Dynamic Design:
Launch and Propulsion

Genesis Launch Vehicle: The Delta Rocket

STUDENT TEXT

There are many rockets that have been used to launch vehicles into space. The United States used the Jupiter C to launch its first satellite, called Explorer I, in 1958. The Mercury Redstone launched the first American into space in 1961. The Delta scout made its debut in 1960. The Delta is one of the most successful rockets in history. It can be configured in several ways in order to meet the specification of a mission. The following details the launch vehicle used to lift Genesis away from the Earth and includes a history of the famous rocket.

Delta II 7326

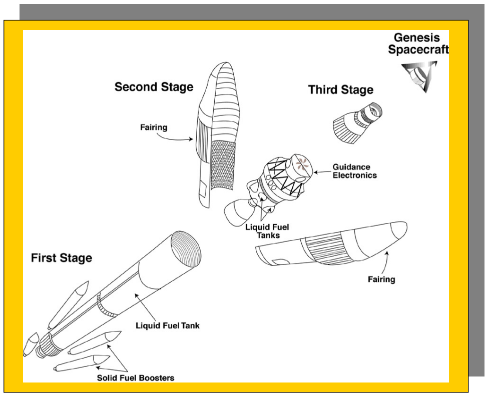
Watch a video of Kris Walsh and see a model of the launch vehicle for the Genesis spacecraft: the Boeing Delta II 7326. The number 7326 is a code that explains a bit of the history about the rocket. The first number, in this case the seven, stands for the fact that the first stage (bottom) of the Delta has been changed seven times. The second number, in this case the three, stands for the numbers of solid rocket boosters that are attached. The third number, in this case the two, means that the second stage (middle) has been changed twice. Finally, the last number, the six, represents the kind of third stage (top) present in the rocket. This rocket meets the mass and volume requirements for the Genesis spacecraft. The 7326 is smaller than the Delta II used by other Discovery missions to date. Table 1 below shows the launch vehicles used for the first five discovery missions.

Spacecraft mass and launch vehicle used for the first five Discovery missions. Based on the launch vehicle numbers, what can you tell about the Delta launch vehicles used by these discovery missions?

Table 1:

Discovery Mission	Spacecraft Mass	Launch Vehicle
NEAR	805 kg	Delta II 7925
Mars Pathfinder	890 kg	Delta II 7925
Lunar Prospector	1,896 kg	Athena II
Stardust	380 kg	Delta II 7425
Genesis	414 kg	Delta II 7326

The first stage is powered by the Boeing **Rocketdyne-built RS-27A** main engine, which is ignited at launch and burns for about four minutes. The first stage also contains three solid fuel boosters with ground lit **Graphite Epoxy Strap-on Motors** (GEM) that are ignited at liftoff and burn for about 66 seconds before they are separated from the vehicle. The liquid fuel in the first stage is kerosene and liquid oxygen. After the first stage burns for four minutes, a liquid-propellant engine that powers the second stage of the Delta II rocket is fired. The second stage can be turned on and off in order to orient the third stage into the proper orbit. For the Genesis spacecraft, the third stage contains a **STAR 37FM** motor. Once the second stage separates, the third stage solid rocket is fired and does not stop firing until the propellant runs out. After the spacecraft has been oriented into the proper trajectory the third stage is separated from the spacecraft.



The image at left shows the three stages of the Delta II rocket, as it appears when mated with the Genesis spacecraft. The Genesis spacecraft sits on top of the third stage, which includes 9.5-foot **fairings**. The solar panels are folded inward during the time in which it is in the rocket. Note that the fairings protect the Genesis spacecraft as well as the second and third stage of the rocket.

The Genesis spacecraft is launched from Cape Canaveral Air Force Station on launch pad 17 A. This launch pad is where all of the Delta rockets are launched. A lot of history has happened at this launch pad, according to author L.B. Taylor; visitors can see impressions of rockets on the north side of the pad. Near the launch pad there is an image of the red bellied woodpecker with a cross beside it, symbolizing a perfect launch.

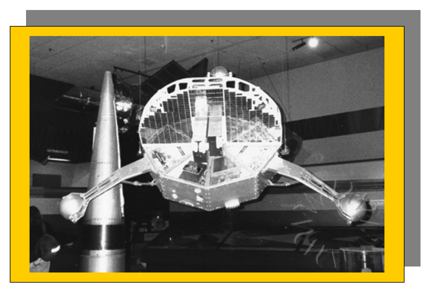
History of the Delta Rocket

The Delta rocket was derived from the Thor rockets used by NASA in the late 1950’s. The fourth modification to the Thor rocket caused NASA Director of Spacecraft and Flight Missions Milton Rosen to refer to the rocket with the Greek letter Delta. The name was officially adopted in January of 1959. In April of that same year NASA signed its first launch vehicle contract with Douglas Aircraft Company for 12 Delta Rockets.

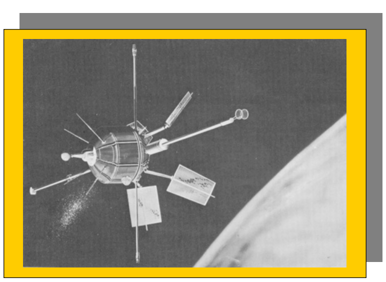
The Echo I satellite was launched in 1960.

The first Delta launch carrying the Echo Passive Communications Satellite failed on May 13, 1960 because the third stage did not ignite. However, the next 22 launches were successful. The first of these was the Delta 2, which carried the Echo I satellite into orbit on August 12, 1960. It reflected a radio message from President Eisenhower across the Nation, demonstrating the feasibility of global radio communications via satellites. The image at left shows technicians as they examine the Echo satellite payload. The 26-inch diameter magnesium sphere contains a balloon, which was launched into orbit, where it was released and inflated. The Echo I had a diameter of 30.48 meters and was the largest satellite launched at the time. Because it was so bright in the night sky, it was probably seen by more people than any other human made object. At the time, the newspapers printed the times that this satellite could be seen. In 1961, Belgian physicist, Barcel Nicolet studied the Echo satellite so closely that he could calculate the drag of the thin atmosphere in which the satellite was traveling. He was then able to calculate the density of this region known as the **heliosphere**

Other notable early launches included the Delta 8, which carried the first Orbiting Solar Observatory (OSO) on March 7, 1962. This was the first time the sun was studied beyond Earth’s atmosphere. The observatory, shown at right, helped scientists study the sun in the ultraviolet, x-ray and gamma regions of the spectrum.



The Orbiting Solar Observatory was the first time we could study the sun above the atmosphere.



The Ariel 1 was the first international satellite.

Sun sensors connected to servo-feedback systems on the upper "sail" portion were designed to keep the pointed instruments aimed toward the center of the sun. The lower spinning portion carried instruments and rotated once every two seconds, allowing those instruments to scan the solar disk and atmosphere. The OSO had three protruding arms that extended after deployment. Among many of the discoveries made from the observations by the battery of instruments on OSO was that the sun's corona had openings, now called coronal holes, which were interpreted as huge fast-moving bubbles rising through the corona.

Delta 9, launched on April 26, 1962, put the Ariel 1 into orbit. It was the first international satellite representing the efforts of the United States and the United Kingdom. This satellite studied the Earth's **ionosphere**, the part of the Earth's atmosphere in which ionization of atmospheric gases affects the propagation of radio waves, and extends from about 30 miles (50 kilometers) to the exosphere.

Although the Echo I could be used to reflect radio waves, the reflection was too weak to be used for anything except to demonstrate that it could be done. Delta 11 launched the first television satellite on July 10, 1962. The Telstar I was able to receive signals and amplify them before sending them back to Earth. The first transmission from Telstar I was a live television program that was transmitted from Maine to stations in England and France. From this point on communications became truly global.

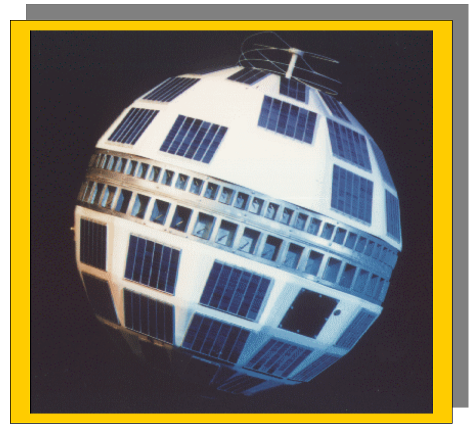

The Telstar I was the first communications satellite.

Table 2 shows the various models of Delta rockets, the year they were introduced and the payload capacity into either **Low Earth Orbit** (LEO) or **Geosynchronous Earth Orbit** (GEO). During the 1970's the Delta was famous for launching the Pioneer space probes, which NASA used to explore the outer planets of our solar system.

Over the years the Delta rockets have become larger and the payload capacity has increased. Solid rocket boosters were strapped onto the first stage to allow for more propellant to be used. Larger fuel tanks, an improved main engine, the addition of advanced guidance systems and the additional upper stages were all changes that led to this increase in size and payload capacity. In May of 1984, NASA transferred the Delta to a private company and by November of that year it was thought that the last Delta had flown. The space shuttle was to take over the task of transporting all of NASA's medium-to-heavy satellites into orbit. The *Challenger* explosion in 1986 changed everything. After the accident, the shuttle fleet was grounded, opening the door for the Delta to be used once again. As a result, the more powerful Delta II, which can be used as a two- or three-stage rocket, was produced in 1989. The three-stage Delta II is used to launch spacecraft into geosynchronous orbit or for deep space missions.

Table 2: Delta Rockets 1959-2002

Delta Model	Introduction Year	Payload Capacity into Low Earth Orbit (LEO) or Geosynchronous Earth Orbit (GEO) in kilograms
Original	1959	45.36 (LEO)
A	1962-1972	68.04 (LEO)
C	1963	544.31 (GEO)
D	1964	453.59 (LEO)
E	1965	Over 544.31 (GEO)
J	1968	544.31 (GEO)
M	1969	635.03 (GEO)
M6	1970	635.03(GEO)
900 series	1972	1678.29 (LEO)
2910	1974	1,995.81 (LEO)
3914	1975	929.86 (GEO)
3910/PAM D	1980	1,088.62 (GEO)
3920/PAM-D	1982	1,270.06 (GEO)
Delta II 7928	1990	1,814.37 (GEO)
Delta III	1998	3,810.18 (GEO)
Delta IV (heavy)	2002	23,042.49 (LEO), 13,585.09 (GEO)

Currently under development are the Delta IV medium to heavy rockets. The United States Airforce has ordered 19 Boeing Delta IV launches. The first commercial Delta IV launch is planned for the year 2001.

The Delta rocket has been a very reliable delivery system since 1960. To date there have been 283 launches of the Delta Rocket. Table 3 shows an overview of the launch history of the Delta rocket.

Table 3: Successes and Failures of all Delta Series Rockets 1959- Present

Year	Success	Failure
1960-1969	69	5
1970-1979	70	5
1980-1989	38	1
1990-1999	81	3
2000-2001	9	0

The Delta II has launched 93 payloads into orbit with only one failure and one that was partially successful.

Countdown To Launch

10, 9, 8, 7, 6, 5, 4, 3, 2, 1…Most people think of a launch as the ten seconds before liftoff. Getting a rocket off the ground is more than lighting the wick, standing back, and watching. More than a thousand people around the world are involved in the launch months or years prior to liftoff. Listen to audio files of Boeing Mission Integration Manager Kris Walsh explaining both the launch campaign and the role of the Mission Integration Manager. The launch campaign starts 45 days before launch with a pre-vehicle on-stand review. This is a four-to-six hour meeting in which all of the aspects of the building of the rocket and mission-specific analyses are discussed between Boeing, the Jet Propulsion Laboratory, and Lockheed Martin Astronautics. At the end of this meeting the three organizations concur that the vehicle is ready to go onto the stand. Then, 14 days before launch, a similar review is held in which a decision is made to put spacecraft onto the rocket. Five days prior to launch, a flight readiness review meeting is held in which Boeing, NASA Kennedy Space Center, the Jet Propulsion Laboratory, Lockheed Martin Astronautics, and the Air Force range, NASA headquarters, and mission assurance staff members review the entire process again. Then a poll is taken and if everyone agrees, fuel is loaded onto the second stage. This is an important decision, since once fuel is loaded, the rocket must be launched within the next 35 days, or the second stage will need to be taken down.

JPL/LMA

Lockheed Martin Astronautics workers assemble the Genesis spacecraft.

The **countdown** normally begins a day or two before launch. Two days prior to launch, a mission rehearsal is conducted in which a countdown is simulated with responses and use of equipment in the mission director's center. A launch readiness review is conducted in which the weather, range, and other issues with the vehicle and spacecraft are addressed prior to a "go for launch." The terminal phase of the countdown, which is familiar to most people, begins several hours before launch. The events that take place during a countdown are critical. Since no job can be rushed, if something needs to be reviewed or double checked, a hold is put on the countdown until it has been taken care of. Four hours prior to launch, everyone is on console when a very standard countdown begins. Following ignition and liftoff, the rocket clears the tower in just eight seconds. After this successful launch, the Boeing team did not cheer until the Genesis spacecraft was in its perfect orbit on its way to L1, the location where Genesis will collect solar wind.

NASA

Workers help guide the crane moving the spacecraft above the upper stage of the Delta rocket.

Let's look at what happens before the terminal phase. The various systems and subsystems of the rocket and spacecraft are assembled in different locations in the United States. The Genesis spacecraft was built at Lockheed Martin Astronautics located in Denver, Colorado. Once the spacecraft and systems for the rocket are built, they are flown into Kennedy Space Center on planes that land on the skid strip, which is a runway named for early missiles that landed on skids instead of wheels. Find the skid strip and Launch Complex 17 on a map of Kennedy Space Center on page 6 of this student text.

During the last two weeks, the exact weight of Genesis is measured so that the third stage can be balanced. The spacecraft is then mated to the third stage. The spacecraft, in the third stage, is transported to the rocket at night, moving no more than five miles per hour. Genesis is "under the hook" by 5:00 AM. The spacecraft in the can is lifted to a white room in which it stays for about 4 hours so any contamination in the white room can be filtered out. The spacecraft is then integrated, the canned segments are taken apart and electrical connections are made.

Finally the fairings are installed. The fairings have doors so that the spacecraft can be accessed. There are blankets attached to the fairings that have to be tied back because the Genesis spacecraft comes very close to the fairings. View images of technicians working on the Genesis spacecraft at: http://www.genesismission.org/mission/viewinggallery/index.html


NASA

The Genesis spacecraft being encapsulated inside the fairing.

The location to be used to launch Genesis is Complex 17, a large, fenced area of several acres. Both the Delta II and Delta III rockets are launched from this complex. There are two launch pads (17A and 17B), a blockhouse, ready room, shops and other facilities needed to prepare service and launch the rockets. Genesis is launched on pad 17 A. The pads are concrete-hard stands.


NASA

Launch Complex 17

The **gantry** is the highly visible service structure located next to the launch pad. It contains large cranes, which are used to erect the rocket. On the opposite side of the pad from the gantry is the umbilical tower. This tower has lines that are used to load propellant and other components into the rocket.

After fueling is completed and final systems checks have been made, a specialist in charge will give permission to "go" for launch. At this point the countdown is completely automated. There is no person that pushes the launch button. If trouble develops, even at a fraction of a second before launch, the computer senses it and the engines are shut down. During a successful launch the temperature on the pad can be over 1900 degrees Celsius (3,452 degrees Farenheit). There are special heat resistant surfaces placed around equipment for protection. Thousands of gallons of water are also poured onto the launch pad to help sound abatement and to cool it down. The water dumped on the pad is momentarily turned to steam which is invisible. The force of the rocket exhausts blasts it away into the cooler air around the pad, causing the steam to condense as small water droplets, forming the familiar white cloud.


NASA

The first stage of a Delta II rocket is lifted up the gantry.

Genesis will employ a single boost-to-orbit trajectory with a flight **azimuth** of 95 degrees. At 35.6 seconds after launch, the rocket will reach **Mach 1**. At just over one minute into the launch, the solid motors burn out and are separated from the rocket. The next significant event is main engine cutoff, which occurs at four minutes after launch. Eight seconds later, the first and second stage then separate, followed by the ignition of the second stage. The payload fairing is then jettisoned at the five-minute mark, followed by the second engine cutoff five minutes later. After the second stage is restarted, the third stage is separated from the second. The third stage burn places the spacecraft into the desired orbit.