National Aeronautics and Space Administration

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Dawn Launch

Mission to Vesta and Ceres

www.nasa.gov

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Media Services Information

NASA Television Transmission

The NASA TV Media Channel is broadcast as an MPEG-2 digital C-band signal accessed via satellite AMC-6, at 72 degrees west longitude, transponder 17C, 4040 MHz, vertical polarization. In Alaska and Hawaii, it's available on AMC-7 at 137 degrees west longitude, transponder 18C, at 4060 MHz, horizontal polarization. A Digital Video Broadcast-compliant Integrated Receiver Decoder is required for reception. For digital downlink information for NASA TV's Media Channel, access to NASA TV's Public Channel on the Web and a schedule of programming for Dawn launch activities, visit **www.nasa.gov/ntv**.

Media Credentialing

Journalists who wish to cover the launch of Dawn at NASA's Kennedy Space Center must contact the KSC Newsroom by close of business July 2, 2007. Accreditation questions should be directed to Laurel Lichtenberger, KSC Media Accreditation Officer, telephone 321-867-4036. News media may apply online at **https://media.ksc.nasa.gov**.

Briefings

A pre-launch news briefing to discuss launch, spacecraft readiness and weather will be held at NASA's Kennedy Space Center at 1 p.m. EDT on Sept. 24. A replay of an earlier briefing on the mission's science will immediately follow this pre-launch briefing.

All briefings will be carried live on NASA Television and on voice circuits provided to on-site news media.

Launch Status

Recorded status reports will be available beginning two days before launch at 321-867-2525 and 301-286-NEWS.

Internet Information

News and information on the Dawn mission, including an electronic copy of this press kit, news releases, fact sheets, status reports and images, are available from the NASA Web site at **www.nasa.gov/dawn**.

Detailed background information on the mission is available from the Dawn project home page at **dawn.jpl.nasa.gov**.

Quick Facts

Spacecraft

Dimensions: 1.64 meters (5.4 feet) long, 1.27 meters (4.2 feet) wide and 1.77 meters (5.8 feet) high. High-gain antenna is 1.52 meters (5 feet) in diameter. When deployed, solar array is 20 meters (65 feet) long tip to tip
Weight: 1,217.7 kilograms (2,684.6 pounds) at launch, consisting of 747.1-kg (1,647.1-pound) spacecraft, 425 kg (937 pounds) xenon propellant and 45.6 kg (100.5 pounds) hydrazine propellant
Power: Two 8.3-meter-by-2.3-meter (27-foot-by-8-foot) solar panels, together providing more than 10 kilowatts, depending on distance from sun. Each wing weighs almost 63 kilograms (139 pounds). Power storage via 35-amp-hour rechargeable nickel hydrogen battery

Ion Propulsion System

Number of thrusters: 3
Thruster dimensions (each): 33 centimeters (13 inches) long, 41 centimeters (16 inches) in diameter
Weight: 8.9 kilograms (20 pounds) each
Fuel: 425 kilograms (937 pounds) of xenon propellant
Spacecraft acceleration via ion propulsion: 0 – 60 mph in 4 days
Thrust: 19 to 91 millinewtons (0.07 to 0.33 ounce)
Estimated days of thrusting for entire mission: 2,000

Mission

Launch period: Sept. 26-Oct. 15, 2007
Launch window: One per day, ranging from 19 to 44 minutes each
Launch window for Sept. 26: 7:25 to 7:54 a.m. EDT
Launch site: Cape Canaveral Air Force Station, Fla., Pad 17B
Launch vehicle: Delta II Heavy 2925H-9.5 including Star 48 upper stage
Earth-Vesta distance at time of launch: 324 million kilometers (202 million miles)
Mars gravity assist: Feb. 4, 2009
Vesta arrival: Aug. 14, 2011
Distance traveled by spacecraft Earth-Vesta: 2.8 billion kilometers (1.8 billion miles)
Vesta departure: May 22, 2012
Ceres arrival: Feb. 1, 2015
Distance traveled by spacecraft Vesta to Ceres: 1.6 billion kilometers (990 million miles)
Total distance spacecraft traveled from Earth to Vesta to Ceres: 4.9 billion kilometers (3 billion miles)
End of mission: July 2015

Program

Cost: $357.5 million total (not including launch vehicle), consisting of $281.7 million spacecraft development and $75.8 million mission operations

Why Dawn?

During its nearly decade-long mission, the Dawn mission will study the asteroid Vesta and dwarf planet Ceres, celestial bodies believed to have accreted early in the history of the solar system. The mission will characterize the early solar system and the processes that dominated its formation.

During the earliest epochs of our solar system, the materials in the solar nebula varied with their distance from the sun. As this distance increased, the temperature dropped, with terrestrial bodies forming closer to the sun, and icy bodies forming farther away.

The asteroid Vesta and the recently categorized dwarf planet Ceres have been selected because, while both speak to conditions and processes early in the formation of the solar system, they developed into two different kinds of bodies. Vesta is a dry, differentiated object with a surface that shows signs of resurfacing. It resembles the rocky bodies of the inner solar system, including Earth. Ceres, by contrast, has a primitive surface containing water-bearing minerals, and may possess a weak atmosphere. It appears to have many similarities to the large icy moons of the outer solar system.

By studying both these two distinct bodies with the same complement of instruments on the same spacecraft, the Dawn mission hopes to compare the different evolutionary path each took as well as create a picture of the early solar system overall. Data returned from the Dawn spacecraft could provide opportunities for significant breakthroughs in our knowledge of how the solar system formed.

To carry out its scientific mission, the Dawn spacecraft will carry three science instruments whose data will be used in combination to characterize these bodies. These instruments consist of a visible camera, a visible and infrared mapping spectrometer, and a gamma ray and neutron spectrometer. In addition to these instruments, radiometric and optical navigation data will provide data relating to the gravity field and thus bulk properties and internal structure of the two bodies.

Asteroids

Large, rocky bodies that orbit the sun are known as asteroids or minor planets. They are smaller than planets or dwarf planets -- both of which are large enough to assume near-spherical shapes -- but are larger than meteoroids, which are usually defined as being 10 meters (about 33 feet) across or smaller. In addition, asteroids are distinguished from comets, which are identified by the fact that they have a visible coma (or atmosphere) and/or a tail. Asteroids can range from the size of a house to objects the size of Vesta -- about 530 kilometers (330 miles) in diameter.

The scientific interest in asteroids is due largely to their status as the remnant debris from the processes that formed the bodies of the inner solar system. Because some asteroids can collide with Earth, they are also important for having significantly modified Earth's biosphere in the past. In addition, asteroids offer a source of volatile compounds and a rich supply of minerals that can be used in human exploration of the solar system.

Main Asteroid Belt

There is a region in the solar system – between Mars and Jupiter – where hundreds of thousands of small bodies orbit the sun. Known as the main asteroid belt, this zone consists of rocky bodies that formed about 4.5 billion years ago, at the same time and in similar environments as the bodies that grew to be the rocky inner planets, Mercury, Venus, Earth and Mars. Scientist believe that when all the mass of the main asteroid belt is added together, there is more than enough to make a healthy-sized planet. So why did these space rocks not work together and ascend the mighty ziggurat of celestial analogues?

Blame it on Jupiter.

Jupiter is more than the top god of the ancient Romans and the fifth planet from the sun. Jupiter is an enormously massive gravity well that tugs at literally everything in the solar system. And the closer you are, the more influence Jupiter's gravity has on you.

The space rocks between Mars and Jupiter were closest of all. Thus, even though they had all the celestial ingredients to form another planet, the gravitational tug of Jupiter denied them the chance of becoming more than the vast rubble field we call the asteroid belt.

Denied the opportunity to fulfill such a destiny, Ceres and Vesta became the two most massive remnants of this epoch of the planet-forming phase of the solar system. Ceres alone accounts for about one-third of the estimated mass of all of the solar system's asteroids, while Vesta's mass is almost one-third that of Ceres.

But all conditions are not benign in the main asteroid belt. Each asteroid is on its own orbital path around the sun and, every once in a while, two asteroids try to be in the same place at the same time. This celestial pinball, and the resulting collisions, can hurl small fragments far beyond the belt. In some cases, these small fragments make their way into the inner solar system where some become meteors hurtling across our sky -- and even fewer survive as meteorites which make it to Earth's surface.

Dwarf Planets

In August 2006 the International Astronomical Union created a new category of celestial body, "dwarf planets." The objects in this category are smaller than planets but larger than asteroids. In order to qualify as a dwarf planet, an object must meet four criteria. First, it has to be in orbit around the sun. Second, the body has to have sufficient mass so its own gravity causes it to assume a near-spherical shape, just like the larger planets. But, third, the body must not have swept clean the neighborhood around its orbit -- which is the feature that distinguishes these minor planets from their bigger siblings. And, fourth, the body must not be a satellite (or moon) or a planet.

The first objects to be designed dwarf planets in 2006 are Ceres, Pluto and Eris. Discovered in 1801, Ceres was at first considered a planet, later classified as an asteroid, and more recently as a dwarf planet. Pluto was discovered in 1930 and was considered a planet for more than 75 years until its reclassification in 2006. Eris was discovered in 2005 from images taken in 2003, and was known as 2003 UB313 until its final name was assigned in 2006.

Dawn's Targets – Vesta and Ceres

Ceres and Vesta are the two most massive residents of the asteroid belt. Vesta is a rocky body, while Ceres is believed to contain large quantities of ice. The profound differences in geology between these two protoplanets that formed and evolved so close to each other form a bridge from the rocky bodies of the inner solar system to the icy bodies, all of which lay beyond in the outer solar system.

At present, most of what we now know about Vesta and Ceres comes from ground-based and Earth-orbiting telescopes like NASA's Hubble Space Telescope. The telescopes pick up sunlight reflected from the surface in the ultraviolet, visible and near-infrared, and by emitted radiation in the far-infrared and microwave regions.

Vesta

Discovered: March 29, 1807 by Heinrich Wilhelm Olbers of Germany
(fourth asteroid discovered)
Dimensions: About 578 by 560 by 458 kilometers (359 by 348 by 285 miles)
Shape: Nearly spheroid, with a massive chunk out of the south pole
Rotation: Once every 5 hours, 20 minutes

The asteroid's official name is "4 Vesta" because it was the fourth asteroid discovered. About the length of Arizona, it appears to have a surface of basaltic rock -- frozen lava -- which oozed out of the asteroid's presumably hot interior shortly after its formation 4.5 billion years ago, and has remained largely intact ever since. Telescopic observations reveal mineralogical variations across its surface.

Vesta has a unique surface feature which scientists look forward to peering into. At the asteroid's south pole is a giant crater – 460 kilometers (285 miles) across and 13 kilometers (8 miles) deep. The massive collision that created this crater gouged out one percent of the asteroid's volume, blasting almost 200,000 cubic miles of rock into space.

What happened to the one percent that was propelled from its Vesta home? The debris, ranging in size from sand and gravel to boulder and mountain, was ejected into space where it began its own journey through the solar system. Scientist believe that about 5 percent of all meteorites we find on Earth are a result of this single ancient crash in deep space.

To get an idea of the size of the crater on Vesta's south pole, the longest dimension of the main-belt asteroid Eros (which the Near Earth Asteroid Rendezvous Shoemaker spacecraft studied in 2000) is 30 kilometers long. That entire asteroid would quite easily be lost in the awesome maw of the crater near Vesta's south pole. Or, as another analogy, if Earth had a crater that was proportionately as large as the one on Vesta, it would fill the Pacific Ocean.

Ceres

Discovered: January 1,1801 by Giuseppe Piazzi of Italy (first asteroid/dwarf planet discovered)
Size: 975 by 909 kilometers (606 by 565 miles)
Shape: Spheroid
Rotation: Once every 9 hours, 4.5 minutes

The object is known by astronomers as “1 Ceres” because it was the very first minor planet discovered. As big across as Texas, Ceres’ nearly spherical body has a differentiated interior – meaning that, like Earth, it has denser material at the core and lighter minerals near the surface. Astronomers believe that water ice may be buried under Ceres’ crust because its density is less than that of the Earth’s crust, and because the dust-covered surface bears spectral evidence of water-bearing minerals. Ceres could even boast frost-covered polar caps.

Astronomers estimate that if Ceres were composed of 25 percent water, it may have more water than all the fresh water on Earth. While much of Ceres’ water is expected to be in the form of water ice located in its mantle, scientists say it is possible that Ceres has liquid water.

NASA's Discovery Program

Dawn is the ninth of 10 missions in NASA's Discovery Program. The others are:

❑ **Near Earth Asteroid Rendezvous** was launched Feb. 17, 1996. It became the first spacecraft to orbit an asteroid when it reached Eros in February 2000. After a year in orbit, it achieved the first landing on an asteroid in February 2001, after returning more than 160,000 detailed images. "Shoemaker" was later added to the spacecraft's name in honor of the late planetary scientist Eugene Shoemaker.

❑ **Mars Pathfinder** was launched Dec. 4, 1996, and landed on Mars on July 4, 1997. It was the first free-ranging rover to explore the Martian surface, conducting science and technology experiments. Pathfinder's lander operated nearly three times longer than its design lifetime of 30 days, and the Sojourner rover operated 12 times its design lifetime of seven days. After sending back thousands of images and measurements, the mission ended Sept. 27, 1997.

❑ **Lunar Prospector** was launched Jan. 6, 1998. It orbited Earth's moon for 18 months, looking for water and other natural resources and returning extensive mapping data to provide insights into lunar origin and evolution. At the mission's end July 31, 1999, the spacecraft was intentionally crashed into a crater near the moon's south pole in an unsuccessful attempt to detect the presence of water.

❑ Launched Feb. 7, 1999, **Stardust** captured and returned to Earth interstellar dust particles and comet dust using an unusual substance called aerogel. On Jan. 2, 2004, it flew within 240 kilometers (149 miles) of the nucleus of Comet Wild 2, collecting samples of comet dust and snapping detailed pictures of the comet's surface. On Jan. 15, 2006, Stardust's sample return capsule returned to Earth, providing scientists worldwide with the opportunity to analyze the earliest materials that created the solar system.

❑ Launched Aug. 8, 2001, **Genesis** collected atoms of solar wind beyond the orbit of Earth's moon to accurately measure the composition of our sun and improve our understanding of solar system formation. Its sample return capsule made a hard landing at the time of Earth return on Sept. 8, 2004. The mission's samples of solar wind were recovered and are currently being analyzed by scientists at laboratories around the world.

❑ The **Comet Nucleus Tour** launched from Cape Canaveral on July 3, 2002. Six weeks later contact with the spacecraft was lost after a planned maneuver that was intended to propel it out of Earth orbit and into a comet-chasing solar orbit. The probable proximate cause was structural failure of the spacecraft due to plume heating during the embedded solid-rocket motor burn.

❑ The **Mercury Surface, Space Environment, Geochemistry and Ranging** (Messenger) spacecraft was launched Aug. 3, 2004. After entering orbit around the planet closest to the sun in March 2011, the spacecraft will map nearly the entire planet in color and measure the composition of the surface, atmosphere and magnetosphere.

❑ Launched Jan. 12, 2005, **Deep Impact** was the first experiment to send a large projectile into the path of a comet to reveal the hidden interior for extensive study. On July 4, 2005, traveling at 39,000 kilometers (23,000 miles) per hour, a larger flyby spacecraft released a smaller impactor spacecraft into the path of Comet Tempel 1 as both recorded observations. The Spitzer, Hubble and Chandra space telescopes also observed from space, while an unprecedented global network of professional and amateur astronomers captured views of the impact, which took place 138 milllion kilometers (83 million miles) from Earth.

❑ The **Kepler** mission is designed to find Earth-sized planets in orbit around stars outside our solar system. As the largest telescope launched beyond Earth orbit and with a vast field of view, Kepler expects to detect transits of thousands of planets, including hundreds in or near a star's habitable zone -- the region where water may exist in liquid form, increasing the probability of life. Planned for launch in October 2008, Kepler will monitor 100,000 stars similar to our sun for four years.

Other Asteroid Encounters

Dawn will provide the most complete picture of the asteroid belt to date. But it is not the first mission to fly close to the solar system's dark and mysterious nomads.

❑ NASA's Jupiter-bound **Galileo** was launched Oct. 18, 1989, and became the first spacecraft to encounter an asteroid when on Oct. 29, 1991 it flew within 1,600 kilometers (1,000 miles) of the object Gaspra. On Aug. 28, 1993, Galileo performed history's second flyby of an asteroid when it came within 2,400 kilometers (1,500 miles) of Ida, and discovered Ida's moon Dactyl.

❑ Launched Feb. 17, 1996, NASA's **Near Earth Asteroid Rendezvous Shoemaker** spacecraft flew within 1,212 kilometers (753 miles) of asteroid Mathilde on June 27, 1997. On Feb. 14, 2000, the spacecraft went into orbit around asteroid Eros. On Feb. 12, 2001, the craft touched down on asteroid Eros, after transmitting 69 close-up images of the surface during its final descent.

❑ **Deep Space 1**, launched Oct. 24, 1998, flew within 16 kilometers (10 miles) of asteroid Braille on July 28, 1999, during a NASA mission designed to flight-test a number of technologies including ion propulsion.

❑ En route to its encounter with comet Wild 2, NASA's **Stardust** (launched Feb. 7, 1999) flew within 3,000 kilometers (1,900 miles) of asteroid Annefrank on Nov. 2, 2002.

❑ Launched by Japan's Institute of Space and Astronautical Science on May 9, 2003, **Hayabusa** rendezvoused with asteroid Itokawa in mid-September 2005. The spacecraft landed on the asteroid Nov. 19, 2005, to collect samples, but it is not clear if this was successful. A sample capsule is scheduled to return to Earth in 2010.

❑ The European Space Agency's **Rosetta** was launched March 2, 2004, and will fly past asteroid Steins in September 2008 and asteroid Lutetia in July 2010 on its way to rendezvous with Comet Churyumov-Gerasimenko in 2014.

Mission Overview

Following launch from Cape Canaveral Air Force Station, Fla., on a conventional rocket, the Dawn spacecraft will use ion propulsion periodically for four years to take it to its first destination, the asteroid Vesta, in 2011. After up to nine months in orbit there, Dawn will depart for a nearly three-year cruise to the dwarf planet Ceres, where it will arrive in 2015. Dawn will spend five months in orbit at Ceres. The spacecraft will be the first ever to orbit one extraterrestrial body, depart, and then orbit a second body.

Mission Phases

Eight mission phases have been defined to describe the different periods of activity during Dawn's travels. These are: launch and initial acquisition; initial checkout; interplanetary cruise; Mars gravity assist; Vesta approach; Vesta orbit; Ceres approach; and Ceres orbit. The orbital phases at both Vesta and Ceres are further broken up into sub-phases.

Launch and Initial Acquisition

For planning purposes, the launch phase is considered to begin at the moment of launch vehicle ignition, and lasts until the Dawn spacecraft has separated from the rocket's third stage, has a valid radio link with the ground, is generating its own electrical power via its solar panels, and has returned telemetry it recorded during launch.

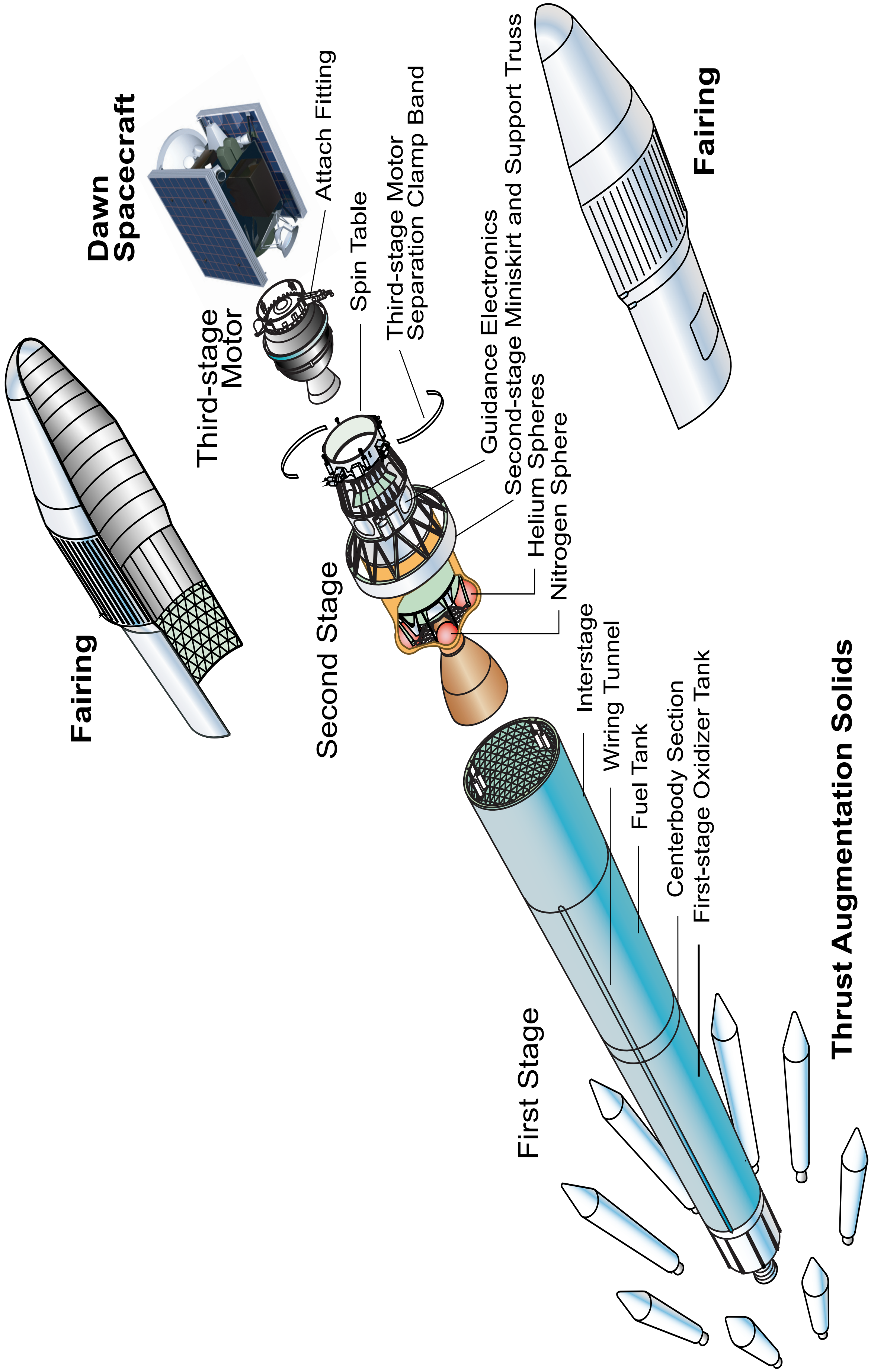
Launch is scheduled from Space Launch Complex 17B at Cape Canaveral Air Force Station, Fla. The launch period is from Sept. 26 to Oct. 15, 2007. One launch window of 19 to 44 minutes occurs each day. On Sept. 26, the launch window is from 7:25 to 7:54 a.m. EDT.

The launch vehicle is a variant of the Delta II known as a Delta 2925H. This version of the Delta II uses a first-stage liquid-fuel rocket with nine solid-fuel boosters, and a second-stage rocket with a restartable liquid-fuel engine. It is topped by a Star 48 solid-fuel upper-stage booster.

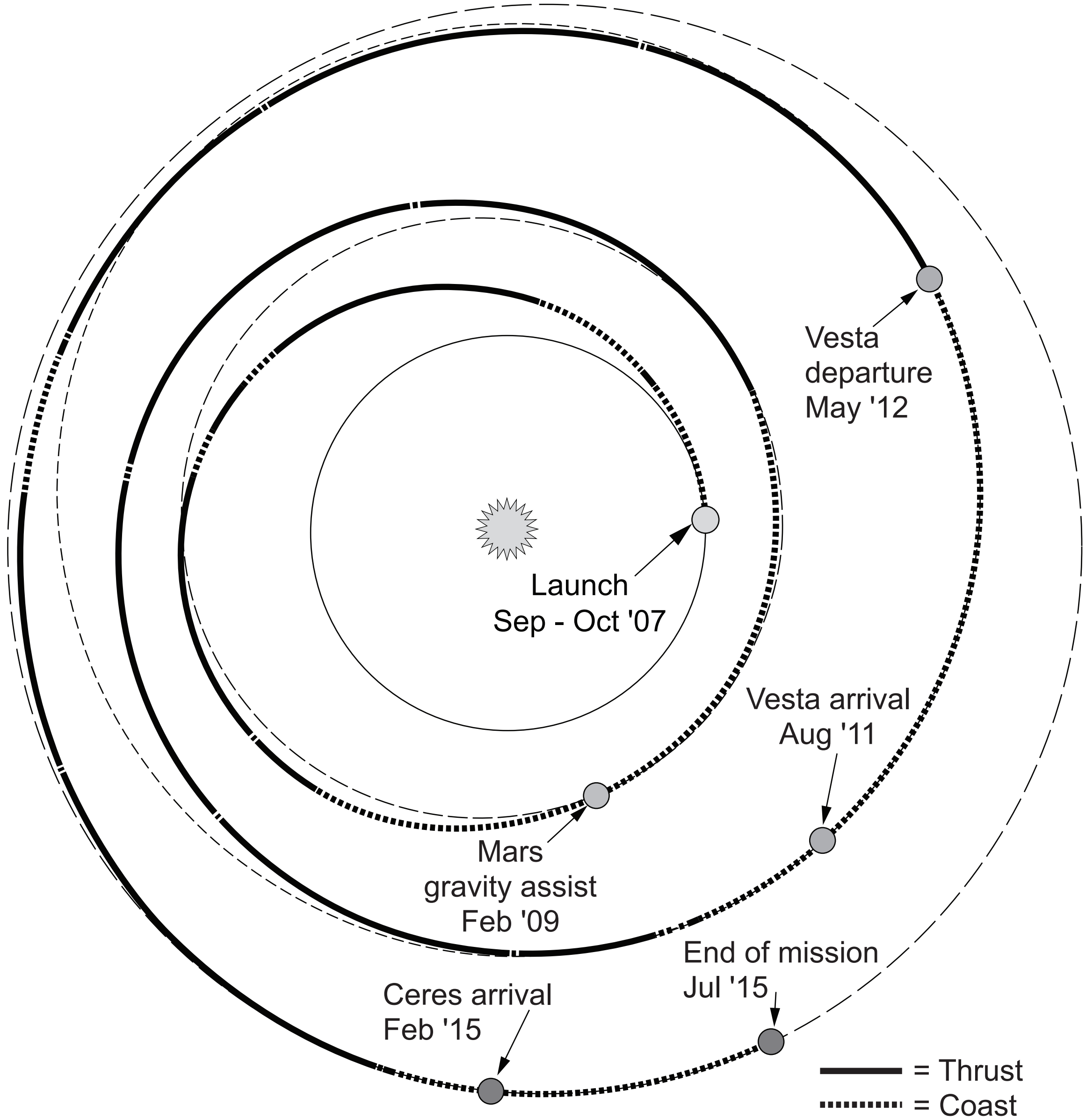
At the moment of liftoff, the Delta II's first-stage main engine ignites, along with six of its nine solid-fuel boosters. The remaining three boosters are ignited in flight following the burnout of the first six. The spent booster casings are jettisoned in sets of three. The first-stage main engine continues to burn for 4 minutes, 23 seconds, when it shuts down.

Eight seconds later, the Delta's first stage falls away, and approximately 5 seconds later the second stage is ignited. The Delta's payload fairing, or nose cone, is jettisoned approximately 4 minutes, 41 seconds into flight. At launch plus 8 minutes, 58 seconds, the Delta's second stage shuts down and the rocket coasts for 42 minutes, 37 seconds before the engine restarts. At launch plus 54 minutes, 14 seconds, the second stage engine shuts down. At this point, the Dawn spacecraft and the Delta's second and third stages are in an orbit 184 kilometers (115 miles) above Earth.

After the second stage completes its burn, the Dawn spacecraft and its Star 48 upper stage are spun up to about 50 rpm, after which the second stage separates. Thirty-seven seconds



Delta launch vehicle



Trajectory

later -- at launch plus 55 minutes, 45 seconds -- the Star 48 upper stage is ignited and burns for about 86 seconds. About 4.7 minutes after the third stage burns out, a yo-yo despin system is used to decrease the spin rate of the stacked Dawn spacecraft and Delta third stage from about 50 rpm to zero, then ending up about 3 rpm in the opposite direction. A few seconds later, pyrotechnic actuators and push-off springs will separate the Dawn spacecraft from the Delta's third stage. The Dawn spacecraft will sense this separation when wires intentionally break.

Although the spacecraft's spinning has slowed considerably by this point, xenon fuel carried onboard will still be spinning. The spacecraft will therefore wait 8 minutes, 20 seconds before starting to fire its thrusters to gradually stop any remaining rotation. Once the rotation rate is under a specific threshold, the spacecraft will take steps to deploy its solar panels and orient them toward the sun. The spacecraft will power on its transmitter and begin sending real-time telemetry to the ground.

Initial Checkout

This phase is considered as beginning when the above events conclude, and lasts until 60 days after launch. During the checkout, flight gear will be tested and calibrated, ensuring that Dawn is ready for its journey ahead.

As a first step, ground controllers will assess the immediate status of the spacecraft and then move it from its launch configuration to normal flight configuration. After that, critical systems will be checked out and exercised. Since thrusting with the ion propulsion system is so critical to the mission, there will be an extended period of thrusting to confirm operation of and calibrate the engines and to verify other systems essential to thrusting including power, attitude control, and thermal control.

Interplanetary Cruise

Once all the initial checkouts have been completed, the cruise segment will begin. During most of the cruise, the ion propulsion system will be thrusting continuously. However, the ion propulsion will be turned off occasionally for coast periods, during which maintenance activities such as instrument and subsystem calibrations will be performed. These planned coast periods also provide extra time to perform ion thrusting in case any thrust time is lost during cruise due to technical issues.

During cruise, ion propulsion thrusting will also be interrupted once a week to turn the spacecraft so that its high-gain antenna points at Earth to permit communication with the ground. Rarely, thrusting may continue while communicating because the direction the spacecraft needs to point for communication is close to the direction it needs to be in for thrusting.

Mars Gravity Assist

For planning purposes, the Mars gravity assist phase is considered as beginning 100 days before and lasting until 30 days after the spacecraft's closest approach to Mars. Dawn will fly within about 500 kilometers (311 miles) of Mars as it passes the planet in February 2009. The spacecraft will have completed slightly under one orbit of the sun following launch by the time it reaches Mars. During the flyby, Dawn may use its science instruments to make observations of the Red Planet.

The main benefit of the Mars flyby is that it will help propel the spacecraft farther out of the ecliptic, the plane containing the mean orbit of Earth around the sun. This is necessary because Dawn's next destination, the asteroid Vesta, has an orbit around the sun that is outside the ecliptic plane.

Overall, the Mars flyby will change Dawn's velocity relative to the sun by 4,020 kilometers per hour (2,498 miles per hour).

Vesta Approach

After departing from Mars, the Dawn spacecraft will settle back into cruise for another orbit around the sun during which it will gradually spiral outward into the asteroid belt between Mars and Jupiter. As it approaches Vesta in 2011, ground controllers will begin preparations for arrival. For planning purposes, the Vesta approach phase begins 85 days before Vesta arrival, and ends when the spacecraft achieves the first planned science observation orbit around Vesta.

By using its ion propulsion system, the spacecraft will match its flight path to that of the asteroid. This slow approach ensures there are no time-critical thruster firings. As it approaches, Dawn will conduct a survey of the region around the asteroid for any possible natural satellites, dust and debris. It will then use ion propulsion to brake itself into a polar mapping orbit around Vesta. By the time it reaches the asteroid, Dawn will have accumulated about 1,000 days of ion engine operation.

Vesta Orbit

This phase extends from the beginning of the first observation orbit at Vesta to the end of the last. The spacecraft will follow a series of circular near-polar orbits allowing it to study nearly the entire surface of the asteroid. These different orbits will be varied in altitude and orientation relative to the sun to achieve the best positioning for the various observations planned. At Vesta, the highest orbit will be roughly 2,500 kilometers (1,550 miles) in altitude, providing a nice vantage point to obtain a global view of the rocky world. The lowest orbit will be at an altitude of less than 200 kilometers (125 miles). Dawn will spend up to nine months at the asteroid.

Ceres Approach

After leaving Vesta, the spacecraft will spend nearly three years en route to Ceres, making about three-fourths of one orbit around the sun as it spirals outward toward the dwarf planet.

The Ceres approach phase begins 85 days before the spacecraft reaches Ceres, and ends when it achieves its first planned science observation orbit around the object. As at Vesta, Dawn will use its ion propulsion to make a slow approach to and drop into orbit around Ceres.

Ceres Orbit

This phase extends from the beginning of the first observation orbit to the end of the last, and includes all Ceres science data-taking, data return and orbit transitions. As at Vesta, Dawn will enter a series of circular near-polar orbits that will provide vantage points for studying nearly the entire surface of the dwarf planet. These different orbits will be varied in altitude and orientation relative to the sun to achieve the best positioning for the various observations planned.

End of Mission

Dawn's prime mission is scheduled to end in July 2015. At that time, the spacecraft will be in a "quarantine" orbit around Ceres at an altitude of about 700 kilometers (435 miles). This orbit ensures that the by-then-decommissioned spacecraft will not impact Ceres for more than half a century.

Telecommunications

Throughout the mission, tracking and telecommunications will be provided by NASA's Deep Space Network complexes in California's Mojave desert, near Madrid, Spain and near Canberra, Australia. Most data from the spacecraft will be received through the network's 34-meter-diameter (112-foot) antennas, but the larger 70-meter (230-foot) antennas may be used during some high-priority telecommunications phases.

Planetary Protection

The United States is a signatory to the United Nations' 1967 Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies. Also known as the "Outer Space Treaty," this document states in part that exploration of the moon and other celestial bodies shall be conducted "so as to avoid their harmful contamination."

The policy used to determine restrictions that are applied in implementing the Outer Space Treaty is generated and maintained by the International Council for Science's Committee on Space Research, which is headquartered in Paris. NASA adheres to the committee's planetary protection policy, which provides for appropriate protections for solar system bodies such as asteroids in addition to planets, moons and comets.

NASA's planetary protection officer has designated Dawn as a "Category III" mission under the policy. This requires the mission to demonstrate that it will avoid crashing into Mars during its flyby, and to document its encounters with Vesta and Ceres, but places no additional operating restrictions during the mission. Asteroids and dwarf planets are bodies that are of intense interest to the study of organic chemistry and the origin of life, but are not typically believed to be vulnerable to contamination by Earth-origin microorganisms. However, the potential for the presence of water ice on Ceres prompted the NASA planetary protection officer to impose an additional requirement that the spacecraft not impact Ceres for at least 20 years after completion of the nominal mission. An analysis by the Dawn project team predicts that, in fact, the spacecraft will remain in orbit around Ceres for more than 50 years after the mission ends.

Earthlings Rising with the Dawn

Some 365,000 intrepid explorers from around the world will hitch a ride aboard the spacecraft. The Dawn project sponsored a "Send Your Name to the Asteroid Belt" campaign, inviting the global public to submit their names via the Internet. More than a third of a million names were received and were etched onto an 8- by 8-millimeter (0.31- by 0.31-inch) silicon chip. The chip was then attached to the Dawn spacecraft where it will be along for the ride into the heart of the asteroid belt.

Spacecraft

The Dawn spacecraft combines innovative state-of-the-art technologies pioneered by other recent missions with off-the-shelf components and, in some cases, spare parts and instrumentation left over from previous missions.

Most systems on the spacecraft are redundant, meaning that there is a backup available if the main system encounters a problem. Automated onboard fault protection software will sense any unusual conditions and attempt to switch to backups.

With its solar array in the retracted position (for launch), the Dawn spacecraft is 2.36 meters (7 feet, 9 inches) long -- about as long as a large motorcycle. With its wide solar arrays extended, Dawn is about as long as a tractor-trailer at 19.7 meters (65 feet).

Structure

The core of the Dawn spacecraft's structure is a graphite composite cylinder. Tanks for the ion engines' xenon gas and the conventional thrusters' hydrazine are mounted inside the cylinder. The cylinder is surrounded by panels made of aluminum core with aluminum facesheets; most of the other hardware is mounted on these panels. Access panels and other spacecraft panels have composite or aluminum facesheets and aluminum cores. Blankets, surface radiators, finishes and heaters control the spacecraft's temperature.

Telecommunication

The telecommunication subsystem provides communication with Earth through any of three low-gain antennas and one 1.52-meter-diameter (5-foot) parabolic high-gain antenna. The high-gain antenna is the primary one used for most communication. The low-gain antennas are used when the spacecraft is not pointing the high-gain antenna toward Earth. Only one antenna can be used at a time.

Attitude Control

The attitude control system is responsible for determining the spacecraft's orientation in space, or "attitude," and providing control for maintaining and changing that attitude. Its hardware consists of two star trackers, three two-axis inertial reference units, 16 sun sensors and four reaction-wheel assemblies. The system controls gimbals to keep the solar arrays pointed towards the sun. In addition, it controls gimbaling of the ion thrusters, which can be moved in two axes. The system usually determines the spacecraft's attitude using its star trackers to sight known stars.

The spacecraft's attitude is usually controlled by the reaction wheels, devices somewhat similar to traditional gyroscopes that use the momentum of spinning mass to maintain or change the spacecraft's orientation. However, the attitude can also be maintained or modified by a set of twelve 0.9-newton hydrazine thrusters that are collectively called the reaction control system. Serving primarily as a backup to the reaction wheels, the thrusters will be used shortly after launch to stop the spacecraft's spinning and point its solar panels at the sun.

Ion Propulsion System

The ion propulsion system will provide the Dawn spacecraft with the thrust that it will require to reach its target asteroids. The demanding mission profile would be impossible without the ion engines -- even a mission only to asteroid Vesta (and not on to Ceres) would require a much larger spacecraft and a dramatically larger launch vehicle. Ion propulsion was proved on NASA's Deep Space 1 mission, which tested it and 11 other technologies while journeying to an asteroid and a comet.

Each of Dawn's three 30-centimeter-diameter (12-inch) ion thrust units is movable in two axes to allow for migration of the spacecraft's center of mass during the mission. This also allows the attitude control system to use the ion thrusters to help control spacecraft attitude.

A total of three ion propulsion engines are required to provide enough thruster lifetime to complete the mission and still have adequate reserve. However, only one thruster will be operating at any given time. Dawn will use ion propulsion for years at a time, with interruptions of only a few hours each week to turn to point its antenna to Earth. Total thrust time through the mission will be about 2,000 days, considerably in excess of Deep Space 1's 678 days of ion propulsion operation.

The thrusters work by using an electrical charge to accelerate ions from xenon fuel to a speed 10 times that of chemical engines. The electrical level and xenon fuel feed can be adjusted to throttle each engine up or down. The engines are thrifty with fuel, using only about 3.25 milligrams of xenon per second (about 10 ounces over 24 hours) at maximum thrust. The Dawn spacecraft carries 425 kilograms (937 pounds) of xenon propellant.

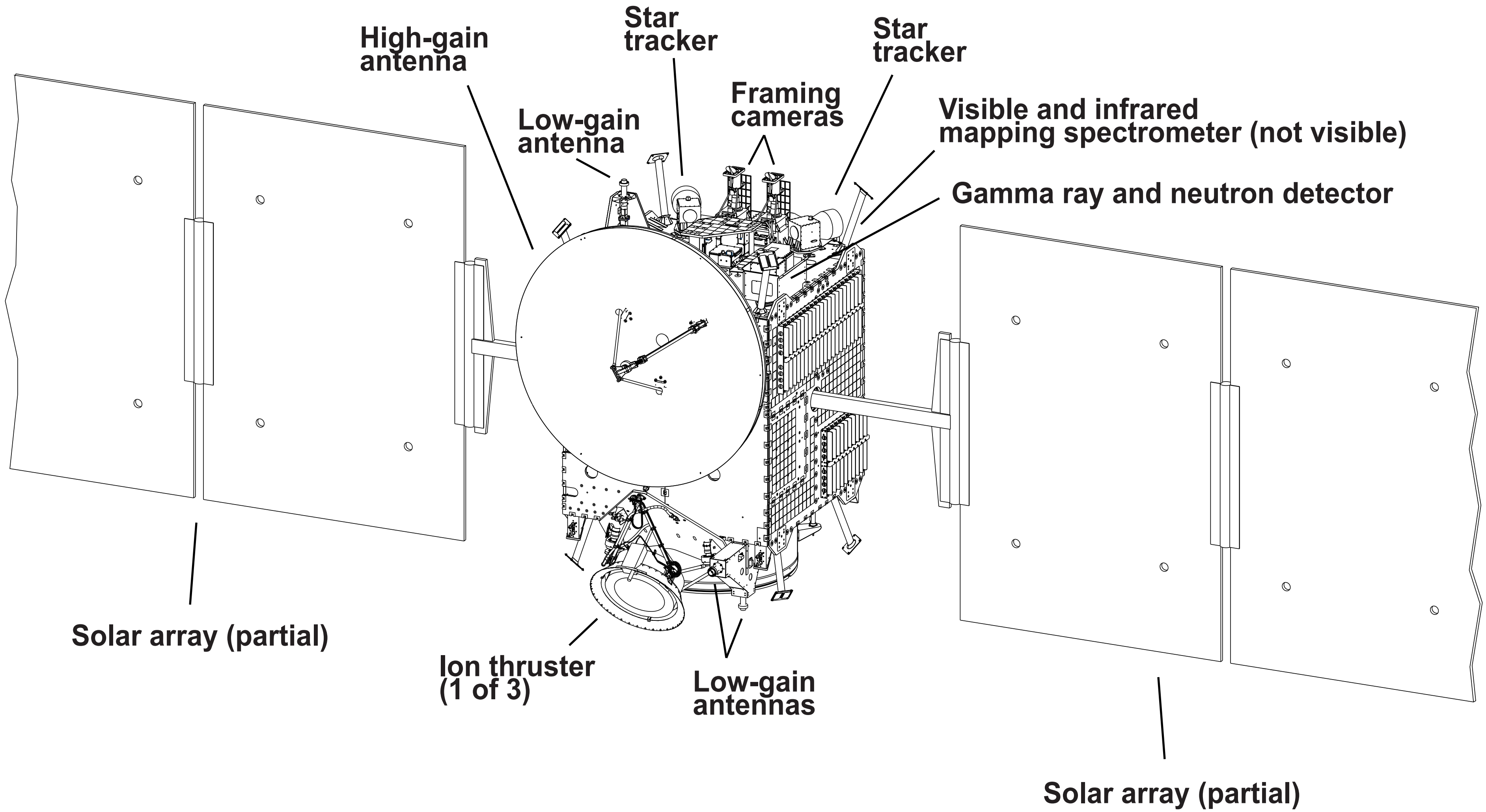
At maximum thrust, each engine produces a total of 91 millinewtons -- about the amount of force involved in holding a single piece of notebook paper in your hand. You would not want to use ion propulsion to get on a freeway -- at maximum throttle, it would take Dawn's system four days to accelerate from 0 to 60 miles per hour.

As slight as that might seem, over the course of the mission the total change in velocity from ion propulsion will be comparable to the push provided by the Delta II rocket that carried it into space -- all nine solid-fuel boosters, plus the Delta's first, second and third stages. This is because the ion propulsion system will operate for thousands of days, instead of the minutes during which the Delta performs.

Power

The electrical power system provides power for all onboard systems, including the ion propulsion system when thrusting. The ion propulsion system requires considerable electrical power, which must be available when the spacecraft is in orbit at Ceres. Since the dwarf planet is three times farther from the sun than Earth is, sunlight there is nine times fainter.

Each of the two solar arrays is 8.3 meters (27 feet) long by 2.3 meters (7.4 feet) wide. On the front side, 18 square meters (21.5 square yards) of each array is covered with 5,740 individual photovoltaic cells. The cells can convert about 28 percent of the solar energy that hits them into electricity. At Earth, the two wings combined could generate over 10,000 watts. The arrays are mounted on opposite sides of the spacecraft, with a gimbaled connection that allows them to be turned at any angle to face the sun.



Dawn spacecraft

A nickel-hydrogen battery and associated charging electronics provide power during launch and at any time the solar arrays are directed away from the sun.

Computer

The Dawn spacecraft's command and data handling system provides overall control of the spacecraft and manages the flow of engineering and science data. The system consists of redundant RAD6000 processors, each with 8 gigabits of memory.

Scientific Instruments

To acquire science data at Vesta and Ceres, Dawn carries three instrument systems. In addition, an experiment to measure gravity will be accomplished with existing spacecraft and ground systems.

❑ The **Framing Camera** is designed to acquire detailed optical images for scientific purposes as well as for navigation in the vicinities of Vesta and Ceres. Dawn carries two identical and physically separate cameras for redundancy, each with its own optics, electronics and structure. Each camera is equipped with an f/7.9 refractive optical system with a focal length of 150mm and can use 7 color filters, provided mainly to help study minerals on Vesta's surface. In addition to detecting the visible light humans see, the cameras register near-infrared energy. Each camera includes 8 gigabits of internal data storage. The Max Planck Institute for Solar System Research, Germany, was responsible for the cameras' design and fabrication, in cooperation with the Institute for Planetary Research of the German Aerospace Center and the Institute for Computer and Communication Network Engineering of the Technical University of Braunschweig.

❑ The elemental composition of both Vesta and Ceres will be measured with the **Gamma Ray and Neutron Detector**. This instrument uses a total of 21 sensors with a very wide field of view to measure the energy from gamma rays and neutrons that either bounce off or are emitted by a celestial body. Gamma rays are a form of light, while neutrons are particles that normally reside in the nuclei of atoms. Together, gamma rays and neutrons reveal many of the important atomic constituents of the celestial body's surface down to a depth of one meter (three feet). Gamma rays and neutrons emanating from the surface of Vesta and Ceres will tell us much about the elemental composition of each. Many scientists believe that Ceres may be rich in water; if that is the case, the signature of the water may be contained in this instrument's data. Unlike the other instruments aboard Dawn, the detector has no internal data storage. The instrument was developed by Los Alamos National Laboratory, Los Alamos, N.M.

❑ The surface mineralogy of both Vesta and Ceres will be measured by the **Visible and Infrared Mapping Spectrometer**. The instrument is a modification of a similar spectrometer flying on both the European Space Agency's Rosetta and Venus Express missions. It also draws significant heritage from the visible and infrared mapping spectrometer on NASA's Cassini spacecraft. Each picture the instrument takes records the light intensity at more than 400 wavelength ranges in every pixel. When scientists compare its observations with laboratory measurements of minerals, they can determine what minerals are on the surfaces of Vesta and Ceres. The instrument has 6 gigabits of internal memory, which may be operated as 3 gigabits of redundant data storage. The spectrometer is provided by the Italian Space Agency, and was designed and built at Galileo Avionica, in collaboration with Italy's National Institute for Astrophysics.

Dawn will make another set of scientific measurements at Vesta and Ceres using the spacecraft's radio transmitter and sensitive antennas on Earth. Monitoring signals from Dawn, scientists can detect subtle variations in the gravity fields of the two space objects. These variations will point to how mass is distributed in each body, in turn providing clues about the interior structure of Vesta and Ceres.

Science Objectives

The primary goal of the Dawn mission is to explore asteroid 4 Vesta and dwarf planet 1 Ceres with the same complement of instruments on a single spacecraft. In-depth analysis and comparison of these two celestial bodies will provide insight into their origin and evolution -- and thus a better understanding of the conditions and processes that have acted upon them from their formation 4.56 billion years ago to the present.

During its orbital studies, Dawn will investigate Vesta's and Ceres' internal structure, density and homogeneity by measuring their mass, shape, volume and spin state with radiometric tracking and imagery, and determine elemental and mineral composition. From this information scientists can determine the relationship between meteorites and their parent bodies, and the thermal histories of the bodies. From images of the surface, knowledge of their bombardment, tectonic and possibly volcanic history will be revealed.

In particular, the mission's scientific objectives are to:

❑ Investigate the internal structure, density and homogeneity of two complementary protoplanets, 1 Ceres and 4 Vesta, one wet and one dry.

❑ Determine surface morphology and cratering via near-global surface imagery in three colors at Vesta and in three at Ceres.

❑ Perform radio tracking to determine mass, gravity field, principal axes, rotational axis and moments of inertia of both Vesta and Ceres.

❑ Determine shape, size, composition and mass of both Vesta and Ceres.

❑ Determine thermal history and size of each body's core.

❑ Determine the spin axis of both Vesta and Ceres.

❑ Understand the role of water in controlling asteroid evolution.

❑ Test the prevailing scientific theory that Vesta is the parent body for a class of stony meteorites known as howardite, eucrite and diogenite, or "HED," meteorites; determine which, if any, meteorites come from Vesta.

❑ Provide a geologic context for HED meteorites.

❑ Obtain surface coverage with the mapping spectrometer from 0.25- to 5.0-micron wavelengths.

❑ Obtain neutron and gamma ray spectra to produce maps of the surface elemental composition of each object, including the abundance of major rock-forming elements (oxygen, magnesium, aluminum, silicon, calcium, titanium and iron), trace elements (gadolinium and samarium), and long-lived radioactive elements (potassium, thorium and uranium).

Science Team

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Program/Project Management

The Dawn project is managed by the Jet Propulsion Laboratory, Pasadena, Calif., for NASA's Science Mission Directorate, Washington. Principal investigator Dr. Christopher T. Russell of UCLA leads the overall mission.

At NASA Headquarters, Dr. Alan Stern is associate administrator for the Science Mission Directorate. Dr. James Green is director of the Solar System Division. Kurt Lindstrom is Dawn program executive, and Dr. David Lindstrom is Dawn program scientist. Paul Gilbert of NASA's Marshall Space Flight Center is manager of the Discovery Program,

At the Jet Propulsion Laboratory, Keyur Patel is Dawn project manager. Ray Morris is mission manager. JPL is a division of the California Institute of Technology, Pasadena, Calif.

Orbital Sciences Corp., Dulles, Va., built the Dawn spacecraft. Michael Mook is the company's Dawn program manager.

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