaces between the payload and the launch vehicle. The Heavy vehicle integrates the DemoSat using the 1194-5 PAF. The 1194 refers to the spacecraft interface diameter and the 5 refers to the diameter of the PAF-second stage and PAF-payload fairing (PLF) interfaces. The 4-m-dia. version of this PAF, the 1194-4, was successfully demonstrated on the Eutelsat W5 mission in 2002. The 1194-5 PAF is an 1194-mm (47-in.) diameter clampband interface attached to our composite conical structure. The 5-m-dia. aft ring of the PAF attaches to the launch vehicle second stage and provides attach points for the PLF.

Cryogenic Second Stage

The spacecraft is propelled to orbit using our flight-proven cryogenic second stage. This second stage comprises a 5-m-diameter fuel tank, a composite intertank structure, a liquid oxygen tank, avionics equipment shelf, avionics suite, attitude control system, and is powered by a Pratt & Whitney RL10B-2 liquid rocket engine that produces 110 kN (24,750 lb.) of thrust. The RL10B-2, with its high-expansion, carbon-carbon nozzle provides an Isp of 460.4 sec. The 5-m second stage for the Heavy launch vehicle is similar to the 4-m Medium in design and operation; however, the Heavy integrates larger tanks for added performance. The heritage redundant inertial flight control assembly (RIFCA) is included to ensure accurate insertion into the desired orbit. To enable the Heavy configuration cryogenic second stage to survive the long coast period and operate its electrical and attitude control systems, a GEO kit made up of added tanks and batteries is added to the second stage to increase capacity for Hydrazine, Helium, and power for DemoSat's GEO mission requirement.

DemoSat

The DemoSat design is based on the demonstration payload originally planned for the Delta IV First Flight. The First Flight Simulator was not used in favor of deploying the Eutelsat W5 spacecraft. DemoSat was designed to emulate as closely as possible the typical mass, center of gravity, frequency, and stiffness characteristics of an operational spacecraft. It was built for Boeing by Process Fab, Inc., of Santa Fe Springs, CA.

DemoSat is a cylindrical structure 1.95 meters (76.6 inches) tall, 1.38 meters (54.5 inches) in diameter, and weighs 5,998 kg (13,224 lb). The outer skin is an aluminum structure, with inner ballast consisting of sixty 4.5-inch-diameter brass rods. Stiffeners, plates, fasteners, and fittings complete the payload. The construction of DemoSat had to meet two major criteria. First, it had to achieve specific mass and center of gravity requirements; second, it had to completely burn in the upper atmosphere upon re-entry. The use of individual brass rods was key in meeting both criteria. The overall height of the brass rods was selected to meet mass and CG requirements specified by design engineers, while the use of brass and aluminum materials facilitates re entry destruction.

The design of the DemoSat payload is very robust, as demonstrated by the late addition of the DoD Space Test Program's Nanosat-2 secondary payload to the mission. Nanosat-2 was manifested on the Heavy Demo launch late in the mission integration process, long after the DemoSat had been designed and built. To quickly integrate Nanosat-2, it was determined that Nanosat-2 could be attached laterally to DemoSat. Therefore, a single circular saddle bracket was designed and attached to DemoSat, approximately 508 millimeters (20 inches) from the aft end. To this bracket was attached a flat plate that will interface directly with the two individual separating payloads that make up Nanosat-2.

NanoSat-2

The Nanosat-2 mission features two satellites built by the Three Corner Sat team (3CS), a group of students and faculty from Arizona State University, New Mexico State University, and the University of Colorado at Boulder. These satellites will be used to demonstrate technologies required for small satellite constellations, including imaging, micropropulsion, and intersatellite communications.

The Nanosat-2 mission will also demonstrate two different low-shock separation systems. Developed by Planetary Systems Inc. and Starsys Research Corp, these separation systems promise to eliminate the adverse pyrotechnic shock associated with typical satellite deployments. With low-shock separation systems, the potential for damage to the satellite is reduced. These separation systems are also safer, and are therefore more conducive to testing than typical pyrotechnic devices.

But technology is only part of the story for the Nanosat-2 mission: by allowing students a chance to build actual flight hardware, this program has helped to train and inspire future workers, an invaluable resource for the US aerospace industry.

Nanosat-2 was developed as part of the University Nanosat Program with funding from the Air Force Research Laboratory (AFRL), The Defense Advanced Research Projects Agency (DARPA), the Air Force Office of Scientific Research (AFOSR), and the Air Force Space and Missile Command's Space Test Program (STP).

Heavy Demo Mission Description

• Launch	December 2004
• Time (EST)	Approximately 14:31 (hr:min)
• Launch Window	Approximately 2:56 (hr:min)
• DemoSat Final Orbit Target*	
– Circular Orbit Altitude**	19,623 nmi
– Inclination	10.0 deg

*   Target orbit at spacecraft separation

** Based on a 3,443.918-nmi Earth radius

Flight Mode Description

Liftoff to SECO-1

- Delta IV Heavy/Heavy Demo launch from Complex 37B at CCAFS
- Flight azimuth: 95 deg
- Direct flight azimuth mode employed (combined pitch/yaw)
- Boost trajectory designed to meet controllability, structural, and environmental constraints while maximizing performance
- At 153 sec after liftoff, the launch vehicle begins a 50-sec roll to "wings-level" with Quad IV down
- Payload fairing is jettisoned ~10 sec after second-stage ignition
  - Free molecular heating remains well below the requirement thereafter
- Second-stage first burn places vehicle in a 99.94 x 134.8 nmi park orbit with an inclination of 28.8 deg at SECO-1
  - SECO-1 occurs in view of the Antigua tracking station

Sequence of Events

Liftoff to SECO-1

Event	Time (hr/min/sec)	Time (sec)
Stage I Liftoff	00:00:00.0	00.0
Initiate Booster Throttle-Down	00:00:50.0	50.0
Booster Throttle at Min Power Level (MPL)	00:00:55.0	55.0
Maximum Dynamic Pressure (356 psf)	00:01:20.9	80.9
Mach = 1.05	00:01:23.9	83.9
End Near-Zero Angle-of-Attack Flight	00:02:33.0	153.0
Initiate Strap-on Throttle-Down	00:03:54.7	234.7
Strap-on Throttle at Min Power Level (MPL)	00:03:59.7	239.7
Strap-on Engine Cutoff	00:04:05.3	245.3
Jettison Strap-on CBCs	00:04:08.4	248.4
Initiate Booster Throttle-Up	00:04:09.3	249.3
Booster Throttle at Full Power Level (FPL)	00:04:14.3	254.3
Maximum Fairing Skin Temperature	00:04:29.2	269.2
Initiate Booster Throttle-Down	00:05:17.0	317.0
Booster Throttle at Min Power Level (MPL)	00:05:22.0	322.0
Main Engine Cutoff (MECO)	00:05:33.4	333.4
Stage I-II Separation	00:05:41.0	341.0
Stage II Ignition	00:05:54.0	354.0
Jettison Fairing	00:06:04.5	364.5
First Cutoff – Stage II (SECO-1)	00:12:47.8	767.8

Flight Mode Description

SECO-1 to SECO-2

- Two settling thrusters are on during the 462-sec coast period
- CVS is on from 2 sec after SECO-1 until 142 sec prior to first restart ignition (begin repressurization)
- 2.5 sec after SECO-1, a "local-level" guidance scheme is used to limit the angle-of-attack to less than 20 deg
  - This mode aligns the vehicle centerline along the inertial velocity vector
- During "local-level" guidance, a 180-deg roll maneuver is performed
  - Vehicle flies Quad II down for the restart burn
- At 945 sec after liftoff (177 sec after SECO-1), the launch vehicle issues a signal to separate Nanosat-2
  - Elevation angle from Cape Verde tracking station is 2.1 deg
- At 983 sec after liftoff (38 sec after receiving the signal), Nanosat-2 separates from the launch vehicle
  - Elevation angle from Cape Verde tracking station is 4.6 deg
- The first restart ignition occurs 462 sec after SECO-1
  - Restart ignition occurs 246.5 sec after Nanosat-2 separation
  - Reorientation maneuver for restart burn occurs during the first 16 sec of burn
- The first restart burn duration is ~482 sec, placing the vehicle in a 148.4 nmi x 19,651 nmi transfer orbit at a 27.3-deg inclination

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Sequence of Events

SECO-1 to SECO-2

Event	Time (hr/min/sec)	Time (sec)
Begin LH_2 Boiloff/Propulsive Venting	00:12:49.8	769.8
Begin Park Orbit Attitude Maneuver (Begin Coast Guidance)	00:12:50.5	770.5
Begin Coast Phase Roll Program	00:14:06.5	846.5
Issue Nanosat-2 Separation Signal	00:15:45.0	945.0
Nanosat-2 Separation	00:16:23.0	983.0
End LH_2 Boiloff/Propulsive Venting	00:18:07.5	1,087.5
End Programmed Roll Rate – Coast Phase	00:18:20.5	1,100.5
End Park Orbit Attitude Maneuver (End Coast Guidance)	00:19:50.0	1,190.0
First Restart – Stage II	00:20:29.5	1,229.5
Begin Restart Burn Control Program	00:20:35.5	1,235.5
End Restart Burn Control Program	00:28:31.2	1,711.2
Second Cutoff – Stage II (SECO-2)	00:28:31.6	1,711.6

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DemoSat and Second-Stage Coast Phase

Post-Nanosat-2 Deployment

Flight Mode Description

SECO-2 to Heavy Demo Payload Separation

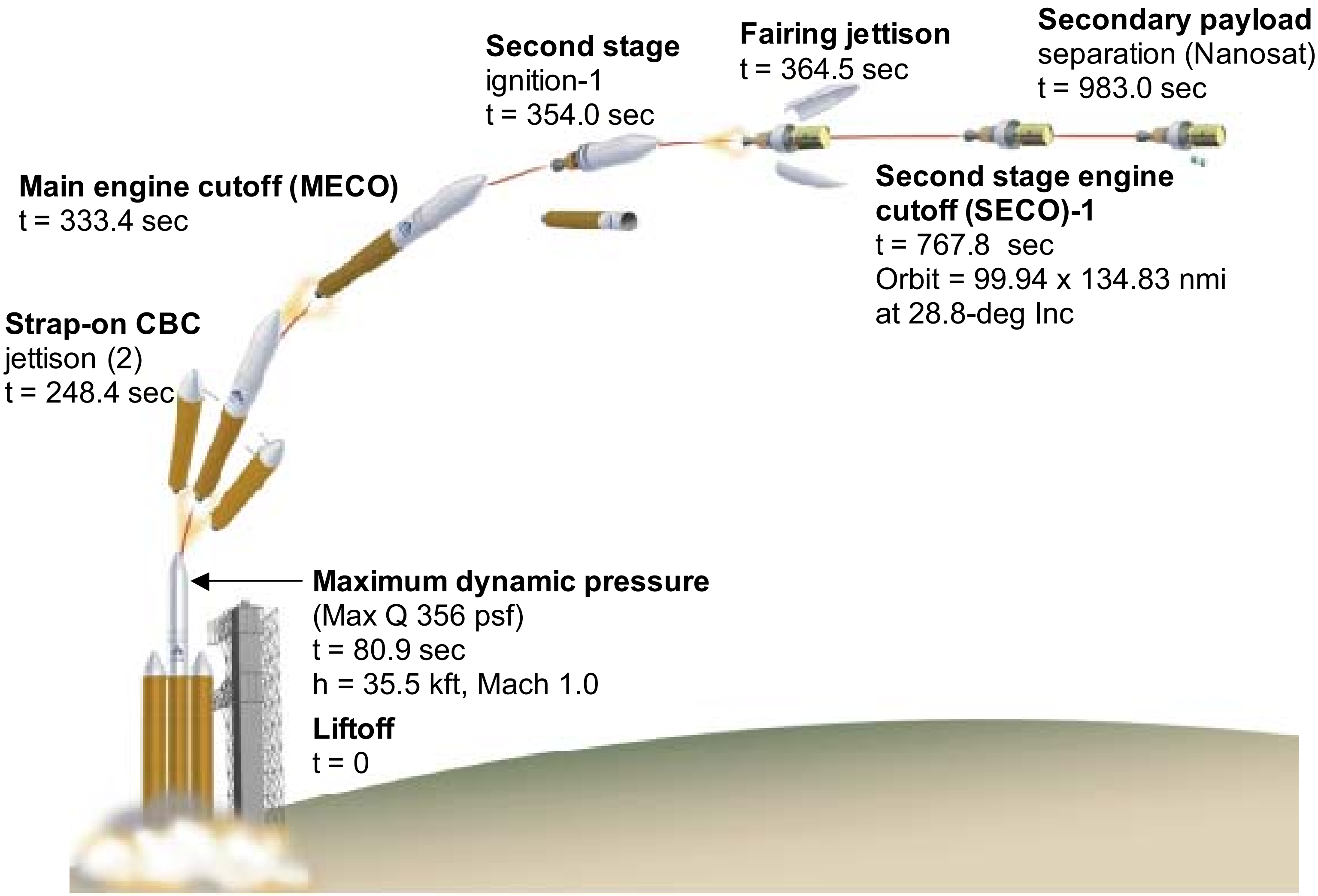
- Following SECO-2, coast guidance orients the vehicle to the required Passive Thermal Control (PTC) attitude orientation
- Six PTC segments and ve dipouts are performed
  - The dipouts are evenly spaced approximately 62 min apart
  - The duration of the four middle PTC segments is approximately 47 min
- 20 sec after the end of the PTC maneuvers, a roll-yaw-roll (coast guidance) sequence is initiated to orient the vehicle to the second restart burn attitude
- Second restart ignition occurs at 20,233 sec after liftoff, within view of Diego Garcia, Guam, Kwajalein, and Hartebeesthoek tracking stations
- Second restart burn duration is ~194 sec, placing the vehicle in a 19,567 nmi x 19,622 nmi orbit at a 10-deg inclination
- 30 sec after SECO-3, a roll-yaw maneuver (coast guidance) begins, which orients the vehicle to the required payload separation attitude
- Payload separation occurs 550 sec after SECO-3 at the required attitude and within view of Diego Garcia, Guam, Kwajalein, and Hartebeesthoek tracking stations
  - Time after liftoff = 20977.5 sec
  - Apogee altitude = 19,623 nmi
  - Perigee altitude = 19,622 nmi
  - Inclination = 10 deg

Sequence of Events

SECO-2 to Heavy Demo Payload Separation

Event	Time (hr/min/sec)	Time (sec)
Second Cutoff – Stage II (SECO-2)	00:28:31.6	1,711.6
Start PTC Segment 1	00:37:37.0	2,257.0
End PTC Segment 1	00:53:36.0	3,216.0
Start Dipout 1	00:58:36.0	3,516.0
End Dipout 1 / Start PTC Segment 2	01:08:36.0	4,116.0
End PTC Segment 2	01:55:38.0	6,938.0
Start Dipout 2	02:00:38.0	7,238.0
End Dipout 2 / Start PTC Segment 3	02:10:38.0	7,838.0
End PTC Segment 3	02:57:39.5	10,659.5
Start Dipout 3	03:02:39.5	10,959.5
End Dipout 3 / Start PTC Segment 4	03:12:39.5	11,559.5
End PTC Segment 4	03:59:41.5	14,381.5
Start Dipout 4	04:04:41.5	14,681.5
End Dipout 4 / Start PTC Segment 5	04:14:41.5	15,281.5
End PTC Segment 5	05:01:43.0	18,103.0
Start Dipout 5	05:06:43.0	18,403.0
End Dipout 5 / Start PTC Segment 6	05:16:43.0	19,003.0
End PTC Segment 6	05:21:23.0	19,283.0
Second Restart – Stage II	05:37:13.0	20,233.0
Third Cutoff – Stage II (SECO-3)	05:40:27.3	20,427.3
DemoSat Spacecraft Separation	05:49:37.5	20,977.5

Boost Profile–Liftoff to Nanosat Separation



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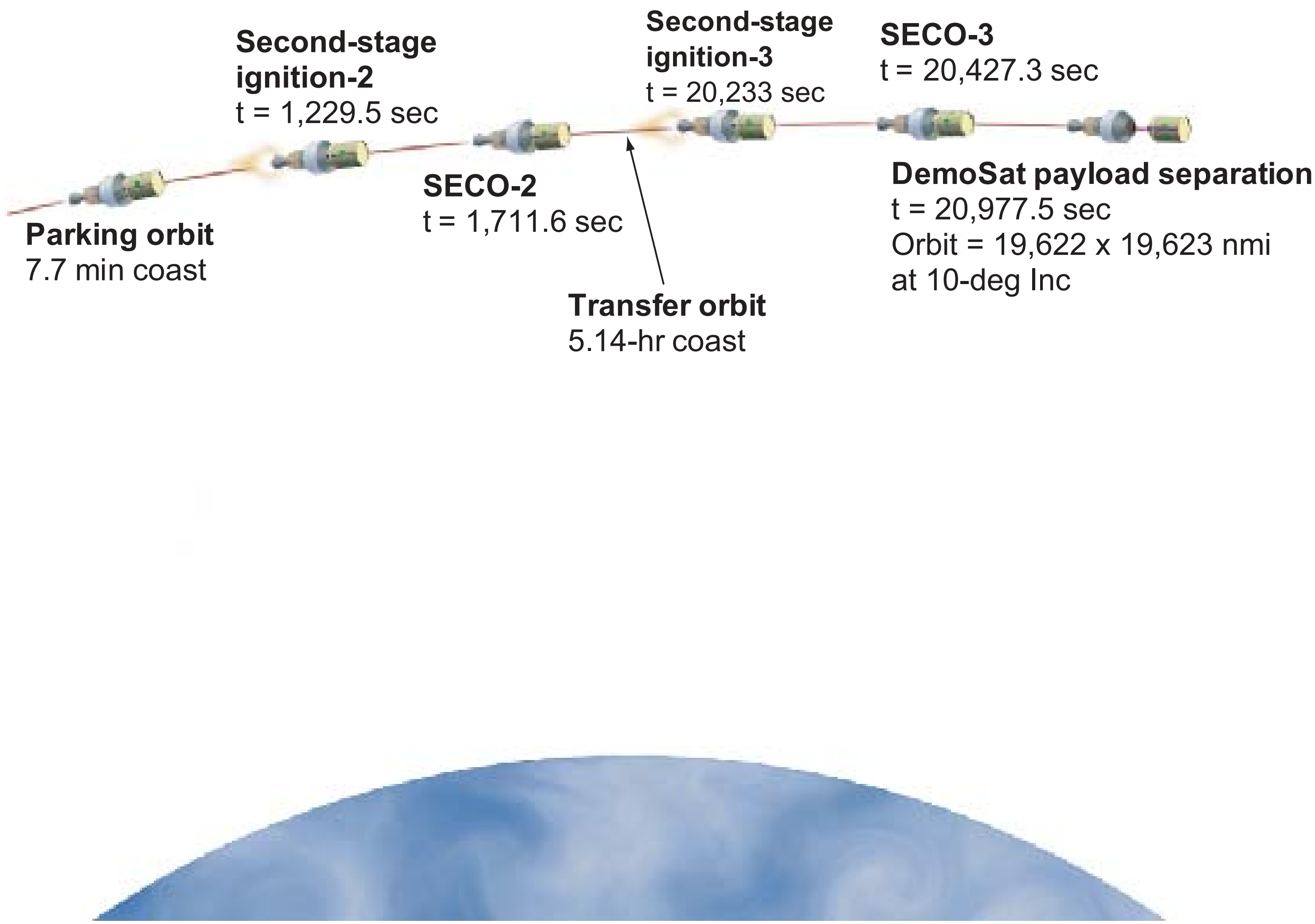
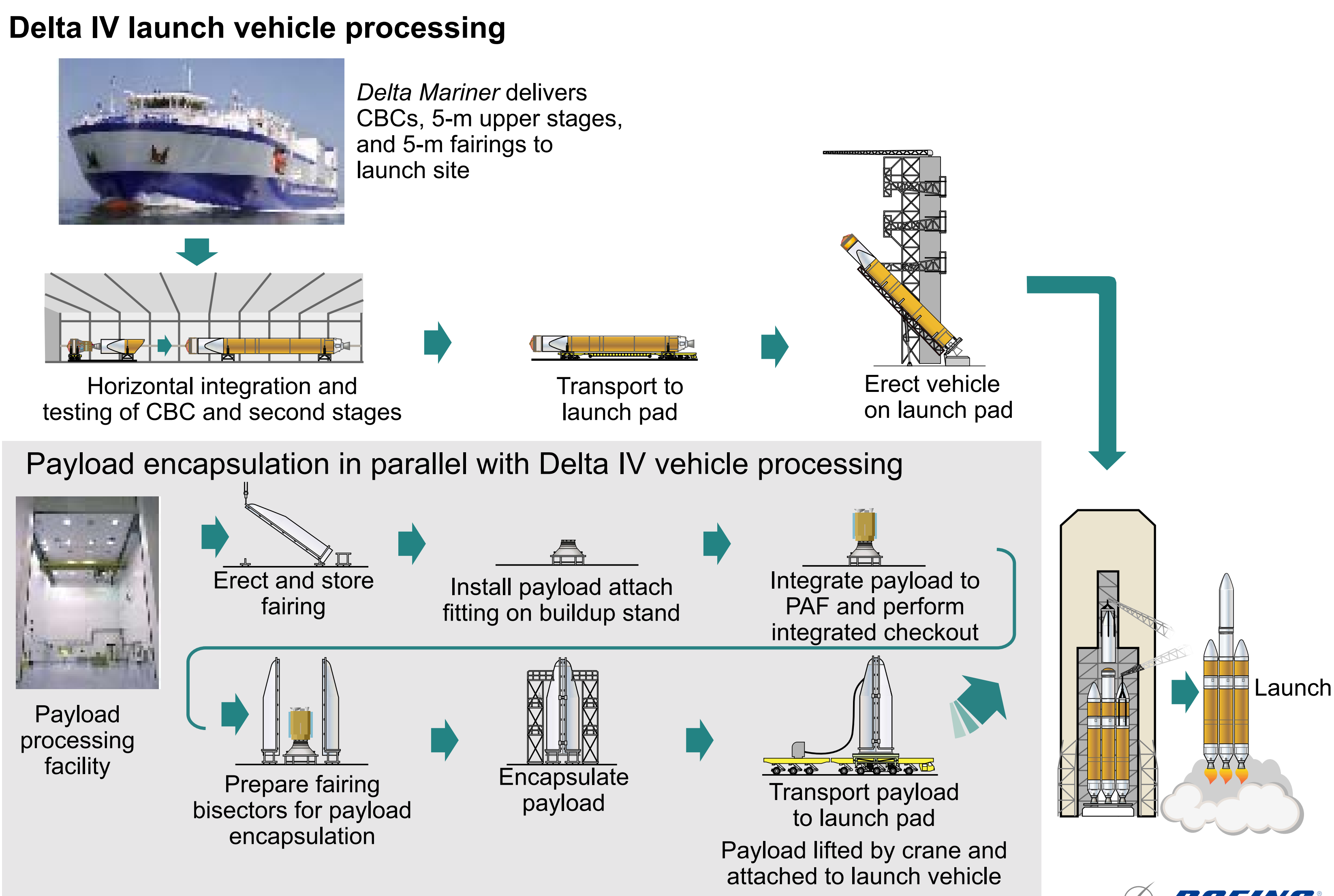
Boost Profile–Second-Stage Ignition-2



Delta IV Hardware Flow at CCAFS




DELTA IV
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• FIRST HEAVY LAUNCH • NRO • EELV • USAF
IV
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50 Years
AIR FORCE
Space & Missiles

Fact Sheet

Integrated Defense Systems
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Boeing Delta IV Heavy Demonstration Launch

Mission:	Delta IV Heavy Demonstration
Payloads:	DemoSat (Primary) Nanosat-2 (Auxiliary)
Date:	December 21, 2004
Time:	2:36 p.m. – 5:32 p.m. EST (two-hour, 56-minute window) Mission duration: five hours and 50 minutes
Launch Site:	Space Launch Complex 37B Cape Canaveral Air Force Station, Fla.
Launch Vehicle:	Boeing Delta IV Heavy Configuration • Three Boeing Common Booster Cores • Three Boeing Rocketdyne RS-68 Main Engines • Boeing Five-Meter Upper Stage/Payload Fairing • Pratt & Whitney RL10B-2 Upper Stage Engine • Height 232.6 Feet (Composite Fairing) • Weight 1,627,038 pounds (at liftoff)
Deployment:	Direct Insertion to Geosynchronous Earth Orbit (GEO)
Customers:	DemoSat U.S. Air Force Evolved Expendable Launch Vehicle Program NanoSat-2 Department of Defense Space Test Program Sponsored by the Air Force Research Laboratory
Overview:	The Delta IV Heavy will fly a demonstration mission for the EELV program that will carry a test payload, DemoSat, that is designed to simulate the size and weight characteristics of a typical heavy-class satellite to validate the performance of the Delta IV Heavy. In addition to DemoSat, the Delta IV heavy will carry an auxiliary payload called Nanosat-2, which are two smaller test satellites built by universities for the Air Force Space Test Program.

Contact:
Boeing Communications: (714) 896-1301
Boeing Launch Hotline: (714) 896-4770
Boeing Delta Web site: www.boeing.com/delta

LINKS

Boeing Delta Web Site

Boeing Launch Services Web Site

Patrick Air Force Base

Three Corner Sat team

Air Force Research Laboratory (AFRL)

Defense Advanced Research Projects Agency (DARPA)

Air Force Office of Scientific Research (AFOSR)

Air Force Space and Missile Command's Space Test Program (STP)

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DELTA IV HEAVY

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DECEMBER 2004

Delta IV Heavy Completes Demonstration!

Completed | December 21 2004 | BACK

On December 21st, 2004 at 4:50 p.m. EST, with a spectacular flash of fire and smoke, the Delta IV Heavy lifted off from the coast of Florida! The first launch of the Delta IV Heavy opened a new era in heavy lift capability for the US space program. Not since the Saturn program has a more powerful liquid -fueled rocket lifted off from Cape Canaveral Air Force Station, Fla. The Delta IV Heavy demonstration

DECEMBER 2004

AUG | SEP | OCT | NOV | DEC

MOVIES

- THE LEGACY CONTINUES
- DELTA IV HEAVY ROLLOUT
- DECATUR TO CCAFS
- WEBCAST REPLAY

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Welcome to The Delta IV Home Page

To get the full benefit of the Boeing Web site, you will need to download and install the latest version of the Flash player. If you were automatically redirected to this page, you either do not have the Flash plug-in or your Flash plug-in needs to be upgraded (if you believe you have reached this page in error, go directly to our Flash page). If you are using Internet Explorer, you also need to make sure ActiveX is enabled. This site also requires a JavaScript-enabled browser.

You can still view a text-only, printer-friendly, ADA-compliant, PDA-compatible web page by clicking on the links below.

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- GUIDANCE & CONTROL QUALS
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- ELECTRICAL COMPATIBILITY TEST
- 1ST POWER ON
- VEHICLE ON STAND (VOS)
- HEAVY LAUNCH VEHICLE PAD ACTIVATION
- HORIZONTAL INTEGRATION FACILITIES OPERATIONS

UPDATES

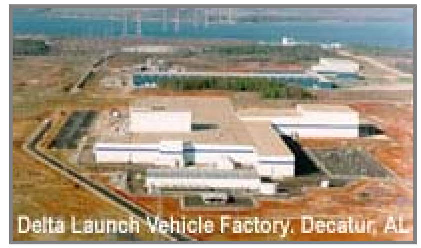
- USAF PRESS RELEASES
- HEAVY MISSION COMPLETED
- WEATHER DELAY
- LAUNCH RESCHEDULE III
- WET DRESS REHEARSAL #2
- LAUNCH RESCHEDULE II
- WET DRESS REHEARSAL #1
- SPACECRAFT ENCAPSULATION
- SECOND TANKING TEST

FIRST TANKING TEST

PARTNERS

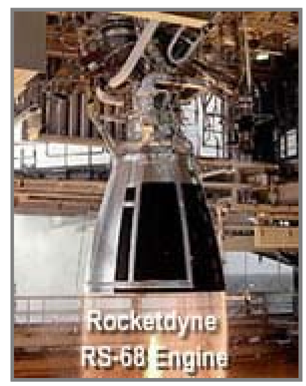
Alliant Composites	Cincinnati Electronics CMC	Goodrich Avionics	L-3 Communications	Air Force SMC
Air Force Space Command	EELV SPO(SMC/EV)	Hamilton Sundstrand	Moog Motion	Space Test Program
Air Force Research Lab	Foss Maritime	KAMAG	Parker Hannifin	Spincraft
Arrowhead Products	Goodrich FLSS	Ketema	Pratt & Whitney	USAF

About Delta IV Heavy


Delta Launch Vehicle Factory, Decatur, AL


SLC-37B, CCAFS, Florida

The Boeing Company's commitment to ensuring access to space is demonstrated by our family of reliable launch vehicles that enables a broad range of lift capabilities. The Delta family features an existing heavy lift launch vehicle configuration and a launch infrastructure allows spacecraft deployment to virtually any orbit. Boeing's Delta IV system design was directed toward producibility and reliability to meet the launch needs of all our customers. Boeing built a state-of-the-art, lean manufacturing Delta Launch Vehicle Factory in Decatur, Alabama, dedicated to the production, assembly, and testing of Delta launch vehicle hardware. Boeing built a modern, robust launch facility at Space Launch Complex 37B (SLC-37B) at Cape Canaveral Air Force Station (CCAFS), which includes the horizontal integration facility (HIF), dedicated to the final integration and testing of Delta IV vehicles. Boeing modified the SLC-6 complex at Vandenberg Air Force Base (VAFB) on the west coast of the United States (US) and is now capable of launching all Delta IV configurations. At SLC-6 Boeing built a HIF, nearly identical to the HIF at CCAFS, for the final integration and testing of launch vehicle hardware. Boeing designed and developed the RS-68 engine at our Rocketdyne facility using robust systems engineering processes and a comprehensive test program with test facilities in Palmdale, California and Stennis Test Center, Mississippi. The RS-68 is the first large, liquid booster engine developed in the US since the Space Shuttle main engine (SSME) over 20 years ago, with a significantly reduced parts count.


Rocketdyne RS-68 Engine


The Delta IV Heavy

Finally, Boeing designed, developed, and qualified the Delta IV Heavy configuration. The Heavy accommodates 5-m class spacecraft and can lift 12,757 kg (28,124 lbs) to a geosynchronous transfer orbit (GTO) of 185 km x 35,786 km (100 nmi x 19,323 nmi) @ 27.0 degrees inclination. The major components of the Delta IV heavy include: three common booster core (CBC) first stage boosters, each powered by a state-of-the-art RS-68 main engine, a single cryogenic second stage that integrates a 5-m-diameter fuel tank, powered by the RL10B-2 engine, and 5-m-diameter payload accommodations hardware.

The Boeing Company is currently evaluating performance improvement options to enable performance growth to meet the heavier lift requirements in support of the space exploration initiative.

Mission description

The Delta IV Heavy configuration can deploy large payloads to GTO, polar, sun-synchronous, planetary/escape and, as it will in its first mission, direct insert into geosynchronous Earth orbit (GEO).

In a typical GTO mission, the mission would include the first stage burn, one burn of the second stage, a short coast in a parking orbit, followed by a second burn of the second stage to establish an elliptical orbit of ~185 km x 35,788 km (100 nmi x 19,324 nmi) @ 27.0 degrees inclination followed by spacecraft separation. Following the acquisition of the spacecraft as the spacecraft nears apogee altitude, or the orbit location on the ellipse farthest away from the Earth, the propulsion system of the spacecraft would perform a series of burns and maneuvers to circularize and remove inclination from the orbit.

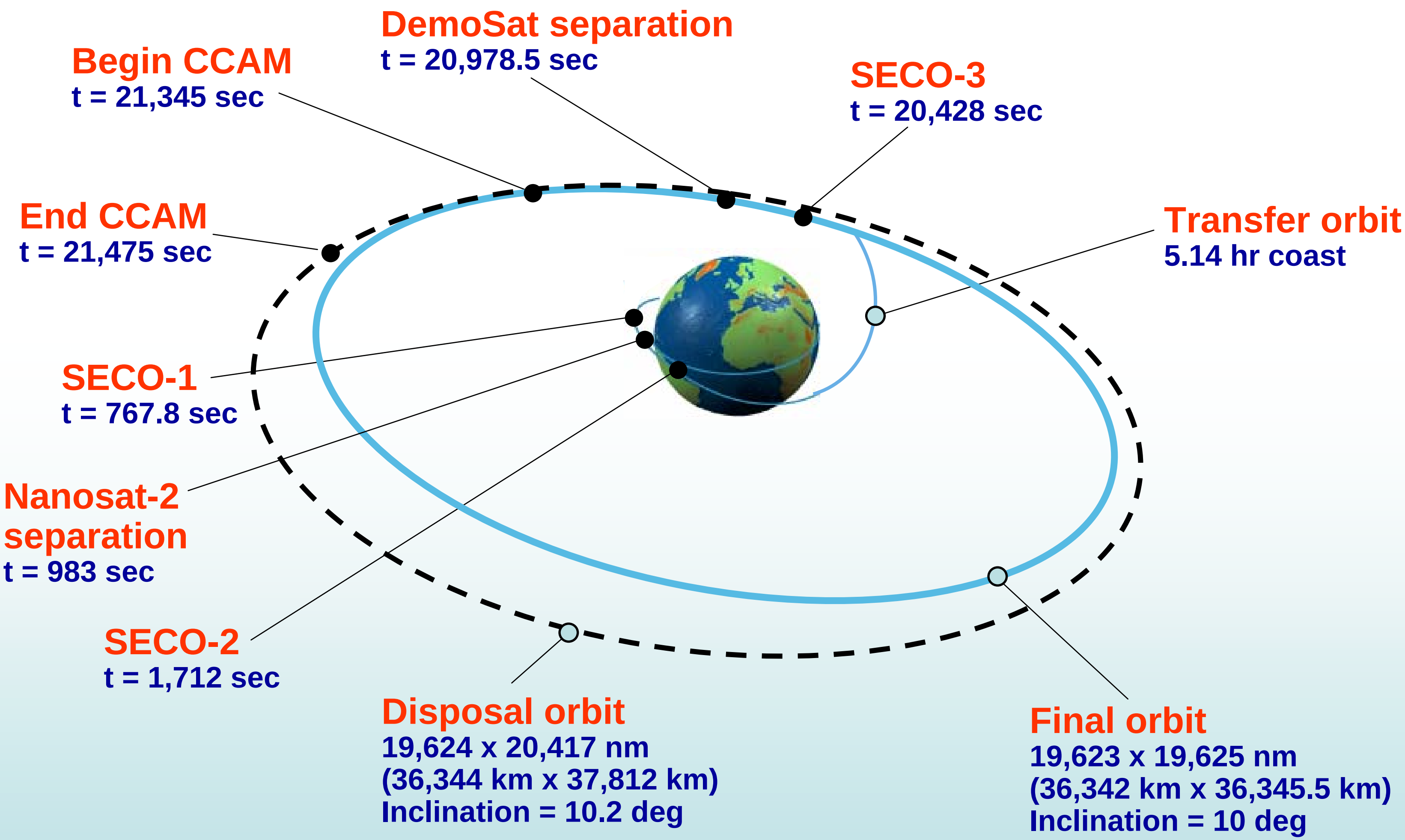
For the first launch of the Delta IV Heavy, the mission requirement is for the deployment of the DemoSat directly into GEO. The direct insertion of the DemoSat to GEO will demonstrate Delta IV capability to directly insert a payload to GEO to ensure future missions can be deployed to GEO.

For this GEO mission, the sequence would duplicate the GTO sequence up to spacecraft separation. In the GEO mission the payload would remain attached to the second stage in the elliptical transfer orbit and perform a long duration coast, just over five hours for the DemoSat launch. As the second stage and DemoSat near apogee, a third burn of the second stage occurs to establish a near circular orbit at geosynchronous altitude, followed by spacecraft separation. This additional maneuver performed by the Delta IV second stage is normally preformed by the spacecraft. By using the second stage to circularize the orbit, the spacecraft saves station keeping propellant and increases its on orbit lifetime.

A typical GEO is 35,786 km (19,323 nmi) circular @ 0.0 degrees. The Delta IV Heavy will deploy DemoSat into a near circular orbit of 36,341 km x 36,355 km (19,623 nmi x 19,630 nmi) @ 27.0 degrees to avoid any contact with a functioning satellite.

The capability and flexibility of the Delta Family ensures that Boeing can meet the current and future needs of our launch service customers far into the 21st century.

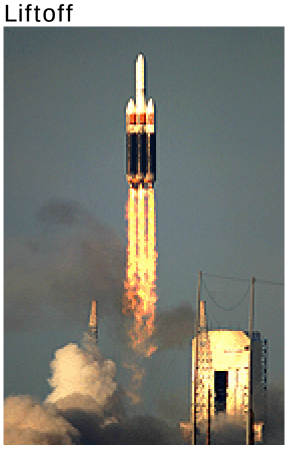
Delta IV Heavy Demo Orbit Profile



CCAM: Contamination and collision avoidance maneuver
SECO: Second stage engine cutoff

Total Mission Duration
5 hours 57 minutes 55 seconds

Milestones

Event	Completed	Comment
Liftoff 	21 Dec. 2004	On December 21 st , 2004 at 4:50 p.m. EST, with a spectacular flash of fire and smoke, the Delta IV Heavy lifted off from the coast of Florida! The first launch of the Delta IV Heavy opened a new era in heavy lift capability for the US space program. Not since the Saturn program has a more powerful liquid-fueled rocket lifted off from Cape Canaveral Air Force Station, Fla. The Delta IV Heavy demonstration mission is the first heavy-lift launch for the Air Force's Evolved Expendable Launch Vehicle (EELV) program. The demonstration mission carried a test payload, called DemoSat, designed to simulate the weight characteristics of a typical heavy-class satellite. In addition to the DemoSat payload, the Delta IV Heavy carried a secondary payload, Nanosat-2, built by university faculty and students, another first for the EELV program. The Three Corner Sat team is composed of students from the University of Colorado, at Boulder, Arizona State University, and New Mexico State University. Following the five-hour and 50-minute flight, the DemoSat payload was successfully separated, however, in a lower than expected orbit. A preliminary review of the data indicates that a shorter than expected first-stage burn led to the low orbit. According to the Air Force EELV program office, the primary flight objectives were accomplished in the all-up test of the new launch vehicle. The heavy boost phase, the new five-meter upper stage and five-meter payload fairing, extended coast, upper stage third burn and payload separation, and activation and usage of Space Launch Complex 37B for a Heavy launch were all successfully demonstrated. This demonstration launch is a major milestone for the EELV program, The Boeing Company, and numerous domestic and international suppliers and partners. Quote from Dan Collins, Vice President of Expendable Launch Systems: *"I want to thank our entire Delta team, including our government and industry partners. Their efforts, hard*

work and focus have once again moved our industry forward. We have a very happy and confident customer, thanks to all the hard work put in by this team."

Launch Readiness Review (LRR) — 9 Dec. 2004

The launch readiness review (LRR) is held on T-1 day. All agencies and contractors are required to provide a ready-to-launch statement. Upon completion of this meeting, authorization to enter terminal countdown is given.

Flight Readiness Review (FRR) — 6 Dec. 2004

The flight readiness review (FRR) defines the status of the launch vehicle after HIF processing and a mission analysis update. It is conducted to determine that the launch vehicle and payload are ready for countdown and launch. Upon completion of this review, authorization is given to proceed with the final phases of countdown preparation. This review also assesses the readiness of the range to support launch and provides predicted weather data. (FRR occurs at T-2 days.)

Wet Dress Rehearsal (WDR) #2 — 27 Oct. 2004

The test conducted on 10/27 is called a "Wet Dress Rehearsal" (WDR). This was the second and final WDR test of the Delta IV Heavy rocket. A WDR simulates an actual countdown scenario in which the launch team sits at their consoles and performs the sequence of events of the countdown. The test is called "Wet" because the launch team fuels the rocket with its propellants during this test. The team checks all the systems involved with the launch vehicle, spacecraft, and ground support equipment on the pad and at Delta IV's mission control center. The test concludes just prior to the point in time in which the team would normally ignite the engines for liftoff. The test results are currently being reviewed and will be confirmed in the coming days. Upon confirmation that all test objectives were successfully met, Boeing and the Air Force will confirm the launch date.

Encapsulated Spacecraft Hoist/Mate — 24 July 2004

The encapsulated DemoSat/Nanosat-2 is transported to the launch pad, hoisted by crane in the Mobile Service Tower (MST), and mated to the Second Stage.

Wet Dress Rehearsal (WDR) #1 ✔ 21 July 2004

The WDR is a similar exercise to the previously completed tanking tests, which load cryogenic propellants into the launch vehicle. For the WDR, all activities are accomplished according to the actual expected launch day timeline, including mission countdown stopping just prior to engine ignition.

Launch Site Readiness Review (LSRR) ✔ 9 July 2004

A key prelaunch review, part of our mission assurance process where we perform a comprehensive review of Spacecraft, Launch Vehicle, and all ground systems to verify readiness to transport the Spacecraft to the pad.

Spacecraft Encapsulation ✔ 7 July 2004

The 5-m-diameter payload fairing (PLF) bisectors are attached to the integrated payload attach fitting (PAF)/

DemoSat/Nanosat-2. The encapsulation is performed vertically inside the payload processing facility (PPF). The PLF then protects the spacecraft from external environments and maintains cleanliness during transportation to the launch pad and during flight.

Tanking Test #2

20 May 2004

Second exercise to load cryogenic propellants in the Delta IV Heavy Core and Strapons, and Second Stage. Verified ability to maintain RS-68 LO2 Turbopump temperatures. On 20 May 2004, the Delta IV Heavy launch vehicle successfully completed its second propellant-loading test.

The test was conducted to verify that all vehicle and ground equipment was operating correctly, to characterize the chilldown of the liquid rocket engines, refine the time it takes to load three CBCs concurrently, and train the crew for launch.This test will be followed by two wet dress rehearsals in which the actual countdown timelines will be used and validated.

Simulated Flight Test

20 Apr. 2004

A launch vehicle simulation of all events from liftoff, through DemoSat separation, continuing through the second stage collision avoidance maneuver. This test simulation verifies all launch vehicle software and electronic systems.

DemoSat mated to payload attach fitting

13 Apr. 2004

The DemoSat demonstration payload was mated to the Payload Attach Fitting using a clampband separation system at the Astrotech payload processing facility.

Tanking Test #1

9 Apr. 2004

First of several exercises to load cryogenic propellants in the Delta IV Heavy Core and Strapons, and Second Stage.

On 9 April 2004, the Delta IV Heavy launch vehicle's first propellant-loading test verified the simultaneous tanking of three Common Booster Cores (CBCs), the launch countdown crew's tasking and timing of various propellant-loading tasks, and the launch control system's automation capabilities.

After the vehicle was fully fueled, all first- and second-stage tanks were unloaded concurrently, flowing the hydrogen and oxygen propellants back into their storage tanks. The test is the first of two tanking tests, which will be followed by two wet dress rehearsals where actual countdown timelines will be used.

Guidance & Control Quals

18 Mar. 2004

Tests of the guidance control computers and the actuators used to gimbal the rocket nozzles and steer the vehicle during flight.

EMI/EMC Test

19 Feb. 2004

Tests to ensure the Delta IV Heavy vehicle is compatible with the Eastern Test Range electromechanical and radio frequency environment. The tests were conducted with

the Mobile Service Tower (MST) around the vehicle and away from the vehicle. Vehicle and Ground Support Equipment (GSE) were monitored to understand the effects of the various range transmitters as they radiated towards the rocket.

Electrical Compatibility Test

2 Feb. 2004

Verification of communications between the electronics boxes within the launch vehicle. Including both primary and secondary communications paths.

1st Power On

19 Dec. 2003

Initial verification of Delta IV launch vehicle and ground system interfaces. Verifies command and monitor capability between the vehicle on pad and the Launch Control Center (LCC).

Vehicle on Stand (VOS)

✓ 10 Dec. 2003

The launch vehicle (integrated 1st/2nd stages) is transported from the HIF to the launch pad, and erected using the Fixed Pad Erector (FPE).

Heavy Launch Vehicle Pad Activation

✓ 9 Dec. 2003

Completion of modifications to the launch pad that allow the Heavy Launch vehicle to be brought out and erected at the launch pad.

Horizontal Integration Facilities Operations

✓ 7 Dec. 2003

Completion of HIF activities which included attaching the two strap-on boosters to the common booster core (CBC), mating the Second Stage to the core CBC interstage, and attaching the CBC's to the Launch Mate Unit (LMU).

IAC-04-V.1.03

THE FLIGHT READINESS AND THE FUTURE OF THE BOEING DELTA IV HEAVY EXPENDABLE LAUNCH VEHICLE

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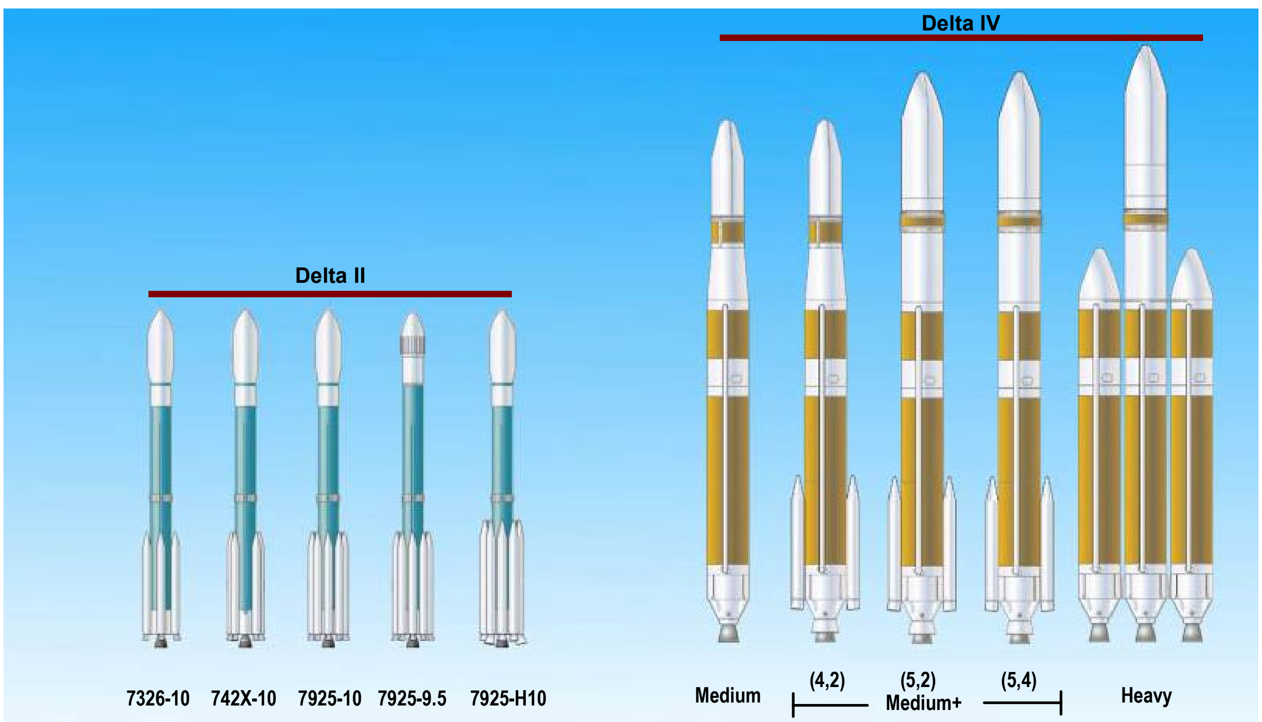
ABSTRACT

In early December 2003, the first Delta IV Heavy launch vehicle was successfully rolled out of the Horizontal Integration Facility (HIF) and erected on Space Launch Complex (SLC) 37 at Cape Canaveral Air Force Station, Florida. The vehicle remains on the launch pad, undergoing a series of launch readiness tests in preparation for liftoff on a qualification flight in the fall of 2004.

The Heavy launch vehicle represents the largest of the five vehicles of the Delta IV family, which consists of the Delta IV Medium, three Delta IV Medium vehicles with solid strap-on rocket motors (Medium-Plus variants), and the Delta IV Heavy.



	7326-10	742X-10	7925-10	7925-9.5	7925-H10	Medium	(4,2)	(5,2) Medium+	(5,4)	Heavy
GTO (kg)	894	1,032	1,759	1,832	2,133	4,231	5,941	4,869	6,822	12,757
LEO (kg)	2,472	2,880	4,598	4,783	5,648	9,106	12,305	10,616	13,864	21,892
GEO (kg)						1,138	2,036	1,686	2,786	6,276

GTO = 185 x 35,786 km at 28.7 deg Delta II and 27.0 deg Delta IV. LEO = 407 km circular at 28.7 deg.
GEO = 35,786 km circular at 0 deg

Figure 1. Family of Delta Launch Vehicles

All vehicle configurations utilize a common booster core (CBC). The Heavy employs two additional CBCs, serving as liquid rocket boosters for added payload capability. The vehicle measures 71.7 m in height when fully stacked with a payload.

This paper describes in detail the Delta IV Heavy launch vehicle and summarizes the flight readiness process in preparation for a successful flight, including wet dress rehearsals. A summary of the sequence of events of the Heavy qualification flight is also included.

INTRODUCTION

The Delta Launch Vehicle Family

The Delta family of launch vehicles has continued to evolve throughout its 40-year legacy to meet customers' growing needs. The successful Delta IV development represents the most dramatic change in capability during this Delta legacy.

As shown in Figure 1, Delta IV adds five vehicles to the Delta family: the Delta IV Medium, three Delta IV Medium vehicles with solid strap-on rocket motors (Medium-Plus variants), and the Delta IV Heavy with two strap-on common booster cores serving as liquid rocket boosters.

The Delta IV family is built on a solid foundation of heritage hardware and proven processes in manufacturing, quality, engineering, and supplier management. The Delta IV family evolves to expand the Delta capability while at the same time creating a robust system with improvements in producibility and operability. The primary avionics system, the 4-m fairing, the 4-m cryogenic second-stage tanks, and the second-stage engine are examples of heritage hardware carried into the Delta IV design. In addition, the strap-on solid rocket motors are derived from the smaller diameter solids used on Delta II and Delta III.

All configurations of the Delta IV family share the same first stage, the common booster core (CBC). The CBC consists of the interstage, liquid oxygen tank, centerbody, liquid hydrogen tank, engine section, and the United-States-developed RS-68 engine.

The RS-68 engine, clean and environmentally friendly, utilizes liquid oxygen and liquid hydrogen propellants producing more than 2918 kN of thrust (sea level).

The Medium-Plus variants consist of a CBC and either two or four 60-in.-diameter graphite-epoxy solid propellant strap-on motors. These motors are designed and manufactured by Alliant Techsystems and have both fixed and vectorable nozzle configurations. The Medium-Plus variants include either a 4- or 5-m-diameter fairing.

The second-stage Pratt & Whitney RL10B-2 engine derives its power from liquid oxygen and liquid hydrogen cryogenic propellants as well and is used on all Delta IV configurations. Producing 24,750 lb of thrust, the engine possesses an extendible nozzle designed for boost-phase environments and longer second-stage burn durations.

HEAVY LAUNCH VEHICLE—FIRST FLIGHT

Vehicle Description

The first-flight Heavy launch vehicle configuration consists of a 5-m-diameter composite payload fairing and the 5-m payload attach fitting assembly with the 1194-mm clampband (Figure 2). The second stage consists of a 5-m-diameter liquid hydrogen tank and the Pratt & Whitney RL10B-2 engine with an extendible nozzle. The interstage is the 5-m configuration. There are three CBC's—the starboard and the port strap-on boosters and the center core. The Boeing Rocketdyne RS-68 engine powers each CBC.

First Flight Objectives

The Heavy launch vehicle configuration can deploy large payloads to geosynchronous transfer orbit (GTO), polar, sun-synchronous, planetary/escape, and direct insert into geosynchronous Earth orbit (GEO).

The first mission, designated as "Heavy Demo," will directly insert a demonstration satellite (DemoSat) into GEO. The DemoSat weighs approximately 13,500 lb.

In addition to DemoSat, the Delta IV Heavy demonstration mission will fly an auxiliary payload for the Department of Defense (DoD) Space Test Program (STP). The STP provides space flight for research and development payloads approved by the DoD Space Experiments Review Board. The payload, NanoSat-2, is sponsored by the Air Force Research Laboratory and consists of a small constellation of two nanosatellites built by university students. The first payload was built by students from the University of Colorado, Boulder, while the second payload was built by students from Arizona State University in Phoenix. The two payloads weigh 24 kg and 21 kg, respectively.

The objectives of these two NanoSat-2 payloads are to demonstrate miniaturized component and collaborative formation flying of nanosat technologies, and to demonstrate a standard deployment system for future government small-satellite missions.

NanoSat-2 is attached to the side of the DemoSat during launch and ascent. After SECO-1, a separation signal is sent from the Delta IV and, 983 sec after launch, both payloads power on and separate from the DemoSat. The on-orbit lifetime of NanoSat-2 is estimated to be 0.5 to 2 days.

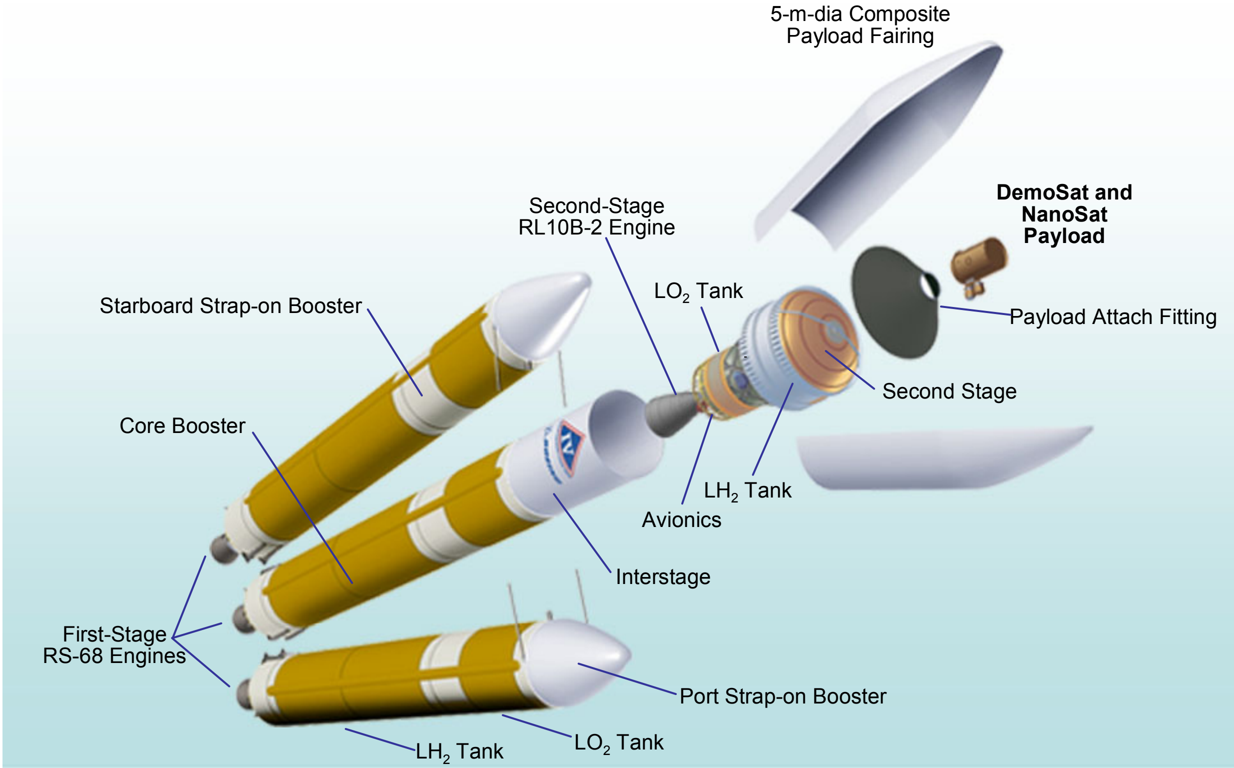


Figure 2. Heavy Demo Launch Vehicle Configuration

HEAVY VEHICLE PROCESSING

The first and second stages of the Heavy Demo mission completed mating operations in the Horizontal Integration Facility (HIF) on 7 December 2003. The Heavy vehicle then exited the HIF and rolled out to Space Launch Complex 37 at Cape Canaveral Air Force Station, Florida, on 9 December 2003. Modifications to the launch pad for the Heavy vehicle were completed and the vehicle was erected on the launch pad (Figure 3).

The electrical compatibility test was completed on 2 February 2004. This test verified the communications between the avionics boxes within the launch vehicle. Electromagnetic interference/electromagnetic compatibility (EMI/EMC) testing was completed on 19 February. This test ensured that the Heavy vehicle is compatible with the Eastern Test Range electromechanical and radio frequency environment. The tests were conducted while the Mobile Service Tower (MST) was around the vehicle as well as rolled back.

On 18 March 2004, qualification testing was complete for the Heavy vehicle guidance and control systems. The DemoSat payload was mated to the payload attach fitting on 13 April 2004 at the Astrotech facility using a clampband separation system (Figure 4).

On 20 April 2004, the Simulated Flight Test was completed. The purpose of this test was to check out vehicle hardware and software performance through the entire mission, from T-0 through the contamination and collision avoidance maneuver, post-spacecraft separation.

In early July the DemoSat encapsulation/fairing installation was completed. Figure 5 shows a fairing bisector in the vertical position being prepared for payload encapsulation.

All of these test activities played a vital role in the flight readiness process in preparation for a successful flight. To further enhance the flight readiness process before the simulated flight test occurred, a series of propellant-loading tests began.

HEAVY DEMO PROPELLANT-LOADING TEST SERIES

To demonstrate the physical and functional integrity and integration of the launch vehicle (LV), Launch Complex 37 Cape Canaveral Air Force Station, and the Launch Control Center (LCC) systems under prelaunch and post-abort conditions, a variety of tanking tests were planned for the Heavy Demo vehicle. Specifically, two cryogenic propellant-loading tests, along

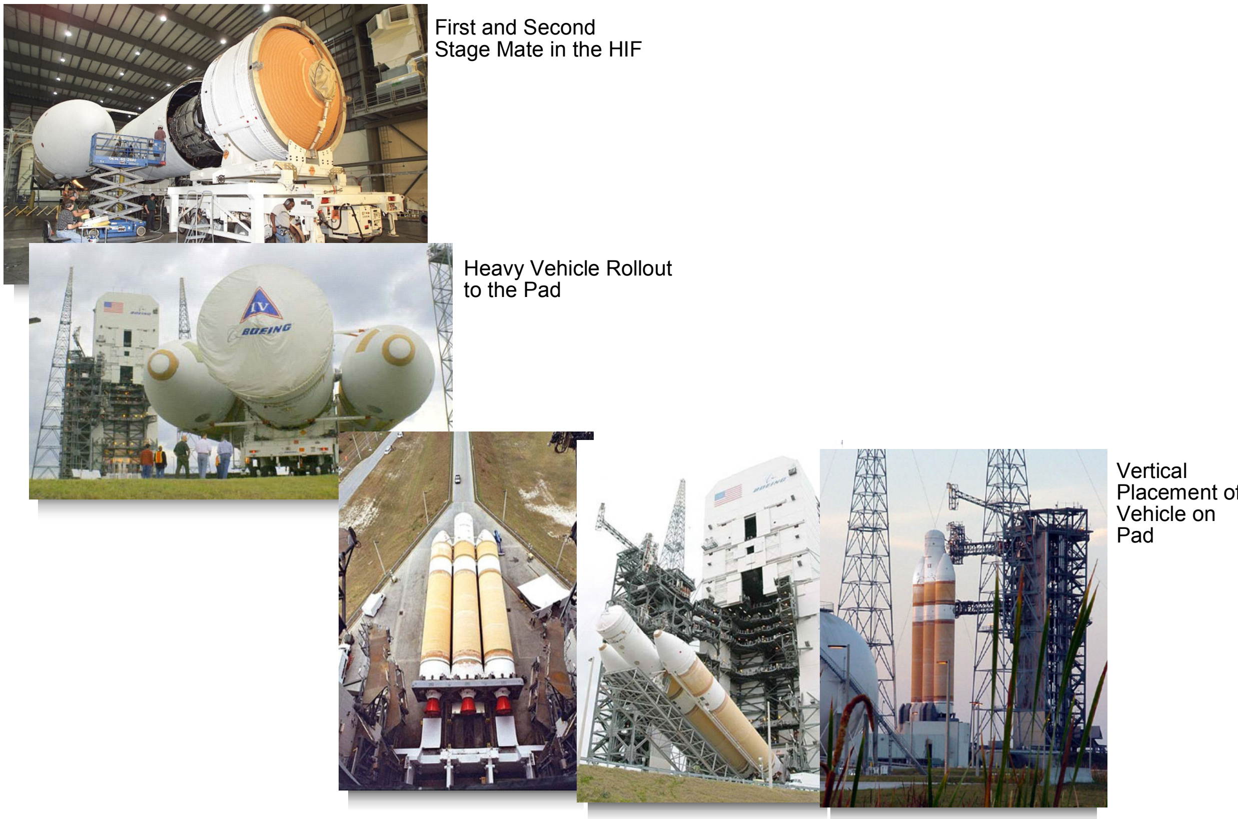


Figure 3. Heavy Demo Vehicle Processing

Figure 4. DemoSat and NanoSat-2 Mate to the Payload Attach Fitting

Figure 5. Payload Encapsulation

with two wet-dress-rehearsals have been scheduled. Figure 6 lists the primary and optional propulsion test objectives for each of the four tests. The standard countdown timeline was used as a model for the tanking tests and the wet dress rehearsals. Figure 7 shows the major sequence of events during the terminal countdown used for Wet Dress Rehearsal 1.

All Delta IV tanking operations are conducted at the LCC in Cape Canaveral. Design center support is provided by the Engineering Support Area (ESA), adjacent to the LCC, as well as by the Launch Support Center (LSC) in Huntington Beach, California.

Tanking Test 1

On 7 April 2004, the Delta team successfully performed the first tanking test of the Delta IV Heavy launch vehicle (Figure 8). In this test, the first-stage and second-stage propellant tanks were filled with liquid oxygen (LO_2) and liquid hydrogen (LH_2) tanks were filled with liquid hydrogen, automatic pre-pressurization and topping system checks were performed, ground umbilical lines were drained and refilled, and the stages were detanked and secured.

The following primary testing objectives were achieved:

- Simultaneous chill-down of the core, starboard, and port common booster core LH_2 and LO_2 tanks.
- Simultaneous propellant loading, slow and fast fill, of the CBCs.
- Fully automated, simultaneous LH_2 vent and relief testing of the CBCs.
- Verification of the Environmental Control System (ECS) heated nitrogen (GN_2) performance.

The following secondary testing objectives were achieved:

- Second-stage LH_2 and LO_2 tank chill-down and LH_2 propellant loading.

This test became the first time three CBCs were fueled simultaneously. Over 330,000 gal of liquid hydrogen and 126,000 gal of liquid oxygen were placed in the CBCs.

	Propulsion Objectives	Tanking Test No. 1		Tanking Test No. 2	Wet Dress Rehersal No. 1	Wet Dress Rehearsal No. 2
		CBC	DCSS			
1	Verify the functional and procedural readiness of the launch vehicle, Launch Control Center, Complex 37, and test personnel for loading operations	x		x	x	x
2	Demonstrate acceptable LH_2 vaporizer performance	x	o	x	x	x
3	Demonstrate acceptable LH_2 tank chill-down operation and thermal gradients	x	NA	x	x	x
4	Demonstrate acceptable facility LH_2 slow-fill/fast-fill operation first and second stages	x	o	x	x	x
5	Demonstrate acceptable vehicle LH_2 V/R and APC operation first and second stages	x		x	x	x
6	Demonstrate acceptable vehicle LH_2 topping operation first and second stages	x	o	x	x	x
7	Demonstrate acceptable LH_2 propellant conditioning/vent system performance	o	o	x	x	x
8	Demonstrate LH_2 detanking operation first and second stages	x	o	x	x	x
9	Demonstrate acceptable facility LO_2 slow-fill/fast-fill operation first and second stages	x	o	x	x	x
10	Demonstrate acceptable vehicle LO_2 V/R and APC operation first and second stages			x	x	x
11	Demonstrate acceptable vehicle LO_2 topping operation first and second stages	o	o	x	x	x
12	Demonstrate acceptable LO_2 propellant conditioning/vent system performance	o	o	x	x	x
13	Demonstrate LO_2 detanking operation first and second stages	x	o	x	x	x
14	Demonstrate LH_2 and LO_2 simultaneous tanking			x	x	x
15	Demonstrate differential thermal expansion is within allowable range	x	NA	x	x	x
16	Demonstrate RS-68 engine pre-start chill-down	q	NA	x	x	x
17	Demonstrate pre-pressurization is capable of maintaining stable flight ullage pressure			x	x	x
18	Demonstrate the integrity of control and instrumentation systems	x		x	x	x
19	Demonstrate acceptable facility helium system pressure and purge capability	o		x	x	x
20	Measure helium system blow-down characteristics	x	x	x	x	x
21	Demonstrate time-based LH_2 tank chill-down procedure		NA	x	x	x
22	Demonstrate tanking timeline			o	x	x
23	Demonstrate acceptable T-5 minute procedure			o	x	x
24	Demonstrate acceptable recycle procedure			o	x	x
25	Demonstrate acceptable ECS system performance	q		x	x	x

x—Primary test objective
o—Optional test objective
q—Quick-look at data for confidence in future operations

Figure 6. Primary and Optional Propulsion Test Objectives

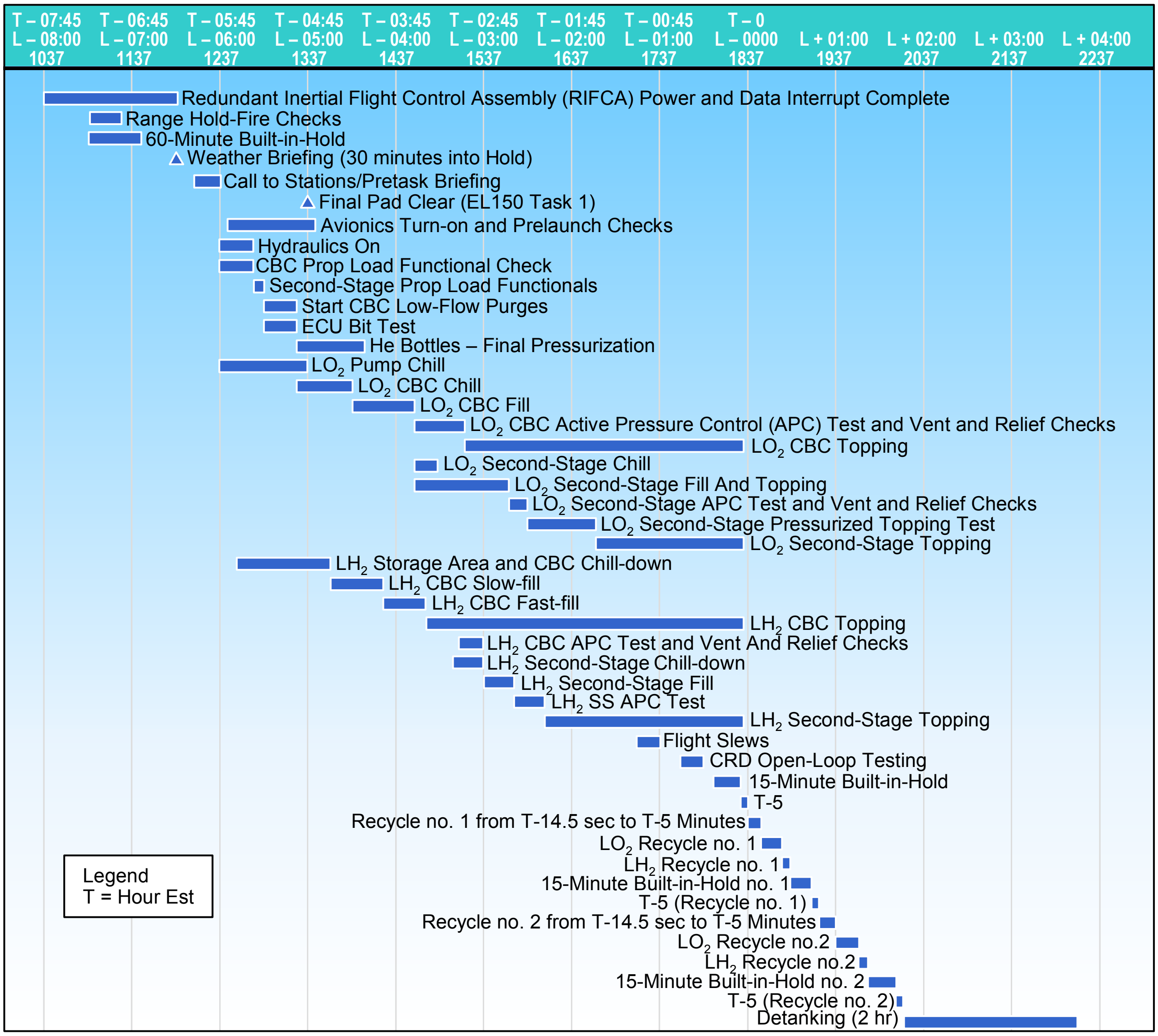


Figure 7. Wet Dress Rehearsal 1 Terminal Count

Tanking Test 2

On 20 May 2004, the Delta team successfully conducted the second tanking test of the Delta IV Heavy vehicle configuration (Figure 9). The team was able to characterize the chill-down of the RS-68 engines, refine the time to load the three CBCs concurrently, and train the crew for actual launch. After the entire vehicle was fully fueled, the team performed a series of propellant-conditioning tests, practiced launch countdowns, and conducted launch control system validation tests.

The primary test objectives achieved that were unique to tanking test 2 included:

- Simultaneous LO_2 tank vent and relief testing and topping.
- Second-stage LO_2 and LH_2 loading.
- RS-68 oxidizer turbopump (OTP) bearing chill-down (achieved on all engines with margin).
- Two T-5 minute simulations.

The secondary objectives achieved unique to tanking test 2 included:

- CBC topping with suppressed boiling by helium bubbling subcooling.
- Detanking with a reduced ECS flow rate to demonstrate a simulated failure of the heated GN_2 purge (engine section only).

Wet Dress Rehearsal 1

A successful Wet Dress Rehearsal was conducted on 21 July 2004. The primary test objectives achieved that were unique to Wet Dress Rehearsal 1 included:

Figure 8. Tanking Test 1 – Simultaneous CBC Loading

Figure 9. Tanking Test 2

- Validation of thermal modifications to the LO_2 skirt and centerbody Y-joint.
- Execution of two T-5-minute simulations.

The day-of-launch timeline could not be fully demonstrated due to the second-stage LH_2 fill/drain valve that failed to close during the test. This issue will be corrected before conducting the second Wet Dress Rehearsal. Also, the team observed that to prepare the vehicle for a second T-5-minute count within the planned 30 minutes, the propellant-topping flow rate would have to be increased.

Wet Dress Rehearsal 2

The Second Wet Dress Rehearsal is scheduled to be conducted in September. The primary objective of this rehearsal will be to fully validate the day-of-launch timeline (Figure 7).

Achieving the objectives of the propellant-loading test series will play a vital role in the successful inaugural launch of the Delta IV Heavy launch vehicle.

HEAVY DEMO MISSION PROFILE

The Heavy Demo mission is scheduled for an October 2004 launch from Space Launch Complex 37 at Cape Canaveral Air Force Station. The following discussion summarizes the main sequence of events.

Figure 10 shows the mission profile from liftoff to the secondary payload (NanoSat-2) separation event. The CBC core engine throttles down to minimum power level 55 sec after the vehicle lifts off the pad. The vehicle then experiences maximum dynamic pressure at 80.4 sec after liftoff.

Further in the count, the starboard and port CBC engines throttle down, cut off, and are then jettisoned at 247.9 sec following liftoff. The core CBC throttles up to full power level again until main engine cut-off (MECO) at T+332.7 sec. The first and second stages then separate, and the second-stage engine ignites. The fairing jettisons at T+363.5 sec and the second-stage engine cuts off (SECO-1) at T+767.8 sec.

Second-stage first burn places the vehicle in a 100 by 134.8 nautical mile (nmi) park orbit with an inclination of 28.8 deg. NanoSat-2 separates from the vehicle at T+983.0 sec.

The vehicle then coasts for 7.7 minutes and the second-stage engine is restarted (Figure 11). The second burn lasts approximately 483 sec, placing the vehicle in a 148.5 nmi by 19,685 nmi transfer orbit at 27.3 deg inclination.

In the transfer orbit, the vehicle coasts 5.14 hr until the second-stage engine reignites for the third and final time. The DemoSat payload is separated at T+20,978.5 sec in an orbit of 19,623 nmi by 19,625 nmi at a 10-deg inclination. An illustration of the Heavy Demo mission orbit profile is provided in Figure 12.

The flight readiness process and the propellant-loading test series will be key contributors to reaching this orbit profile and achieving ultimate mission success.

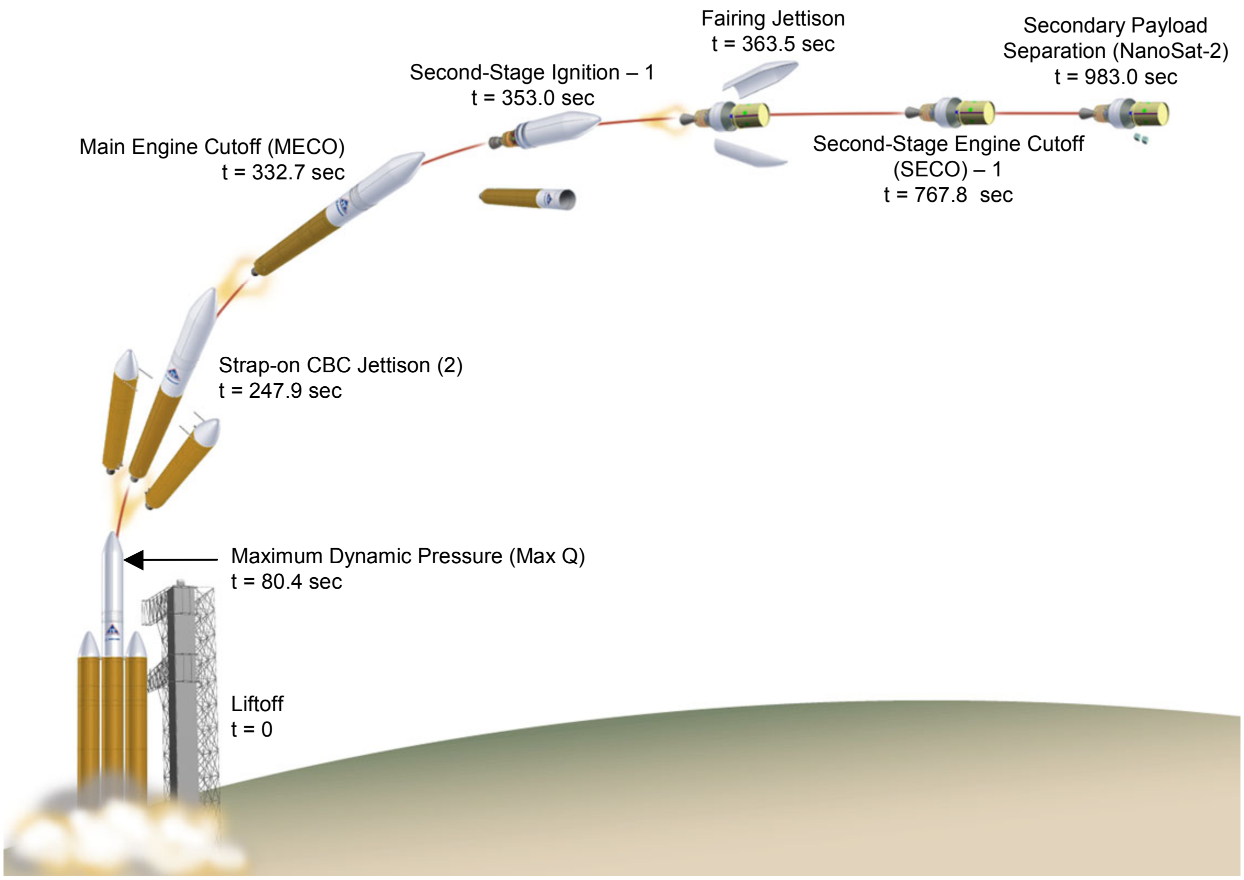


Figure 10. Liftoff to NanoSat-2 Separation

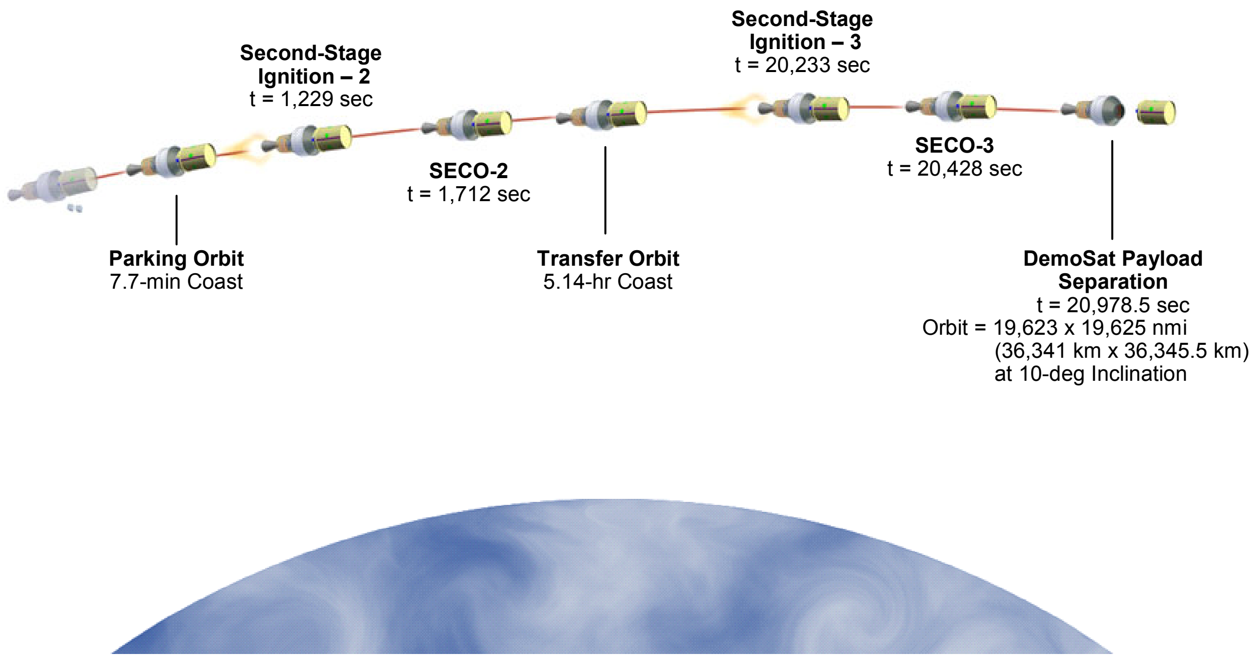


Figure 11. Second-Stage Ignition to DemoSat Separation

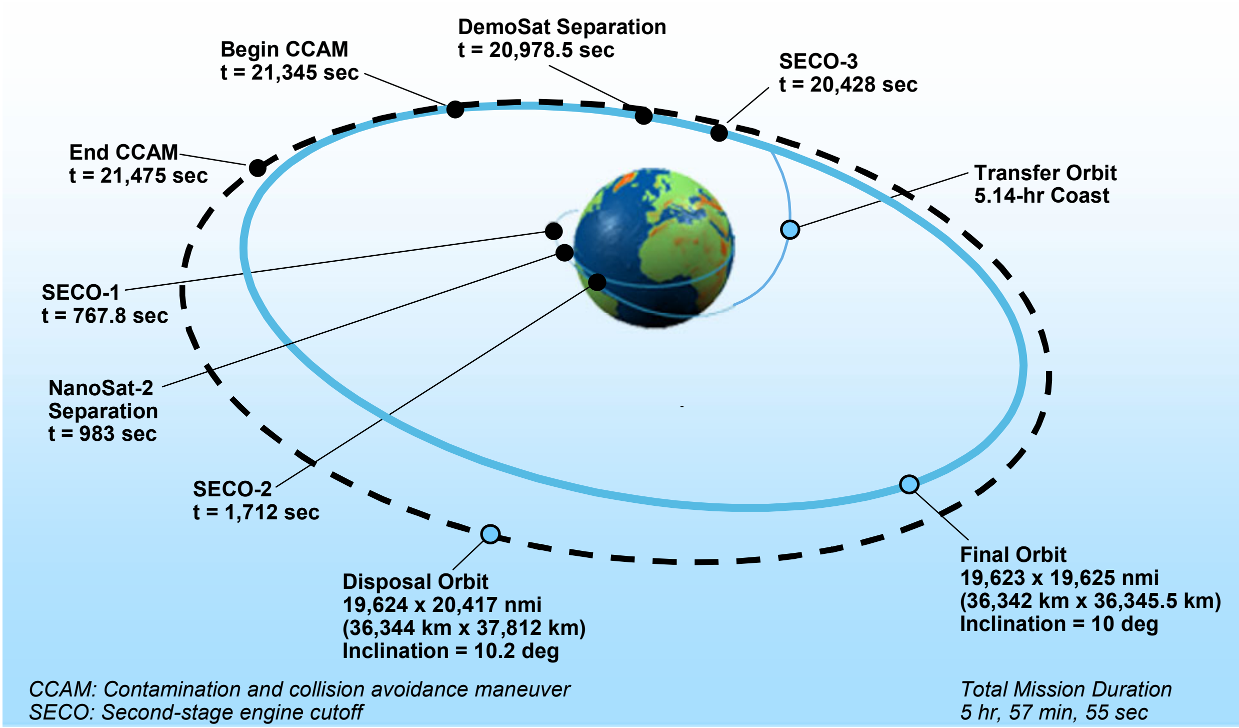


Figure 12. Delta IV Heavy Demo Orbit Profile

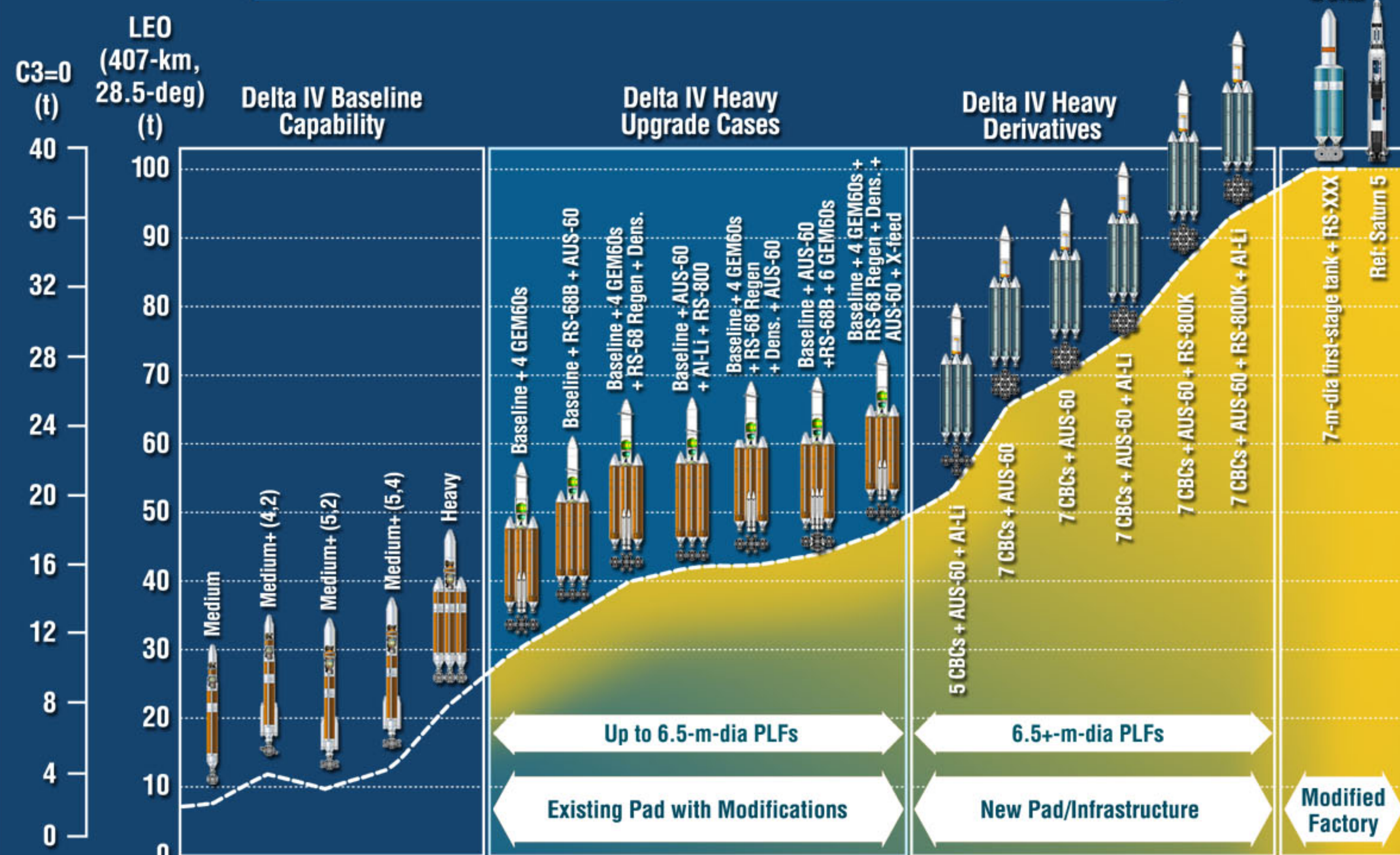
Delta IV Launch Vehicle and Spacecraft Processing

A unique aspect of Delta IV preparation for launch is that the core vehicle (not including the payload) is integrated horizontally, as opposed to vertical integration on most other launch systems. This approach provides for more efficient processing and less hazardous operations. Vehicle integration takes place in the HIF, which contains an integration support and test control area. The vehicle integration area includes two bays for parallel processing of launch vehicles.

Within the HIF, the Heavy launch vehicle stages (CBC and second stage) are joined together and attached to the launch mate unit (LMU). The LMU provides a physical interface between the vehicle and the launch pad. The combined vehicle undergoes testing in the HIF, where all systems are verified ready for launch. Once these efforts are complete, the integrated launch vehicle is transported horizontally to the launch pad and erected vertically using the fixed platform erector. Once in the vertical position, the encapsulated payload is hoisted in the mobile service tower and mounted atop the vehicle.

The demonstration payload for the Delta IV Heavy first launch, as is performed for all Delta IV mission, are encapsulated vertically at the payload processing facility. The process of encapsulating a payload at an offsite payload processing facility allows for a significant reduction in the amount of time an operational spacecraft would be required on the launch pad. This is a significant improvement over traditional launch pad operations, increasing personnel and equipment safety, while reducing exposure of the satellite and core vehicle to undesirable weather conditions.

Delta IV Heavy Growth Options for Space Exploration



AUS-60: Advanced Upper Stage, 60,000-lb thrust
RS-68 Regen: RS-68 main engine with regenerative nozzle
Dens: Cryogenic propellant densification
RS-68B: Upgraded RS-68 main engine
Al-Li: Aluminum lithium lightweight material

X-feed: Cryogenic propellant cross-feed from liquid strap-ons to center core
RS-800: New main engine
GEM60: 60 in. (1.5 m) dia graphite-epoxy motor
PLF: Payload Fairing

+ Visit the NASA Web Site

Boeing Launch Services

Delta IV Heavy Launch Vehicle

Providing Assured Access to Space

The Space Access Solution for the 21st Century

Delta IV Heavy Launch Vehicle

The Next Generation Heavy-Lift Launch Vehicle

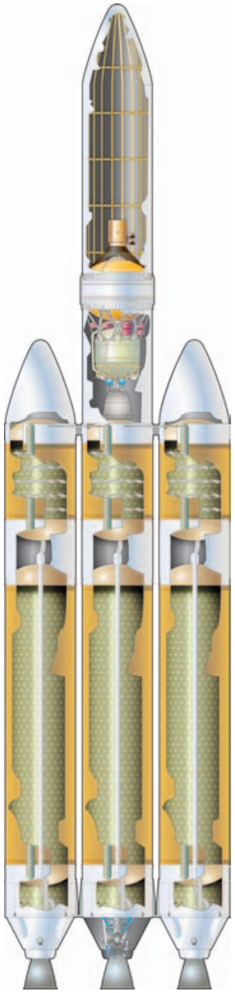
Delta IV Heavy

Providing Assured Access to Space

Developed in partnership with the U.S. Air Force Evolved Expendable Launch Vehicle (EELV) program, the Delta IV Heavy represents the next generation heavy-lift capability. The Delta IV Heavy vehicle accommodates 5-m-class spacecraft and can deliver payloads to any orbit and meet the needs of interplanetary missions. The major components of the Delta IV Heavy include three Common Booster Core (CBC) first-stage boosters, each powered by the first new U.S.-built engine in over 20 years, the RS-68; a single 5-m-diameter cryogenic second stage, powered by the RL10B-2 engine; and 5-m-diameter payload fairing and accommodation hardware.

To meet the evolving needs of our customers, Boeing is evaluating performance improvement options to enable performance growth sufficient to meet the heavier lift requirements of NASA's Vision for Space Exploration, as well as future National Security missions.

The Boeing Company's commitment to ensuring access to space is demonstrated by our state-of-the-art Delta manufacturing facility, an evolved family of launch vehicles, and extensive launch infrastructure that enables a broad range of lift capabilities. Delta IV offers design simplicity, manufacturing efficiency, and streamlined off-pad mission and vehicle integration, enabling rapid turnaround, near-day-of-launch spacecraft access, and 100% success for its first three launches.



Delta IV: A National Asset

Fully activated CCAFS and VAFB launch facilities

State-of-the-art lean manufacturing facility in Decatur, AL

RS-68 ñ first U.S.-built rocket engine in over 20 years

Delta IV ñ Ready, Heavy, Go!

Vehicle Performance	(kg/lb)
GEO 35,786 km circular at 0.0 deg	6,280/13,840
GTO 185 km x 35,786 km at 27.0 deg	12,760/28,120
LEO (Reference) 407 km circular at 28.7 deg	21,890/48,260
LEO (ISS) 407 km circular at 51.6 deg	21,890/48,260
C3 (Mars) 10.0 km^2/sec^2 at 27.0 deg	8,000/17,650
C3 (Reference) 0.0 km^2/sec^2 at 27.0 deg	9,590/21,140
C3 (Trans-Lunar Injection) -2.0 km^2/sec^2 at 27.0 deg	9,960/21,950

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Delta IV Heavy Mission Schedule – 17 December 2004

The launch team is now working to launch windows for the Delta IV Heavy vehicle on the 21 st & 22 nd December 2004. T he two hour and 56 minute (2:56) launch windows open at 2:36 pm EST and close at 5:32pm EST. The Delta IV Heavy vehicle will be launched from Cape Canaveral Air Force Station, Fla.

A launch readiness review is scheduled for 20 December 2004.

Boeing Launch Services will continue to update this website with the latest information about this important mission. For additional information, call the Boeing Launch Hotline for updates: (714) 896-4770.

Delta IV Heavy Mission Scrub – 12 December 2004

The launch of the Boeing Delta IV Heavy demonstration mission is being rescheduled. Engineers have resolved all issues related to launch delays over the weekend.

The launch team is now awaiting word on the first available date on the range at Cape Canaveral Air Force Station, Fla.

Boeing Launch Services will continue to update this website with the latest information about this important mission. For additional information, call the Boeing Launch Hotline for updates: (714) 896-4770.

Delta IV Heavy Mission Scrub – 11 December 2004

The first launch of the Delta IV Heavy vehicle was scrubbed and rescheduled to 12 December 2004. A problem with the Terminal Countdown Sequencer Rack (TCSR) a system that automates the final seconds of the countdown and significant upper level winds convinced the launch team to scrub the mission and re-schedule for Sunday 12 December 2004.

Launch teams are preparing for a Sunday December 12th launch with a two-hour and 56-minute window that opens at 2:32 p.m. EST.

Boeing Launch Services will continue to update this website with the latest information about this important mission. For additional information, call the Boeing Launch Hotline for updates: 714) 896-4770.

Delta IV Heavy Demonstration Weather Delay

The first launch of the Boeing Delta IV Heavy launch vehicle is being delayed due to adverse weather. The forecast gives just a 30 percent chance of acceptable conditions on Friday, December 10th due to the threat of strong winds, clouds, rain and lightning. The launch was scheduled for liftoff during a two-hour and 56-minute window that opened at 2:31 p.m. EST from Cape Canaveral Air Force Station, Fla.

Launch teams are preparing for a Saturday December 11th launch with a two-hour and 56-minute window that opens at 2:31 p.m. EST.

Boeing Launch Services will continue to update this website with the latest information about this important mission. For additional information, call the Boeing Launch Hotline for updates: 714) 896-4770.

Delta IV Heavy Demonstration Launch Reschedule III

The Delta IV Heavy Demonstration launch for the United States Air Force has been rescheduled from November 18 to December 10, 2004. The launch will take place from Cape Canaveral Air Force Station, Florida, with a 2 hour 56 minute launch window scheduled to open at 2:31 p.m. EST.

The revised launch date enables Boeing to perform necessary mission assurance activities related to launch vehicle impacts from the last hurricane and ensure all components and systems are ready for launch.

The next major mission assurance milestones are the Flight Readiness Review (FRR) on 8 December 2004 and the Launch Readiness Review (LRR) 9 December 2004.

Boeing Launch Services will continue to update this website with the latest information about this important mission. For additional information, call the Boeing Launch Hotline for updates: 714) 896-4770

Delta IV Heavy Demonstration Launch Reschedule II

The Delta IV Heavy Demonstration launch for the United States Air Force has been rescheduled from October 20 to November 18, 2004. The launch will take place from Cape Canaveral Air Force Station, Florida, with a 3 hour launch window scheduled to open at 2:28 p.m. EST.

The revised launch date takes into account lost time for launch site personnel securing the Delta Launch facilities, including the SLC-37B launch complex, against three consecutive hurricanes (Frances, Ivan and Jeanne), as well as post hurricane facility and launch vehicle inspections. It also provides time for the Delta IV team to perform minor vehicle hardware verification in preparation for launch, including removal and retest of Electronic Control Unit (ECU) boxes. In addition, the encapsulated payload is being de-mated from the Heavy Demo launch vehicle in order to remove and replace second stage ullage pressure transducers, and to ultrasonically inspect the composite Payload Adapter Fitting (PAF).

The next major mission assurance milestone is Wet Dress Rehearsal #2, currently scheduled for mid-October, delayed from September as a result of the hurricanes.

Boeing Launch Services will continue to update this website with the latest information about this important mission.

Delta IV Heavy Demonstration Launch Reschedule I

The Delta IV Heavy Demonstration launch for the United States Air Force has been rescheduled from September 10 to October 20, 2004. The launch will take place from Cape Canaveral Air Force Station, Florida, with a 2 hour and 42 minute launch window scheduled to open at 4:06 p.m. EDT.

The revised launch date takes into account lost time in securing the SLC-37B launch complex against Hurricane Charley, as well as providing the Delta IV team with sufficient time to perform some minor adjustments to the vehicle in preparation for launch. A second stage liquid hydrogen fill and drain valve will be replaced and thermal augmentation of the first stage umbilical interfaces will be performed with the vehicle on the pad.

The next major mission assurance milestone is Wet Dress Rehearsal #2, currently scheduled for mid-September. Boeing Launch Services will continue to update this website with the latest information about this important mission.

Delta IV Heavy completes Wet Dress Rehearsal #2

The Boeing Delta launch team conducted the second and final Wet Dress Rehearsal (WDR) of the Delta IV Heavy launch vehicle Wednesday, October 27th 2004, at Space Launch Complex 37B, Cape Canaveral Air Force Station, in Florida.

A WDR is a test in which the launch team sits at their consoles and performs the sequence of events of an actual countdown. The WDR is called "Wet" because the launch team fuels the rocket with propellants during the test. The team checks all systems involved with the launch vehicle, spacecraft and ground support equipment on the pad and at the Delta IV's mission control center.

The test concludes just prior to the point in time in which the team would normally ignite the engines for liftoff. The results of Wednesday's test are being reviewed and will be confirmed in the coming days.

"This rocket will launch on the day it is ready," said Dan Collins, vice president, Boeing Expendable Launch Systems. "We want to ensure that all the testing is completed and all systems are performing flawlessly."

WDR #2 represents the fourth tanking test performed on the Heavy Demo vehicle. After confirmation that all test objectives are successfully met, Boeing and the U.S. Air Force will confirm a launch date for the Delta IV Heavy Demonstration mission, which will carry the DemoSat test payload. DemoSat was designed to simulate a heavy payload in terms of weight and has no on-orbit function other than serving as a test payload to put the Heavy vehicle through its paces. Two smaller auxiliary payloads, called Nanosat-2, are integrated directly on the side of DemoSat and will be deployed around 16 minutes after launch. Nanosat-2 was built by three universities that will demonstrate technologies required for small satellite constellations.

Concurrent with the test, a media briefing on the Delta IV Heavy's upcoming mission was held at the Delta Operations Center . Participating were Collins; Lt. Col. James Planeaux, EELV program manager, U.S. Air Force; Mike Costas, RS-68 program manager, Boeing Rocketdyne; and Dennis Mills, RL10B-2 program director, Pratt & Whitney.

Wet Dress Rehearsal #1
Third Major Delta IV Heavy Tanking Test Completed

The third in a series of four critical pre-launch tanking tests was completed on July 21 to bring the Delta IV Heavy First-Flight vehicle one step closer to liftoff.

"This was a very successful test," observed an elated Dan Collins, Boeing Delta Programs vice president and program manager. "Hundreds of things had to go right for this test to be completed, and I am very pleased with the results. This was a great effort on the part of our Delta IV Heavy launch team."

This test was the first of two Wet Dress Rehearsals, where the entire rocket is fueled and the team proceeds through the terminal countdown until just prior to igniting the liquid rocket engines.

"During a Wet Dress Rehearsal, we adhere closely to the actual launch timeline to verify steps and procedures," Collins explained.

The Wet Dress Rehearsal began with the technicians and engineers moving the 33-story Mobile Service Tower north of the rocket. Beginning at the L-6 hour mark, the team then marched through the sequence of steps to load the three Common Booster Cores and Delta Cryogenic Second Stage.

Upon completion of fueling the entire vehicle, the team continued with the countdown to the timelines of the actual launch, including functional tests of the vehicle pressurization, control and arming systems.

Once the test objectives had been satisfied, de-tanking and vehicle systems-securing operations were initiated.

The Wet Dress Rehearsal confirmed the countdown timelines were correct and provided additional training for the crew, who will conduct the Heavy Vehicle launch. The test will be followed by mating of the satellite, one more Wet Dress Rehearsal and the final processing for launch later this summer.

Delta IV Heavy Team Completes Encapsulation of Payload

Another major milestone toward the inaugural launch of the Delta IV Heavy was completed July 7, 2004 with the successful encapsulation of the Delta IV Heavy Demonstration Satellite at the Astrotech facility in Titusville, Fla.

“We’re continuing our steady march toward first flight of the Delta IV Heavy launch vehicle with the completion of this latest milestone,” said Dan Collins, Delta vice president & program manager. “The Delta team is doing an excellent job of moving forward with our launch preparations.”

The Delta team placed two sectors of the composite fairing around the payload and secured them with over 600 fasteners to complete the encapsulation. This will be the largest payload fairing flown on the Delta IV to date and is approximately 19.2 meters (63-feet) tall and 5 meters (16 feet-7 inches) in diameter. The demonstration payload, with Nanosat-2 integrated, weighs 6123.5 kg (13,500 lbs.) and will imitate the center of gravity for satellites manifested for the Delta IV Heavy vehicle.

Nanosat-2, a secondary payload consisting of two nanosats, will fly attached to a pedestal that is mounted to the sides of the heavy demonstration satellite. The Nanosat-2 satellites were designed and built by a team of staff and students, one satellite from Arizona State University and the other by the University of Colorado at Boulder in conjunction with the Air Force Research Laboratory’s Space Vehicles Directorate. After deployment from the demonstration satellite, the Nanosat-2 will send data back to Earth on the performance of two low-shock satellite separation systems.

The Delta IV Heavy demonstration mission slated for late summer will illustrate the ascent environment of the Delta IV Heavy configuration. This configuration consists of three Common Booster Cores mated together with three Boeing Rocketdyne RS-68 engines that will create the thrust power of 33 Hoover Dams at liftoff. The vehicle’s performance will be monitored by ground and flight sensors, and contains five on-board cameras to look at critical aspects during flight.

Delta IV Heavy Passes Second Tanking Test

The Delta IV Heavy is another step closer to its inaugural launch with the successful completion of a second propellant loading test. Tanking Test #2 simultaneously transferred almost 1.4 million pounds of liquid hydrogen and liquid oxygen into the Delta IV's eight propellant tanks on 20th May 2004. The vehicle, based at Cape Canaveral Air Force Station, Fla., is scheduled for launch this summer.

At the initiation of the operation, the Delta team began chilling the ground and vehicle systems, then initiated loading of liquid hydrogen (LH2) and liquid oxygen (LO2) into their respective tanks within the three Common Booster Cores.

Once the CBC tanks were nearly full, the team began transferring LH2 and LO2 into the Second Stage tanks. Over 345,000 gallons of LH2 and 126,000 gallons of LO2 were transferred into the vehicle.

After the entire vehicle was fully fueled, the team performed a series of propellant conditioning tests, practice countdowns, and launch control system validation tests. Once the test objectives had been satisfied, detanking operations were initiated, unloading all eight tanks concurrently and flowing the propellant back into the LH2 and LO2 storage tanks.

The team conducted the tanking test to verify that all vehicle and ground equipment was operating correctly, to characterize the chilldown of the liquid rocket engines, refine the time it takes to load three CBCs concurrently, and train the crew for launch. This test will be followed by two wet dress rehearsals in which the actual countdown timelines will be used and validated.

First Tanking of a Boeing Delta IV Heavy Rocket Successful

Successfully completing the first of two tanking tests — on 9 April 2004 — gave the Boeing Delta team the opportunity to prove its day-of-launch countdown approach by verifying several key elements:

- The simultaneous propellant-loading of three Common Booster Cores (CBCs)
- The launch countdown crew's tasking and timing of the different propellant loading tasks
- A checkout of the launch control system automation capabilities that allow control over three CBCs at the same time

Once in service, the Delta IV Heavy will be the world's most powerful launch vehicle, able to place 28,950 pounds into geosynchronous transfer orbit. Built for the U.S. Air Force Evolved Expendable Launch Vehicle program, this mighty rocket is second only to the enormous Saturn V rocket of the country's Apollo moon landing program. This test became the first time three CBCs were fueled simultaneously. Together they make up the rocket's first stage. Over 330,000 gallons of liquid hydrogen and 126,000 gallons of liquid oxygen were placed in the vehicle. The team also loaded the second stage liquid hydrogen tank with 16,000 gallons. After the vehicle was fully fueled, all seven tanks were unloaded concurrently, flowing the hydrogen and oxygen propellants back into their storage tanks. The test was a resounding success and will be followed by another tanking test, then two wet dress rehearsals where the actual countdown timelines will be used.