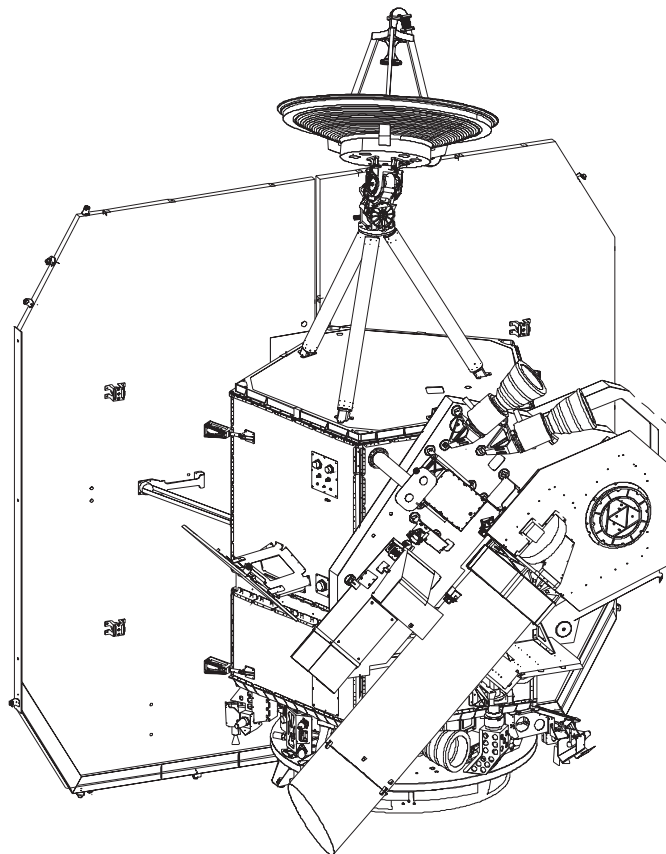


NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Deep Impact Launch

Press Kit
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GENERAL RELEASE:

NASA SET TO LAUNCH FIRST COMET IMPACT PROBE

Launch and flight teams are in final preparations for the planned Jan. 8, 2005, liftoff from Cape Canaveral Air Force Station, Fla., of NASA's Deep Impact spacecraft. The mission is designed for a six-month, one-way, 431-million-kilometer (268-million-mile) voyage. Deep Impact will deploy a probe that essentially will be "run over" by the nucleus of comet Tempel 1 at approximately 37,000 kph (23,000 mph).

"From central Florida to the surface of a comet in six months is almost instant gratification from a deep space mission viewpoint," said Rick Grammier, Deep Impact project manager at NASA's Jet Propulsion Laboratory, Pasadena, Calif. "It is going to be an exciting mission, and we can all witness its culmination together as Deep Impact provides the planet with its first human-made celestial fireworks on our nation's birthday, July 4th," he said.

The fireworks will be courtesy of a 1- by 1-meter (39- by 39-inch) copper-fortified probe. It is designed to obliterate itself, as it excavates a crater possibly large enough to swallow the Roman Coliseum. Before, during and after the demise of this 372-kilogram (820-pound) impactor, a nearby spacecraft will be watching the 6-kilometer-wide (3.7-mile) comet nucleus, collecting pictures and data of the event.

"We will be capturing the whole thing on the most powerful camera to fly in deep space," said University of Maryland astronomy professor Dr. Michael A'Hearn, Deep Impact's principal investigator. "We know so little about the structure of cometary nuclei that we need exceptional equipment to ensure that we capture the event, whatever the details of the impact turn out to be," he explained.

Imagery and other data from the Deep Impact cameras will be sent back to Earth through the antennas of the Deep Space Network. But they will not be the only eyes on the prize. NASA's Chandra, Hubble and Spitzer space telescopes will be observing from near-Earth space. Hundreds of miles below, professional and amateur astronomers on Earth will also be able to observe the material flying from the comet's newly formed crater.

Deep Impact will provide a glimpse beneath the surface of a comet, where material and debris from the solar system's formation remain relatively unchanged. Mission scientists are confident the project will answer basic questions about the formation of the solar system, by offering a better look at the nature and composition of the celestial travelers we call comets.

"Understanding conditions that lead to the formation of planets is a goal of NASA's mission of exploration," said Andy Dantzler, acting director of the Solar System Division at NASA Headquarters, Washington. "Deep Impact is a bold, innovative and exciting

mission which will attempt something never done before to try to uncover clues about our own origins."

With a closing speed of about 37,000 kph (23,000 mph), what of the washing machine-sized impactor and its mountain-sized quarry?

"In the world of science, this is the astronomical equivalent of a 767 airliner running into a mosquito," said Don Yeomans, a Deep Impact mission scientist at JPL. "It simply will not appreciably modify the comet's orbital path. Comet Tempel 1 poses no threat to Earth now or in the foreseeable future," he added.

Ball Aerospace & Technologies in Boulder, Colo., built NASA's Deep Impact spacecraft. It was shipped to Florida Oct. 17 to begin final preparations for launch. Liftoff is scheduled for Jan. 8 at 1:39:50 p.m. EST, with another opportunity 40 minutes later.

Principal Investigator A'Hearn leads the mission from the University of Maryland, College Park. JPL manages the Deep Impact project for the Science Mission Directorate at NASA Headquarters. Deep Impact is a mission in NASA's Discovery Program of moderately priced solar system exploration missions.

For more information about Deep Impact on the Internet, visit:

<http://www.nasa.gov/deepimpact>

For more information about NASA and agency programs on the Internet, visit:

<http://www.nasa.gov>

- End of General Release -

Media Services Information

NASA Television Transmission

NASA Television is carried on the satellite AMC-6, at 72 degrees west longitude, transponder 9, 3880 MHz, vertical polarization, audio at 6.8 MHz. For those in Alaska or Hawaii, NASA TV will now be seen on AMC-7, at 137 degrees west longitude, transponder 18, at 4060 MHz, vertical polarization, audio at 6.8 MHz. The schedule for Deep Impact mission television will be available on the NASA website at www.nasa.gov .

Media Credentialing

Journalists who wish to cover the launch of Deep Impact at NASA's Kennedy Space Center must contact the KSC Newsroom by close of business Dec. 27, 2004. Accreditation questions should be directed to Kandy Warren, KSC Media Accreditation Officer, telephone 321-867-7711 or -7819.

Briefings

A mission overview news briefing will be held at NASA Headquarters on Dec. 14, 2004, at 1 p.m. EST.

A pre-launch news briefing to discuss launch, spacecraft readiness and weather will be held at NASA's Kennedy Space Center the day before launch (Jan. 7 based on a Jan. 8 launch date). A briefing on the mission's science will immediately follow this pre-launch briefing.

All briefings will be carried live on NASA Television and the V circuits.

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 Deep Impact mission, including an electronic copy of this press kit, news releases, fact sheets, status reports and images, are available from the NASA website at www.nasa.gov/deepimpact .

Detailed background information on the mission is available from the Deep Impact project home page at deepimpact.jpl.nasa.gov .

Quick Facts

Flyby Spacecraft

Dimensions: 3.3 meters (10.8 feet) long, 1.7 meters (5.6 feet) wide, and 2.3 meters (7.5 feet) high

Weight: 601 kilograms (1,325 pounds) at launch, consisting of 515 kilograms (1,135 pounds) spacecraft and 86 kg (190 lbs) fuel

Power: 2.8-meter-by-2.8-meter (9-foot-by-9 foot) solar panel providing up to 92 watts, depending on distance from Sun. Power storage via small 16-amp-hour rechargeable nickel hydrogen battery

Impactor

Dimensions: 1 meter (39 inches) long, 1 meter (39 inches) in diameter

Weight: 372 kilograms (820 pounds) at launch, consisting of 364 kilograms (802 pounds) spacecraft and 8 kilograms (17 pounds) of fuel

Power: Non-rechargeable 250-amp-hour battery

Mission

Launch period: Jan. 8-28, 2005 (two instantaneous launch windows available daily 39-40 minutes apart)

Launch site: Cape Canaveral Air Force Station, Florida

Launch vehicle: Delta II 7925 with Star 48 upper stage

Earth-comet distance at time of launch: 267 million kilometers (166 million miles)

Comet impact: July 4, 2005

Earth-comet distance at time of impact: 133.6 million kilometers (83 million miles)

Total distance traveled by spacecraft from Earth to comet: 431 million kilometers (268 million miles)

Closing speed of impactor relative to comet nucleus at time of impact: 36,700 kilometers per hour (22,800 miles per hour)

End of mission: Aug. 3, 2005 (30 days after impact)

Program

Cost: \$267 million total (not including launch vehicle), consisting of \$252 million spacecraft development and \$15 million mission operations

Why Deep Impact?

Out beyond the orbits of the planets on the outer fringes of the solar system, a swarming belt of billions of dormant comets circles the Sun. Frozen balls of ice, rocks and dust, they are the undercooked leftovers that remained after a sprawling cloud of gas and dust condensed to form the Sun and planets about 4.6 billion years ago. From time to time, the gravitational pull of other comets or the giant outer planets will nudge some of them out of their orbits, plunging them into the inner solar system, where they erupt with sparkling tails as they loop around the Sun.

One of these nomadic frozen ice balls is the target for NASA's Deep Impact mission. On July 4, 2005, Deep Impact will produce a crater on the surface of comet Tempel 1 that could range in size from a two-bedroom house to the Roman Coliseum. The impact is expected to eject ice and dust from the surface of the crater and reveal untouched, primordial material beneath. While this is happening, the spacecraft's cameras will radio images to Earth of the comet's approach, impact and aftermath.

Data returned from the Deep Impact spacecraft could provide opportunities for significant breakthroughs in our knowledge of how the solar system formed, the makeup of cometary interiors, and the role that cometary impacts may have played with Earth's early history and the beginning of life.

Comets

Though frequently beautiful, comets traditionally have stricken terror as often as they have generated wonder as they arc across the sky during their passages around the Sun. Astrologers interpreted the sudden appearances of the glowing visitors as ill omens presaging famine, flood or the death of kings. Even as recently as the 1910 appearance of Halley's Comet, entrepreneurs did a brisk business selling gas masks to people who feared Earth's passage through the comet's tail.

In the 4th century B.C., the Greek philosopher Aristotle concluded that comets were some kind of emission from Earth that rose into the sky. The heavens, he maintained, were perfect and orderly; a phenomenon as unexpected and erratic as a comet surely could not be part of the celestial vault. In 1577, Danish astronomer Tycho Brahe carefully examined the positions of a comet and the Moon against the stars during the evening and predawn morning. Due to parallax, a close object will appear to change its position against the stars more than a distant object will -- the same effect that you see if you hold up a finger and look at it while closing one eye and then the other. The Moon appeared to move more against the stars from evening to morning than the comet did, leading Tycho to conclude that the comet was at least six times farther away.

A hundred years later, the English physicist Isaac Newton established that a comet

Comet Missions

Comets have been studied by several spacecraft, not all of which were originally designed for that purpose. Several new missions to comets are being developed for launch in coming years.

Past cometary missions include:

- ❑ In 1985, NASA modified the orbit of the International Sun-Earth Explorer spacecraft to execute a flyby of Comet 21P/Giacobini-Zinner. At that point, the spacecraft was renamed **International Comet Explorer**. It successfully flew through the tail of comet Giacobini-Zinner in 1985 and flew past comet 1P/Halley in 1986.
- ❑ An international armada of robotic spacecraft flew out to greet Halley's Comet during its return in 1986. The fleet included the European Space Agency's **Giotto**, the Soviet Union's **Vega 1** and **Vega 2**, and Japan's **Sakigake** and **Suisei** spacecraft.
- ❑ Comet Shoemaker-Levy 9's spectacular collision with Jupiter in 1994 was observed by NASA's **Hubble Space Telescope**, the Jupiter-bound **Galileo** spacecraft and the Sun-orbiting **Ulysses** spacecraft.
- ❑ **Deep Space 1** launched from Cape Canaveral on October 24, 1998. During a highly successful primary mission, it tested 12 advanced, high-risk technologies in space. In an extremely successful extended mission, it encountered comet 19P/Borrelly and returned the best images and other scientific data taken from a comet up to that time.
- ❑ The **Comet Nucleus Tour**, or **Contour**, mission launched from Cape Canaveral on July 3, 2002. Six weeks later, on August 15, contact with the spacecraft was lost after a planned maneuver that was intended to propel it out of Earth orbit and into its comet-chasing solar orbit.

Other active cometary missions are:

- ❑ NASA's **Stardust** mission flew within 236 kilometers (about 147 miles) of the nucleus of comet 81P/Wild 2 on Jan. 2, 2004. Its flight path took it through the comet's inner coma, the glowing cloud that surrounds the comet nucleus. The flyby yielded the most detailed, high-resolution comet images ever, revealing a rigid surface dotted with towering pinnacles, plunging craters, steep cliffs, and dozens of jets spewing material into space. Launched in 1999, the Stardust spacecraft is headed back to Earth with its payload of thousands of captured particles. The spacecraft's sample return capsule is scheduled to make a soft landing in the Utah desert in January 2006.
- ❑ A European Space Agency mission, **Rosetta**, was launched March 2, 2004 to orbit comet 67P/Churyumov-Gerasimenko and deliver a scientific package to its surface via a lander in 2014. NASA provided scientific instruments for the cometary orbiter.

appearing in 1680 followed a nearly parabolic orbit. The English astronomer Edmond Halley used Newton's method to study the orbits of two dozen documented cometary visits. The orbits of three comets seen in 1531, 1607 and 1682 were so similar that he concluded they in fact were appearances of a single comet wheeling around the Sun in a closed ellipse every 75 years or so. He successfully predicted the next visit in 1758-9, and the comet thereafter bore his name.

Since then, astronomers have concluded that some comets return relatively frequently, in intervals ranging from 3 to 200 years; these are called "short-period" comets. Others have enormous orbits that bring them back only once in hundreds of millennia.

In the mid-1800s, scientists also began to turn their attention to the question of comets' composition. Astronomers noted that several major meteor showers took place when Earth passed through the known orbits of comets, leading them to conclude that the objects are clumps of dust or sand. By the early 20th century, astronomers studied comets using the technique of spectroscopy, breaking down the color spectrum of light given off by an object to reveal the chemical makeup of the object. They concluded that comets also emitted gases as well as molecular ions.

In 1950, the American astronomer Fred L. Whipple (1906-2004) authored a major paper proposing what became known as the "dirty snowball" model of the cometary nucleus. This model, which has since been widely adopted, pictures the nucleus as a mixture of dark organic material, rocky grains and water ice. ("Organic" means that the compound is based on carbon and hydrogen, but is not necessarily biological in origin.) Most nuclei of comets range in size from about 1 to 10 kilometers (1/2 to 6 miles) in diameter.

If comets contain icy material, they must originate somewhere much colder than the relatively warm inner solar system. In 1950, the Dutch astronomer Jan Hendrick Oort (1900-1992) used indirect reasoning from observations to predict the existence of a vast cloud of comets orbiting many billions of miles from the Sun - perhaps 50,000 astronomical units (AU) away (one AU is the distance from Earth to the Sun), or nearly halfway to the next nearest star. This region has since become known as the Oort Cloud.

A year later, the Dutch-born American astronomer Gerard Kuiper (1905-1973) pointed out that the Oort Cloud is too distant to act as the nursery for short-period comets. He suggested the existence of a belt of dormant comets lying just outside the orbits of the planets at perhaps 30 to 100 AU from the Sun; this has become known as the Kuiper Belt. (Other astronomers such as Frederick Leonard and Kenneth Edgeworth also speculated about the existence of such a belt in the 1930s and 1940s, and so the region is sometimes referred to as the Edgeworth-Kuiper Belt, the Leonard-Edgeworth-Kuiper Belt, and so on.) Close encounters with other dormant comets sometimes change their orbits so that they venture in toward the Sun and fall under the influence

NASA's Discovery Program

Deep Impact is the eighth mission in NASA's Discovery Program, which sponsors frequent, cost-capped solar system exploration missions with highly focused scientific goals. Created in 1992, the Discovery Program competitively selects proposals submitted by teams led by scientists, supported by organizations that manage the project, as well as partners that build and fly the spacecraft. In recent years, NASA has identified several finalists from dozens of mission proposals submitted. These finalists receive funding to conduct feasibility studies for an additional period of time before a final selection is made.

Other missions in the Discovery Program are:

- ❑ The **Near Earth Asteroid Rendezvous** spacecraft (later renamed **Near Shoemaker**) was launched Feb. 17, 1996 and became the first spacecraft to orbit an asteroid when it reached Eros in February 2000. A year later, it became the first spacecraft to land on an asteroid when it put down on Eros, providing the highest resolution images ever obtained of an asteroid, showing features as small as one centimeter across. The mission was managed by Johns Hopkins University's Applied Physics Laboratory.
- ❑ **Mars Pathfinder** was launched Dec. 4, 1996 and landed on Mars on July 4, 1997, demonstrating a unique way of touching down with airbags to deliver a small robotic rover. Mars Pathfinder was managed by NASA's Jet Propulsion Laboratory.
- ❑ Launched Jan. 7, 1998, **Lunar Prospector** entered orbit around Earth's Moon five days later, circling at an altitude of about 100 kilometers (60 miles). The principal investigator was Dr. Alan Binder of the Lunar Research Institute, Gilroy, Calif., with project management by NASA's Ames Research Center.
- ❑ **Stardust** was launched Feb. 7, 1999. On Jan. 2, 2004, it collected samples of cometary and interstellar dust as it flew through the coma surrounding the nucleus of Comet Wild 2. The samples will be returned to Earth in January 2006 at the Utah Test & Training Range. The principal investigator is Dr. Donald Brownlee of the University of Washington, with project management by NASA's Jet Propulsion Laboratory.
- ❑ Launched Aug. 8, 2001, **Genesis** collected pristine samples of solar wind beyond the Moon's orbit. The Genesis sample return capsule entered Earth's atmosphere over the Utah Test & Training Range on Sept. 8, 2004, but its parachute system did not deploy. The mission's samples of solar wind were recovered and are currently being analyzed by scientists at NASA's Johnson Space Center. Genesis was managed by the Jet Propulsion Laboratory, with Dr. Donald Burnett of the California Institute of Technology as principal investigator.
- ❑ The **Comet Nucleus Tour** or **Contour**, launched from Cape Canaveral on July 3, 2002. Unfortunately, six weeks later, on Aug. 15, contact with the spacecraft was lost after a planned maneuver that was intended to propel it out of Earth orbit and into its comet-chasing solar orbit. Contour was managed by Johns Hopkins University's Applied Physics Laboratory, and the principal investigator was Dr. Joseph Veverka of Cornell University.
- ❑ The **Mercury Surface, Space Environment, Geochemistry and Ranging (Messenger)** mission was launched Aug. 3, 2004. Entering orbit around the planet closest

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to the Sun in September 2009, the spacecraft will produce a global map and details about Mercury's surface, interior, atmosphere and magnetosphere. The mission is managed by Johns Hopkins University's Applied Physics Laboratory, and the principal investigator is Dr. Sean C. Solomon of the Carnegie Institution.

□ The **Dawn** mission will undertake a journey in both space and time by traveling to two of the oldest and most massive asteroids in our solar system, Vesta and Ceres. Planned for launch in May 2006, the ion-propulsion-powered spacecraft will reach Vesta in 2010 and Ceres in 2014. These minor planets have existed since the earliest time of solar system formation. Dawn is managed by NASA's Jet Propulsion Laboratory, and Dr. Christopher Russell of UCLA is the principal investigator.

□ The **Kepler** mission is designed to find Earth-size planets in orbit around stars like our Sun outside of the solar system. It will survey our galactic neighborhood to detect and characterize hundreds of terrestrial and larger planets in or near the "habitable zone," defined by scientists as the distance from a star where liquid water can exist on a planet's surface. Planned for launch in fall 2007, Kepler will monitor 100,000 stars similar to our Sun for four years. Dr. William Borucki of NASA's Ames Research Center is the principal investigator, with project management by NASA's Jet Propulsion Laboratory.

of the gravities of the giant outer planets -- first Neptune, then Uranus, then Saturn and finally Jupiter.

The Oort Cloud, by contrast, would be the home of long-period comets. They are periodically nudged from their orbits by any one of several influences - perhaps the gravitational pull of a passing star or giant molecular cloud, or tidal forces of the Milky Way Galaxy.

In addition to the length of time between their visits, another feature distinguishes short- and long-period comets. The orbits of short-period comets are all fairly close to the ecliptic plane, the plane in which Earth and most other planets orbit the Sun. Long-period comets, by contrast, dive inwards toward the Sun from virtually any part of the sky. This suggests that the Kuiper Belt is a relatively flat belt, whereas the Oort Cloud is a three-dimensional sphere surrounding the solar system.

Where did the Oort Cloud and Kuiper Belt come from? Most astronomers now believe that the material that became comets condensed in the outer solar system around the orbits of Uranus and Neptune and beyond. Gravitational effects from those giant planets flung some of the comets outward to the Oort cloud, while the comets in the Kuiper Belt may have remained there.

Residing at the farthest reaches of the Sun's influence, comets did not undergo the same heating as the rest of the objects in the solar system, so they retain, largely unchanged, the original composition of solar system materials. As the preserved build-

ing blocks of the outer solar system, comets offer clues to the chemical mixture from which the planets formed some 4.6 billion years ago.

The geologic record of the planets shows that, about 3.9 billion years ago, a period of heavy cometary and asteroidal bombardment tapered off. The earliest evidence of life on Earth dates from just after the end of this heavy bombardment. The constant barrage of debris had vaporized any water on Earth, leaving the planet too hot for the survival of the fragile carbon-based molecules upon which life is based. Scientists therefore wonder: How could life form so quickly when there was so little liquid water or carbon-based molecules on Earth's surface? The answer may be that comets, which are abundant in both water and carbon-based molecules, delivered essential ingredients for life to begin.

Comets are also at least partially responsible for the replenishment of Earth's ocean after the vaporization of an early ocean during the late heavy bombardment. While Earth has long been regarded as the "water planet," it and the other terrestrial planets (Mercury, Venus and Mars) are actually poor in the percentage of water and in carbon-based molecules they contain when compared to objects that reside in the outer solar system at Jupiter's orbit or beyond. Comets are about 50 percent water by weight and about 10 to 20 percent carbon by weight. It has long been suspected that what little carbon and water there is on Earth was delivered here by objects such as comets that came from a more water-rich part of the solar system.

While comets are a likely source for life's building blocks, they have also played a devastating role in altering life on our planet. A comet or asteroid is credited as the likely source of the impact that changed Earth's climate, wiped out the dinosaurs and gave rise to the age of mammals 65 million years ago.

Right Place, Right Time, Right Snowball

The Deep Impact mission's target, Comet 9P/Tempel 1, was discovered on April 3, 1867 by Ernst Wilhelm Leberecht Tempel of Marseilles, France, while visually searching for comets. It was the ninth periodic comet to be recognized as such. Tempel 1 is a short-period comet - meaning that it moves about the Sun in an elliptic orbit between the planets Mars and Jupiter. In Tempel 1's case that is once every 5.5 years. Its nucleus is thought to be of low density, with a diameter of about 6.5 kilometers (about 4 miles). Earth-based observations indicate it makes one full rotation about its axis about every 41 hours.

Deep Impact's 'Impact'

Deep Impact's flyby spacecraft literally drops off the impactor in a position to be hit by the comet.

The spacecraft's impactor will collide with comet 9P/Tempel 1 when the comet is near its perihelion, or the closest point to the Sun in its orbit. The 372-kilogram (820-pound)

impactor will strike it at a relative velocity of 10.2 kilometers per second (22,800 miles per hour). This will change the comet's velocity by 0.0001 millimeter per second (about 0.014 inch per hour). It will decrease the comet's perihelion distance (the closest it gets to the Sun) by 10 meters (about 33 feet), and decrease its orbital period by far less than one second of time. The net impact on the comet will be undetectable -- the astronomical equivalent of a mosquito running into a 767 airliner.

By comparison, when the comet passes by Jupiter in 2024, its perihelion distance will change by 34 million kilometers (about 21 million miles). In other words, the changes in the motion of comet Tempel 1 caused by Deep Impact are completely negligible when compared to the comet's orbital changes as it passes by Jupiter.

Mission Overview

Deep Impact is the first mission ever to attempt impact with a cometary nucleus in an effort to probe and discover the secrets that lie beneath its surface. Scheduled for launch in January 2005, Deep Impact will fly directly to its encounter with comet Tempel 1, making no planetary flybys along the way. The voyage will take about six months.

The mission has been designed as the most expedient way to accomplish the project's primary scientific objective - to observe close-up the internal composition of a comet. The mission is part of NASA's Discovery program, aimed at launching many small, relatively low-cost missions that perform focused science with fast turn-around times, and are joint efforts with industry, small business and universities.

Mission Phases

Six mission phases have been defined to simplify descriptions of the different periods of activity during the mission. These are the launch, commissioning, cruise, approach, encounter and playback phases.

Launch

Deep Impact will be launched from Space Launch Complex 17B at Cape Canaveral Air Station, Florida. The launch period opens on Jan. 8, 2005, and continues through Jan. 28. Two instantaneous launch windows occur each day. On Jan. 8, the first is at 1:40 p.m. EST, with a second window 39 minutes later.

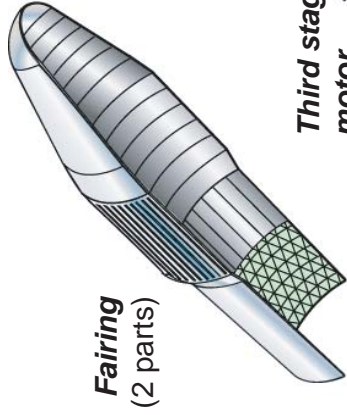
The spacecraft will be launched on a variant of the Delta II launch vehicle known as a Delta 7925. This version of the Delta II uses a first-stage rocket with nine solid-fuel boosters and a second-stage rocket with a restartable engine. It is topped by a Star 48 solid-fuel upper-stage booster.

Launch Events

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 solids are ignited in flight following the burnout of the first six. The spent booster casings are then jettisoned in sets of three. The first-stage main engine continues to burn for 4.4 minutes, when it shuts down.

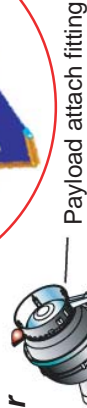
Seconds later, the Delta's first and second stages are separated, and approximately 5 seconds later the second stage is ignited. The Delta's payload fairing, or nose cone, is jettisoned approximately 5 minutes into flight. The rocket's second stage continues to burn until a 167-kilometer-high (90-nautical-mile) circular parking orbit is achieved. The second stage shuts down just under 10 minutes after liftoff.

Deep Impact spacecraft
(shown ~2x larger)



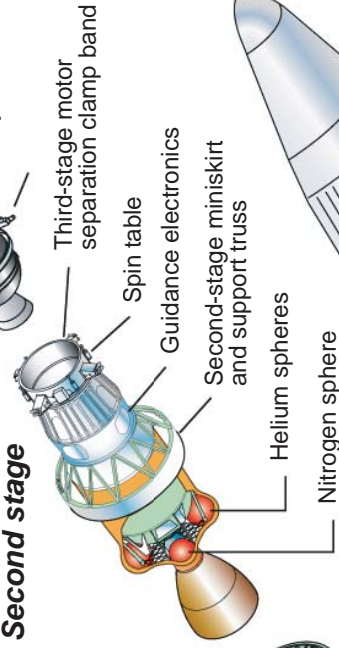
Fairing
(2 parts)

Third stage motor



Payload attach fitting

Second stage



Third-stage motor separation clamp band

Spin table

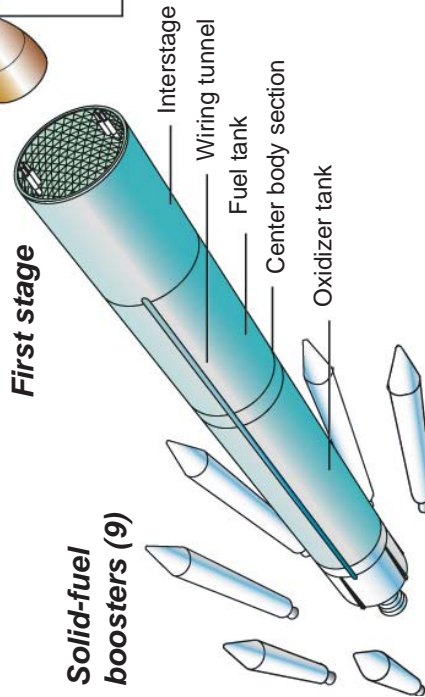
Guidance electronics

Second-stage miniskirt and support truss

Helium spheres

Nitrogen sphere

First stage



Solid-fuel boosters (9)

Interstage
Wiring tunnel
Fuel tank
Center body section
Oxidizer tank

Conical section

Access door

Delta launch vehicle

After achieving this parking orbit, the Delta rocket and Deep Impact spacecraft will coast for approximately 17 minutes before reaching the proper position to depart from Earth orbit. At this point the Delta's second-stage engine is restarted and burns for almost 2 minutes. After a brief coast lasting 50 seconds, the Star 48 upper stage with attached Deep Impact spacecraft is spun up to about 60 rpm to stabilize the vehicle for the third-stage burn. Three seconds later, the second stage separates from the upper stage. Thirty-seven seconds after separation of the second and third stages, the Star 48 spin-stabilized third stage is ignited. The burn lasts for approximately 87 seconds.

Approximately 4-1/2 minutes after burnout of the third stage, a yo-yo despin system is used to decrease the spin rate of the third-stage/spacecraft stack from about 60 rpm to nearly 0 rpm. A few seconds later, the spacecraft is separated from the spent third-stage motor. Pyrotechnic actuators and push-off springs on the launch vehicle release the Deep Impact spacecraft on its trajectory to comet Tempel 1.

About one minute after third-stage separation, the spacecraft's solar array will be deployed, and the spacecraft will rotate to point it at the Sun in about 5 minutes.

In order to assess the health of the spacecraft and respond to any anomalies, mission controllers plan to establish communications with the spacecraft as soon as possible after separation from the third stage. The Delta's upper stage sends the spacecraft out of Earth orbit over southern Africa, so the spacecraft is headed east over the Indian Ocean when it separates from the launch vehicle. The first opportunity for contact with NASA's Deep Space Network is via the tracking complex near Canberra, Australia. The first downlink from the spacecraft is expected 11 to 15 minutes after separation depending on the launch date and time.

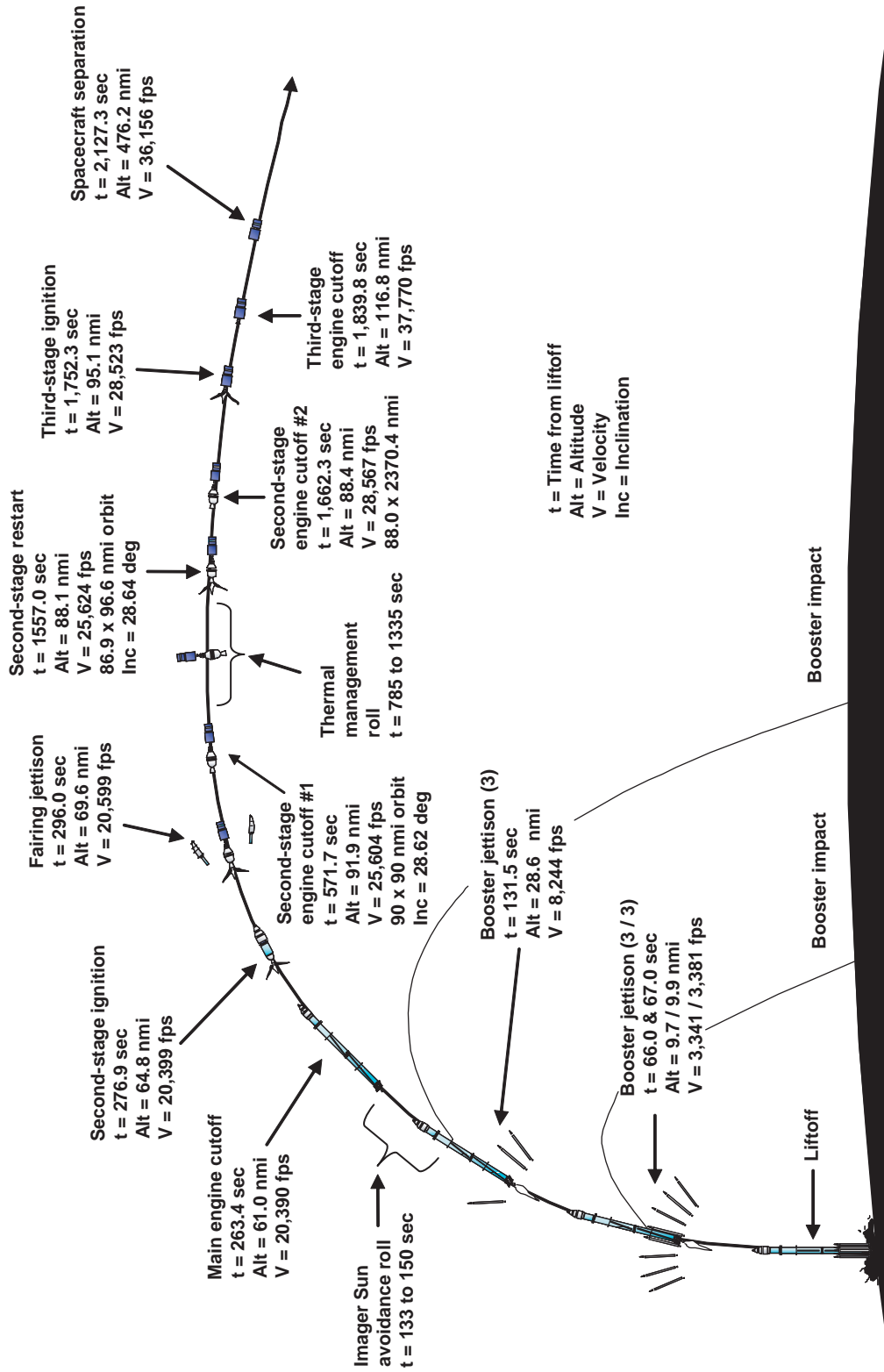
Commissioning Phase

The phrase "commissioning phase" is used to describe the period after the spacecraft is stabilized in flight until 30 days after launch. This is a time of initial operation, check-out and calibration for the spacecraft and payload. Thrusters will be fired in one initial trajectory maneuver to correct for any errors in the flight path remaining from the launch.

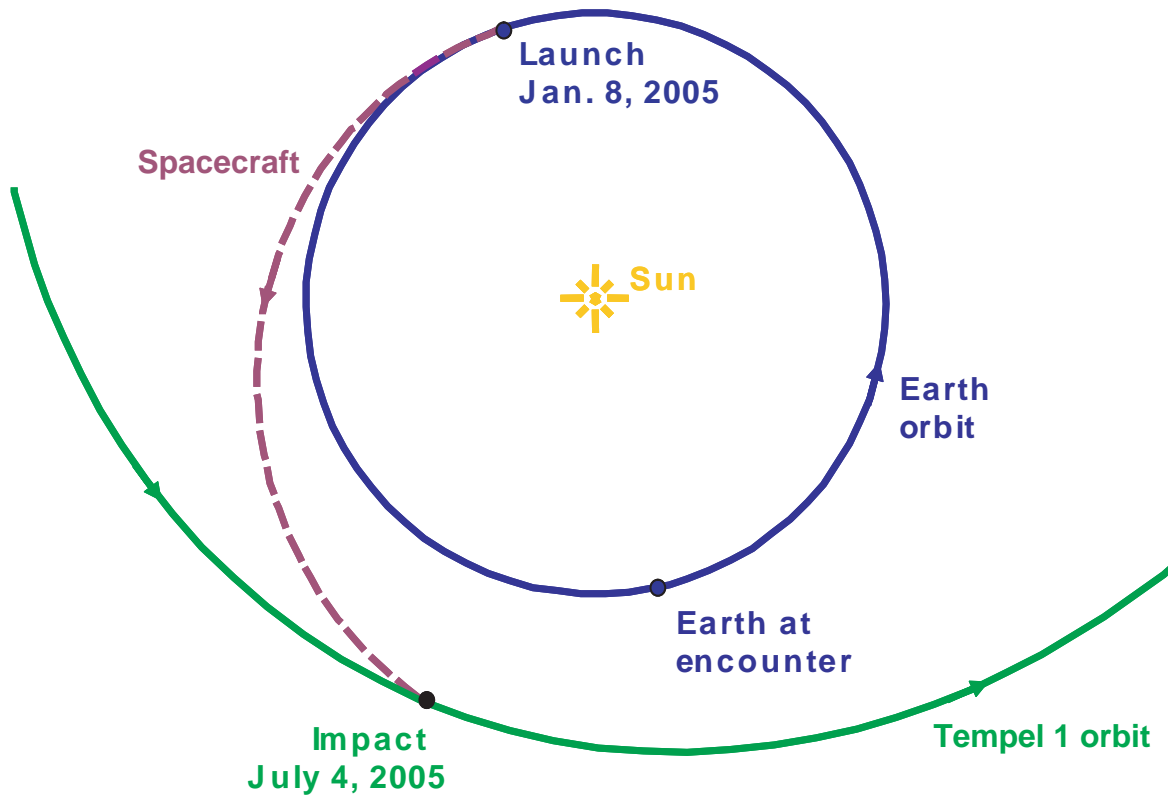
During this phase, the spacecraft's scientific instruments will be tested using the Moon as a calibration target. The spacecraft's autonomous navigation system will be tested using the Moon and Jupiter as practice targets.

Cruise Phase

The cruise phase begins 30 days after launch and ends 60 days before the cometary encounter. As the spacecraft flies toward the comet, the mission team will conduct scientific calibrations, an encounter demonstration test, ground operational readiness



Launch events



Mission trajectory

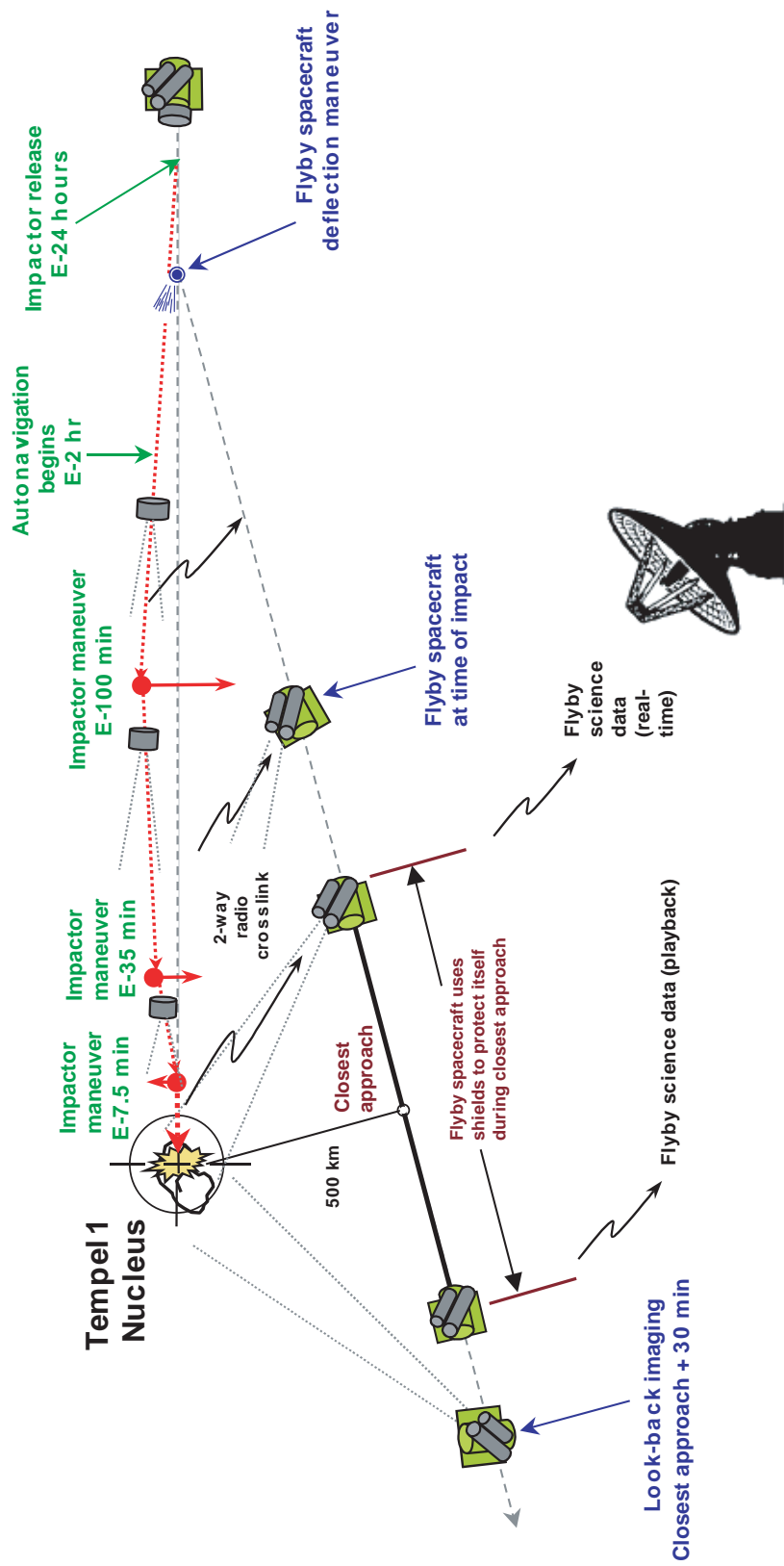
tests and a second trajectory correction maneuver. In addition, some initial observations of comet Tempel 1 will be attempted.

Approach Phase

The approach phase extends from 60 days before to five days before encounter. Sixty days out roughly coincides with the earliest time that the team expects the spacecraft to be able to detect comet Tempel 1 in its high-resolution camera. This milestone marks the beginning of an intensive period of observations to refine knowledge of the comet's orbit. Regular scientific observations will be used to study the comet's rotation, activity and dust environment.

Comet Encounter

The encounter phase begins five days before and ends one day after the impact with comet Tempel 1. This brief but very intense period includes two final targeting maneuvers, leading up to release of the impactor and its dramatic collision with the comet's nucleus. After releasing the impactor, the flyby spacecraft will execute a deflection maneuver so that it does not also collide with the comet; the maneuver will also slow it down enough to make observations after the impact and before flying past the nucleus.



Encounter events

The flyby spacecraft then observes the impact event, the resulting crater and ejected material, before transmitting these data to Earth.

Both the Deep Impact spacecraft and comet Tempel 1 are in curved orbits around the Sun. However, the comet is traveling substantially faster in its orbit than is the spacecraft so the comet actually runs over the spacecraft at a relative velocity of 10.2 kilometers per second (about 22,820 miles per hour).

After releasing the impactor directly in the path of the oncoming comet, the flyby spacecraft fires its thrusters to change course, safely passing by the nucleus with adequate time to observe the impact and resulting crater. This deflection maneuver is designed to make the spacecraft miss the cometary nucleus by 500 kilometers (311 miles). This distance was chosen to provide a survivable path through the comet's inner coma dust environment while still allowing a sufficiently close view of the crater by the spacecraft's high-resolution camera. The spacecraft will be protected by dust shields and oriented in a way to allow its cameras to continue taking pictures throughout the approach until it comes to within about 700 kilometers (420 miles) of the comet's nucleus. At this point, the spacecraft will stop taking pictures and fix its orientation so that its dust shields protect it as much as possible during the closest pass by the comet.

The kinetic energy released by the collision event will be 19 gigajoules, which is about the equivalent of the amount of energy released by exploding 4.5 tons of TNT. This in turn is about the amount of energy used in an average American house in one month.

Encounter Timing

The impact with the comet on July 4, 2005 has been scheduled during a 55-minute window in which Deep Space Network complexes in both California and Australia can track the spacecraft. Besides allowing for fully redundant coverage by these two ground stations, the timing also permits the event to be observed by the major observatories at Mauna Kea on the island of Hawaii (where it will still be the evening of July 3). Another consideration in the encounter timing was to provide an optimal opportunity for observations by two NASA spaceborne observatories, the Hubble Space Telescope and the Spitzer Space Telescope.

Playback Phase

The playback phase begins one day after impact and continues until the end of mission 30 days after the cometary encounter -- or Aug. 3, 2005. Wrapping up the primary mission, data taken during the impact and subsequent crater formation will be transmitted to Earth. Backwards-looking observations of the departing comet will be continued for 60 hours after the impact to monitor changes in the comet's activity and to look for any large debris in temporary orbit around the nucleus.

Telecommunications

Throughout the Deep Impact 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 return through the Deep Space Network's 34-meter-diameter (110-foot) antennas, but the 70-meter (230-foot) antennas will be used during some critical 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 and also adverse changes in the environment of the Earth resulting from the introduction of extraterrestrial matter."

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 comets.

For the Deep Impact mission, NASA's planetary protection officer has assigned a "Category II" status under the policy. This requires documentation of the mission and its encounter with Tempel 1, but places no additional operating restrictions on the mission. Comets are bodies that are of interest to the study of organic chemistry and the origin of life, but are not going to be contaminated by Earth-origin microorganisms.

It should also be noted that comets are exceedingly numerous in the solar system, and any particular comet has a finite lifetime. Indeed, Tempel 1 is a representative of a family of abundant comets. In this case, therefore, the benefits of the Deep Impact mission to cometary study far-outweigh any potential concerns about the fate of the comet itself.

Nom de Plumes to Help Make Cometary Plume

Space fans worldwide may celebrate July 4, 2005, as the day their names reach a comet. The Deep Impact project sponsored a "Send Your Name to a Comet" campaign that invited people from around the world to submit their names via the Internet to fly onboard the Deep Impact impactor. A mini-compact disc bearing the names of more than half a million space enthusiasts is onboard Deep Impact. The mini-CD will melt, vaporize and essentially be obliterated -- along with everything else aboard the impactor -- when it collides with comet Tempel 1.

Spacecraft

The Deep Impact flight system is actually two spacecraft mated together. One part, an impactor, will fly into the nucleus of comet Tempel 1. The second part, a flyby spacecraft, acts as the mothership of the combo, carrying and powering the impactor until 24 hours before the comet impact. Each of these two spacecraft has its own instruments and capabilities to receive and transmit data.

Slightly less than half of the impactor spacecraft is composed of copper, a material chosen because it is not expected to appear in the natural chemical signature of the comet itself that will be studied by the mission's scientific instruments. For its short period of operation, the impactor uses simpler versions of the flyby spacecraft's hardware and software, and contains fewer backup systems.

Flyby Spacecraft

The flyby spacecraft is about the size of an average mid-sized sport utility vehicle. It provides power, communications and maneuvering for both itself and the impactor while en route to the comet nucleus. It releases the impactor, receives impactor data, supports the instruments as they image the impact and resulting crater, and then transmits the scientific data back to Earth.

The flyby spacecraft is three-axis-stabilized, meaning that it does not spin as it flies through space. Its structure is constructed from aluminum and aluminum honeycomb. Blankets, surface radiators, finishes, and heaters passively control the temperature.

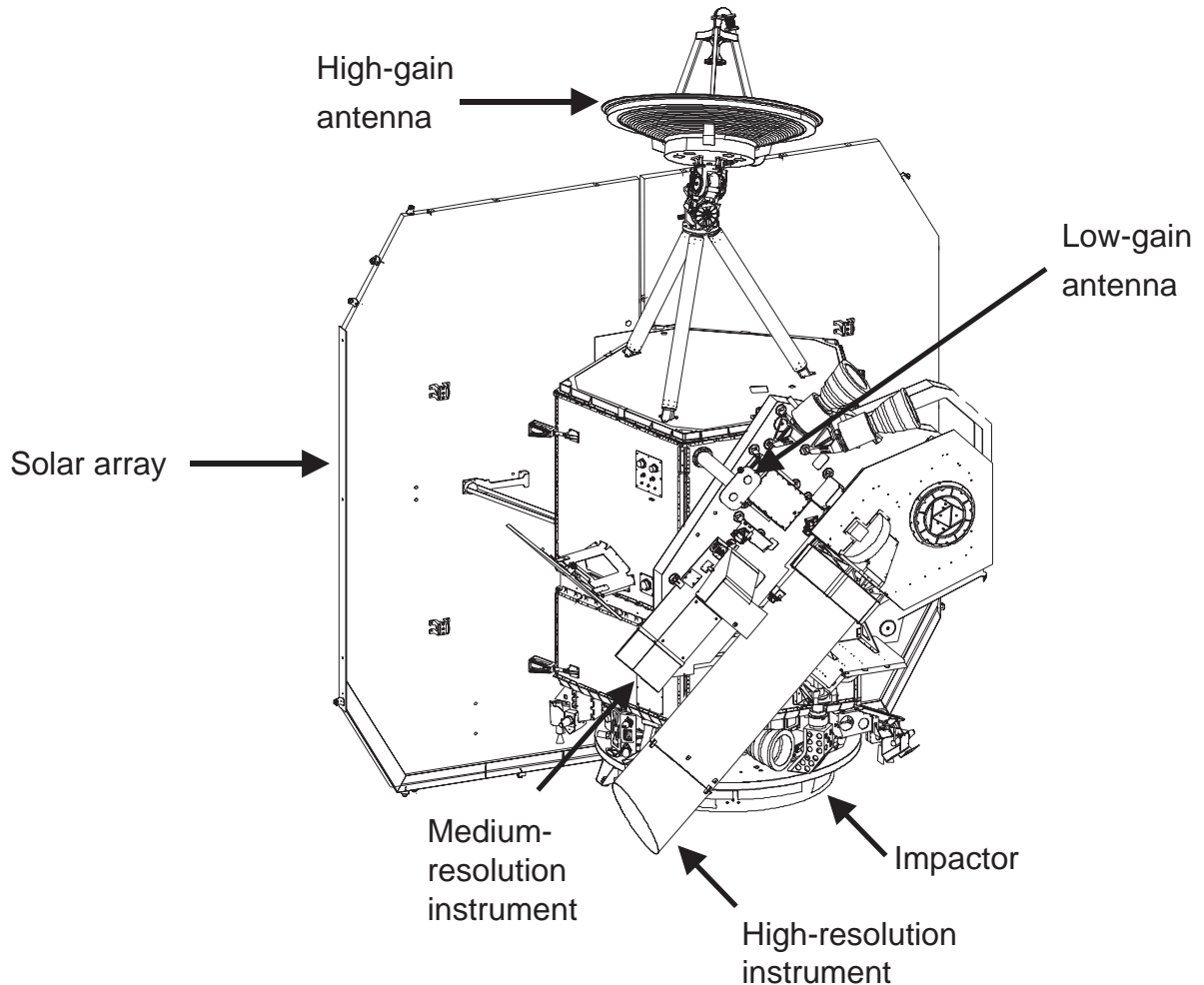
Most systems on the flyby spacecraft are redundant, meaning that there is a backup available if the main system encounters a problem. Automated onboard fault protection software will sense any unusual conditions and attempt to switch to backups. Both the flyby spacecraft and impactor will use onboard navigation software to find comet Tempel 1.

The spacecraft's main computer is based around a Rad 750 chip, a radiation-hardened version of a PowerPC processor used in various consumer computers. There are two redundant computers on the flyby spacecraft. Between them they have a total memory of 1,024 megabytes.

The flyby spacecraft uses an X-band radio to transmit to Earth at a frequency of about 8 gigahertz, and listens to the impactor on a different frequency. It is equipped with a single steerable, high-gain antenna and two fixed, low-gain antennas.

The spacecraft draws its power from a fixed solar array consisting of 7.5 square meters (about 80 square feet). A rechargeable 16-amp-hour nickel hydrogen battery provides power during one solar eclipse and while the solar array is directed away from the Sun.

To adjust its flight path through space, the flyby spacecraft has a propulsion system consisting of a group of thrusters. The fuel used by the thrusters is hydrazine.



Deep Impact spacecraft

Flyby Scientific Instruments

The scientific instruments on Deep Impact's flyby spacecraft have two main purposes. During the first part of the mission, they guide the flyby spacecraft and impactor onto a collision course with the cometary nucleus. Then, during the mission's climax, they collect scientific observations before, during and after the impact. This includes observing material thrown off by the collision event, called "ejecta," as well as the crater created by the event and the surrounding area on the comet's nucleus.

□ The **High-Resolution Instrument** is the main scientific instrument on the Deep Impact flyby spacecraft. It features a 30-centimeter-diameter (11.8-inch) telescope that delivers light simultaneously to both a multispectral camera and an infrared spectrome-

ter. When the flyby spacecraft comes within 700 kilometers (420 miles) of the comet's nucleus, the camera will image parts of the comet with a scale better than 2 meters (about 6 feet) per pixel. This camera is one of the largest instruments flown to date on a planetary mission.

□ The **Medium-Resolution Instrument** is the other scientific instrument on the flyby spacecraft. It is a smaller telescope with a diameter of 12 centimeters (4.7 inches). Due to its wider field-of-view, it can observe more of the field of ejected material as well as the crater created by the impact event. It can also observe more stars around the comet and is therefore slightly better at navigation during the final 10 days of approach to the comet. When the flyby spacecraft comes within 700 kilometers (420 miles) of the comet's nucleus, this instrument can image the entire comet with a resolution of about 10 meters (about 33 feet) per pixel.

Impactor

The impactor spacecraft weighs a total of 372 kilograms (820 pounds), with 113 kilograms (249 pounds) of that being "cratering mass" -- dead weight designed to help the impactor make a substantial crater in the cometary nucleus. The cratering mass is made up of copper plates at the impact end of the impactor. The copper plates are machined to form a spherical shape.

The impactor is powered during its brief solo flight by a single 250-amp-hour battery. The computer and avionics interface box are similar to those on the flyby spacecraft; star trackers, inertial reference units and many propellant subsystem components are the same on both spacecraft. Like the flyby spacecraft, the impactor has a group of thrusters to refine its flight path. Because of its brief mission, the impactor does not have redundant backups as does the flyby spacecraft.

The impactor's single scientific instrument, called the impactor targeting sensor, is an imaging system identical to the medium-resolution instrument on the flyby spacecraft, but without a filter wheel. A 12-centimeter-diameter (4.7-inch) telescope provides navigation images as well as closeup scientific images of the comet just before impact. The best resolution expected from this instrument is about 20 centimeters (approximately 8 inches) per pixel when the impactor is 20 kilometers (about 12 miles) away from the comet's nucleus -- although the dust surrounding the comet is likely to sandblast the mirror significantly in the last half minute or so. Dust impacts may also disturb the instrument's pointing in the final minute before impact.

Science Objectives

The primary goal of the Deep Impact mission is to explore the interior of Comet Tempel 1 by using an impactor to excavate a crater in the comet's surface, after which the flyby spacecraft will take data on the newly exposed cometary interior. Scientists believe in-depth analysis of this new view of Tempel 1 will reveal a great deal not only about this comet but also the role of comets in the earliest history of the solar system.

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

- Dramatically improve the knowledge of key properties of a cometary nucleus and, for the first time, directly assess the interior of a cometary nucleus by means of a massive impactor hitting the surface of the nucleus at high velocity.
- Determine properties of the comet's surface layers such as density, porosity, strength and composition.
- Study the relationship between the surface layers of the comet's nucleus and the possibly pristine materials of the interior by comparing the interior of the crater with the pre-impact surface.
- Improve our understanding of the evolution of cometary nuclei, particularly their approach to dormancy, by comparing the interior and surface.

The main scientific investigation is to understand the differences between the interior of a cometary nucleus and its surface. Some of the questions that will be addressed are:

- If the crater depth reaches 20 meters (about 60 feet), does the material suddenly become carbon monoxide or carbon dioxide ice?
- Or, is the ice still predominantly water (H₂O)? If water ice, is its structure crystalline or amorphous?
- Is the mantle devoid of volatile materials to depths of centimeters, or meters, or tens of meters?
- Is the comet's structure homogeneous from side to side on various scales?
- How does the ratio of ice to refractory (non-melting) material change?
- How old is the surface?
- Does the mantle seal off vaporization from certain areas? Or are certain areas just more devoid of volatile materials than others?

❑ Where will future missions have to go to really sample primordial material?

As a secondary investigation, Deep Impact will look at the question of whether comets become dormant or extinct as they evolve. If comets tend to become dormant, then the outer layers of the nucleus have hardened over time, trapping ice in the interior. In this case, the impactor may break through these outer layers, reactivating the area. On the other hand, if comets tend to become extinct, then an area stays active until all of the ice is gone. In that case, even an impactor the size of Deep Impact's will not reactivate the area. Since Tempel 1 is a relatively inactive comet, it provides a good opportunity to study this issue.

Though they know that the collision event will create a roughly circular crater on the comet nucleus' surface, scientists do not know what size and type of crater will form. There are three likely scenarios that the crater formation can take.

❑ In the first scenario, the crater formation is governed mostly by the gravity of the cometary nucleus (known as a "**gravity-dominated**" process). In this case, the cone of ejected material spreads outwards at an angle of around 45 to 50 degrees from the surface of the comet. The cone's base remains attached to the cometary nucleus. The majority (roughly 75 percent) of the material will fall back down onto the surface of the comet, forming a large-diameter ejecta blanket. In this model, the crater may be as large as a football stadium (around 200 meters or roughly 650 feet in diameter), and 30 to 50 meters (about 100 to 150 feet) deep.

❑ The second possibility is that the more dominant resisting force of the crater formation is the strength of the material (known as a "**strength-dominated**" process). In this case, the ejecta cone will be at a higher angle (around 60 degrees). The cone's base will detach from the crater, and may detach from the comet entirely. Less material (around 50 percent) will fall back to the surface of the comet in this scenario, leaving a smaller ejecta blanket. In this model, the crater will be much smaller, on the order of 10 meters (roughly 30 feet) or less. Predictions of the volume of ejecta produced differ by a factor of a thousand.

❑ A third possibility is that the cometary material is so porous that most of the impactor's energy and momentum are absorbed in the process of compression and heating (known as a "**compression-dominated**" process). Since so much energy is used in compression, there is less available for excavation, and the result is a much smaller diameter crater than expected. In this scenario, the crater will be deep, but produce a very small ejecta cone.

The cratering process will help reveal what type of material makes up the nucleus (or at least the outer layer), and therefore how the comet formed and evolved. If the crater turns out to be gravity-dominated, this lends evidence to the theory that the comet's

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nucleus consists of porous, pristine, unprocessed material, and that the comet formed by accretion.

If, however, the crater turns out to be strength-dominated, then this suggests that the material of the nucleus is processed somehow, resulting in a comet that can hold together better under impact. This would mean that it is not the pristine, untouched material of accretion. It's also possible that the initial crater formation will be strength-dominated, suggesting a processed outer shell to the nucleus, but that the bulk of the crater is gravity-dominated, suggesting that the impactor has punched through this outer shell into the pristine material below.

Scientists also hope that observing the radius of the ejecta plume and the speed with which the plume changes over time will give them a better estimate of the nucleus material's density. Since the comet's volume will be known, an estimate of density allows for an estimate of the comet's mass.

Others in the Audience

Along with the Deep Impact Flyby spacecraft, there will be numerous other "sets of eyes" watching the events unfold around comet Tempel 1. Assisting the Deep Impact team in their celestial pursuit of comet Tempel 1 are several teams of Earth-based astronomers. The Deep Impact team will use these ground-based observations to complement the data taken by the spacecraft.

In addition to large observatories such as the Hubble Space Telescope, the Spitzer

Space Telescope and large instruments on Mauna Kea in Hawaii, the collision with the comet will be witnessed by a wide network of astronomers, both professional and amateur. The Deep Impact project has organized a small telescope science program, calling on technically proficient amateurs to fill in gaps of observations by large observatories. These observers are able to look at the comet on a repeated basis over a long period of time from many locations around the world, which helps to refine knowledge of how the cometary nucleus rotates. The first observing campaign ran from February 2000 through March 2001, after which the comet became too faint to observe. The program relaunched in October 2004.

Watching for the Comet

Even those not participating in the formal scientific program may be able to get a look at comet Tempel 1 as it brightens in early 2005 and swings inward toward the Sun, if they have access to a small telescope or large set of binoculars. Early in the year the comet will be very dim, but it will begin to brighten after early April as it continues to approach the Sun and Earth. From that point forward until the collision event, it will appear in the evening sky in the constellation of Virgo.

If it weren't for the Deep Impact mission, the comet would only reach a magnitude of about 9.5. The limit of the unaided human eye is about magnitude 6 (larger numbers mean dimmer objects), so some form of telescope or powerful binoculars would be necessary. But the impact could make the comet 15 to 40 times brighter than normal -- perhaps as bright as 6th magnitude, around the limit of the human unaided eye. The comet's position and orbit are listed on NASA's Near-Earth Object website at neo.jpl.nasa.gov .

Program/Project Management

Led by principal investigator Dr. Michael A'Hearn of the University of Maryland, College Park, Md., the Deep Impact mission is managed by the Jet Propulsion Laboratory, Pasadena, Calif., for NASA's Space Science Directorate, Washington.

At NASA Headquarters, Alphonso V. Diaz is associate administrator for space science. Andrew Dantzler is director of the Solar System Division. Steve Brody is program executive for the Discovery Program, Lindley Johnson is Deep Impact program executive, and Dr. Thomas Morgan is Deep Impact program scientist.

At the Jet Propulsion Laboratory, Rick Grammier is project manager. David Spencer is mission manager. JPL is a division of the California Institute of Technology, Pasadena, Calif.

Ball Aerospace & Technologies Corp., Boulder, Colo., designed and built the spacecraft. Monte Henderson is the company's Deep Impact program manager.

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