EPOXI COMET ENCOUNTER
FACT SHEET

Nov. 2, 2010

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 517 kilograms (1,140 pounds) spacecraft and 84 kilograms (185 pounds) fuel.
On 10/25/10 there was 4 kilograms (8.8 pounds) of fuel remaining.
Power: 2.8-meter-by-2.8-meter (9-foot-by-9 foot) solar panel providing up to 750 watts, depending on distance from sun. Power storage via small, 16-amp-hourrechargeable nickel hydrogen battery

Comet Hartley 2
Nucleus shape: Elongated
Nucleus size (estimated): About 2.2 kilometers (1.4 miles) long
Nucleus mass: Roughly 280 million metric tons
Nucleus rotation period: About 18 hours
Nucleus composition: Water ice, carbon dioxide ice, silicate dust

Mission
Launch: Jan. 12, 2005
Launch site: Cape Canaveral Air Force Station, Florida
Launch vehicle: Delta II 7925 with Star 48 upper stage
Impact with Tempel 1: 10:52 p.m. PDT July 3, 2005 (1:52 a.m. EDT 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 Tempel 1: 431 million kilometers (268 million miles)
Flyby of Hartley 2: About 10 a.m. EDT or 7 a.m. PDT Nov. 4, 2010
Additional distance traveled by spacecraft to Hartley 2: About 4.6 billion kilometers (2.9 billion miles)

Program
Cost of Deep Impact: $267 million total (not including launch vehicle), consisting of $252 million spacecraft development and $15 million mission operations
Cost of EPOXI extended mission: $42 million, for operations from 2007 to end of project at the end of fiscal year 2011. This includes mission and science operations for both Extrasolar Planet Observations and Characterization (EPOCh), and Deep Impact Extended Investigation (DIXI) operations.

What is EPOXI?

EPOXI is the name for the supplemental mission of NASA's Deep Impact spacecraft. The mission uses the flyby spacecraft that is part of the Deep Impact flight system. The impactor spacecraft of Deep Impact collided with the nucleus of comet Tempel 1 on July 4, 2005. The second part, a flyby spacecraft, acted as the mother ship, carrying and powering the impactor until 24 hours before the comet impact. NASA extended the flyby spacecraft's mission on July 3, 2007.

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.

NASA's Deep Impact spacecraft visited one of these nomadic ice balls in 2005, when it became the first spacecraft ever to send an impactor into a comet's nucleus, to discover the secrets that lay beneath its surface. With the flyby orbiter still fit to fly, mission managers gave the spacecraft a new mission, dubbed EPOXI, to explore other celestial targets of opportunity. Mission controllers at JPL began directing Deep Impact towards Hartley 2 on Nov. 1, 2007.

The flyby of Hartley 2 on Nov. 4, 2010, will go down in space history books as only the fifth comet ever to have a spacecraft fly close enough to take images. It is also the first time in history that two comets have been imaged with the same instruments and same spatial resolution. More than 118,000 frames are anticipated from the Hartley 2 encounter.

The name EPOXI is a combination of the names for the two extended mission components: the extrasolar planet observations, called Extrasolar Planet Observations and Characterization (EPOCh), and the flyby of comet Hartley 2, called the Deep Impact Extended Investigation (DIXI). The spacecraft will continue to be referred to as "Deep Impact."

EPOXI is a Mission of Opportunity, part of NASA's Discovery program, aimed at launching many small, relatively low-cost missions that perform focused science with fast turnaround times, and are joint efforts with industry, small business and universities.

Why comet Hartley 2?

Hartley 2 was chosen as EPOXI's destination after the initial target, comet Boethin, could not be found. Scientists theorize comet Boethin may have broken up into pieces too small for detection.

Recent observations by EPOXI indicate that comet 103P/Hartley 2 has a nucleus that is highly elongated and about 2.2 kilometers [1.4 mile] long, and that it rotates around itself about once every 18 hours.

Hartley 2 belongs to the Jupiter family of comets (comets with periods less than 20 years). It has an orbital period of 6.46 years. The comet was discovered in 1986 by astronomer Malcolm Hartley using the UK Schmidt Telescope at the Siding Spring Observatory in Australia.

The comet has been seen at every return since its discovery. The 2010 return is exceptional, as the comet passed within 17.7 million kilometers (11 million miles) of Earth on Wednesday, Oct. 20 at noon PDT (3 p.m. EDT). This was its closest pass to Earth since its discovery.

Other suns, other planets
During Deep Impact’s cruise to Hartley 2, the spacecraft conducted and completed the Extrasolar Planet Observations and Characterization (EPOCh) component of its extended EPOXI mission. It carefully studied a small number of stars in order to learn more about planets that we know are orbiting those stars, and to search for clues to other planets that might be orbiting the same stars.

On to Hartley 2
The DIXI component (Deep Impact Extended Investigation) of the EPOXI mission is observing comet 103P/Hartley 2 to compare it with comets observed by other spacecraft missions.

The Deep Impact spacecraft will compare Hartley 2 and Tempel 1, using measurements from the exact same instruments. This will be particularly useful for determining which cometary features represent primordial differences and which result from subsequent evolutionary processes.

EPOXI Mission Phases

Before EPOXI Start: Prior to the official conclusion of the Deep Impact mission, mission controllers at JPL ordered the spacecraft to execute one final adjustment to its flight path, called a trajectory correction maneuver. This maneuver placed the Deep Impact spacecraft on an Earth flyby trajectory. In late July 2005, the spacecraft was put in hibernation. For the next two years it was awakened roughly once every 6 months to check its health and safety, and then it was put back to sleep.

EPOXI Project Begins: EPOXI project officially began in July 2007.

Cruise-1: On September 26, 2007, commands from Earth awakend the flyby spacecraft and the cruise-1 phase began. The spacecraft executed one trajectory correction maneuver during cruise-1, on Nov. 1, 2007.

This was the ninth maneuver since launch of the Deep Impact spacecraft, which is now being used for the EPOXI mission. This maneuver adjusted its orbit so that it would fly past comet Hartley 2 in Nov. 2010.

Earth Flyby-1: On Dec. 31, 2007, the Deep Impact spacecraft made a flyby of Earth, During this encounter, the spacecraft's High Resolution Instrument, including its infrared spectrometer, and Medium Resolution Instrument were recalibrated using our moon as a reference source.

Cruise-2: This phase started in January 2008 and lasted all the way up until the start of the Hartley 2 Approach Phase in September 2010. This phase encompassed the EPOCh observations, spacecraft and instrumentation testing and calibration, two Earth flybys, and the first test in history of the Interplanetary Internet.

The spacecraft performed EPOCh observations from January to March 2008 and from May to August 2008.

The first test of the deep space communication network, or Interplanetary Internet, was successfully conducted from mid-October to mid-November 2008. During the test, the EPOXI mission spacecraft transmitted dozens of images to and from Earth, which was 32 million kilometers (20 million miles) away at the time.

Comet Approach Phase: The mission's comet approach phase began 60 days before the planned comet Hartley 2 encounter, on Sept. 5, 2010. The main activity during this phase was to gather navigational data to plan trajectory correction maneuvers to refine the spacecraft's path toward the comet, and to obtain scientific observations.

The science team used images of the comet taken during this phase to search for outbursts of volatile material from the comet's surface.

Encounter Phase: The Encounter Phase, beginning the afternoon of Nov. 3 (PDT and EDT), occurs when the spacecraft is 18 hours from its closest approach to the comet's nucleus. At that time, the spacecraft will point its imagers at the comet nucleus and continue to do so for the next 18-plus hours.

The spacecraft's flight path through encounter is chosen in such a way that there is always sunlight on the solar panels.

At the time of closest approach, on Nov. 4 at about 7 a.m. PDT, or 10 a.m. EDT, the spacecraft will be about 700 kilometers (435 miles) from the comet. The spacecraft will be traveling by Hartley 2 at a speed of 12.32 kilometers per second (27,560 mph).

The EPOXI mission spacecraft will fly past Hartley 2 when the comet is between Earth and Mars. At the time of closest approach, the spacecraft and comet will be about 162 million kilometers (about 101 million miles) away from the sun and about 21 million kilometers (13 million miles) away from Earth.

Because the spacecraft was configured for the 2005 encounter with Tempel 1, the spacecraft's high-gain antenna during closest approach to Hartley 2 will not be in an optimal position for direct communications with the NASA's Deep Space Network antennas on Earth. Within minutes after closest approach, the spacecraft will re-orient itself so the high-gain antenna is pointed at Earth. The download of data and imagery stored in the spacecraft's memory since before closest approach is expected to begin within the first 30 minutes after closest approach. Over the next two days, the spacecraft will continue to make observations, while simultaneously downlinking stored observations.

Departure Phase: Two days after closest approach to Hartley 2, the spacecraft enters Departure Phase. During this phase, a 21-day period for look-back observations is planned. At the end of this phase and after a final calibration run, the spacecraft is to be decommissioned.

Telecommunications: Throughout the comet encounter, 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.

Spacecraft

The flyby spacecraft is about the size of a mid-sized sport utility vehicle.

It is three-axis-stabilized, meaning it does not spin as it flies through space and is able to continuously point the instruments at the comet. Its structure is made 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. The flyby spacecraft will use onboard navigation software to find comet Hartley 2.

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 at the turn of the century. 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. 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.

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 toward its encounter with Hartley 2. Then, during the encounter, they collect scientific observations before, during and after closest approach.

The flyby spacecraft's two imaging instruments are mounted on a common platform. Each has a nine-position filter wheel that allows the science team to take pictures in different parts of the color spectrum.

The **High-Resolution Instrument** is one of two imagers on the flyby spacecraft. It features a 30-centimeter-diameter (11.8-inch) telescope that delivers light simultaneously to both a multispectral camera and an infrared spectrometer contained within the instrument. This camera is one of the largest instruments flown to date on a planetary mission. The instrument's camera will obtain the best, most detailed pictures of a comet ever taken. Tests after launch indicated that the imager's focus was not as expected. Although the focus improved after the instrument was heated, or "baked out," to remove normal residual moisture, spatial resolution remains a factor of 3 to 4 less than planned. A "tiger team" of engineers found that the most likely cause of the problem was a mirror that, while flat at room temperature, developed some curvature at the cryogenic temperatures of the thermal-vacuum tests. The team will compensate by using an image processing technique called deconvolution, which was also used to improve images from NASA's Hubble Space Telescope before its second camera instrument was installed. The science team is confident that the technique will allow them to recover resolution essentially the same as that planned before launch.

The **Medium-Resolution Instrument** is the other scientific instrument on the flyby spacecraft. This instrument takes pictures of stars and the comet for guidance and navigation. It also collects visible images with a wide field-of-view of material ejected from the comet as well as the comet nucleus itself for scientific purposes. The Medium-Resolution Instrument provides context and coma science to the detailed science provided by the High-Resolution Instrument. The Medium-Resolution Instrument is a smaller telescope, with a diameter of 12 centimeters (4.7 inches).

Due to its wider field-of-view, the medium-resolution imager can 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 (4,354 miles) of the comet's nucleus, this instrument can image the entire comet with a resolution of about seven meters (about 23 feet) per pixel.

Science Objectives

There are two primary objectives of the Hartley 2 comet encounter:

- To determine the degree of diversity among comets by comparing comets of analogous ages
- To separate which aspects of the discoveries at Hartley 2 are likely to be associated with the comet's evolution, and which are likely to be primordial.

Missions to Comets

Encounter Date(s)	Mission	Agency	Comet(s)
Dec. 15, 1984	Vega 1	IKI	Halley
Dec. 21, 1984	Vega 2	IKI	Halley
September 11, 1985 March 28, 1986	International Cometary Explorer	NASA	Giacobini-Zinner (1985) Halley (1986)
March 13, 1986 July 10, 1992	Giotto*	ESA	Halley (1986) Grigg-Skjellerup (1992)
1986	Sakigake	JAXA	Halley
1986	Suisei,	JAXA	Halley
Sept. 2001	Deep Space 1*	NASA	Borrelly
Jan. 2, 2004	Stardust*	NASA	Wild 2
July 4, 2005	Deep Impact*	NASA	Tempel 1
Nov. 4, 2010	EPOXI	NASA	Hartley 2
Feb. 14, 2011	Stardust-Next	NASA	Tempel 1
2014	Rosetta	ESA	67P/Churyumov-Gerasimenko

* imaged comet nucleus

Program/Project Management

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

At NASA Headquarters, Ed Weiler is associate administrator for the Science Mission Directorate. Jim Green is director of the Planetary Science Division. Dennon Clardy is the manager of the Discovery/New Frontiers Program office, Lindley Johnson is EPOXI program executive, and Michael Kelly is program scientist.

At JPL, Tim Larson is project manager. Don Sweetnam is deputy program manager, and Al Nakata is mission manager. JPL is a division of the California Institute of Technology in Pasadena.

Ball Aerospace & Technologies Corp., Boulder, Colo., designed and built the spacecraft. Len Andreozzi is the company's EPOXI program manager.

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