SAMPLE

Solar System Missions: Deep Impact

Comet Tempel 1

Aira Astralis

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Conclusion

This free sample contains the Introduction and Chapter 1. The complete book contains the full contents above.

Introduction

Deep Impact was a NASA space probe launched from Cape Canaveral Air Force Station pad SLC-17B on January 12, 2005, and the first mission in history designed to reach beneath the surface of a comet. Previous missions to comets, from Giotto's distant pass by Halley in 1986 onward, could photograph and examine only the dark crust of a nucleus, and only from considerable range. Deep Impact was built to change that: it would strike a comet, excavate material from its interior, and watch what came out.

The target was Comet 9P/Tempel 1, a Jupiter-family comet discovered by the German-French astronomer Ernst Wilhelm Tempel at Marseille on April 3, 1867, and returning to the inner solar system roughly every six years. By the time the mission was designed, Tempel 1 was one of the best-studied short-period comets, which made it an ideal candidate for an experiment that would leave a permanent mark.

The spacecraft was really two vehicles in one. A Flyby craft, about 3.3 meters long and 1.7 meters wide, carried the High Resolution Instrument and the Medium Resolution Instrument for imaging and infrared spectroscopy, along with a Whipple debris shield for protection from cometary dust. Attached to it rode the Impactor: a 372-kilogram, mostly copper projectile carrying its own targeting camera, the Impactor Targeting Sensor, and thrusters for steering itself into the comet's path. Copper was chosen because it was not expected to occur naturally on the comet, so the projectile's own vaporized material would not confuse the spectrometers.

On July 3, 2005, near the comet, the two craft separated. The Impactor aimed itself at Tempel 1 and, at 05:45 UTC on the morning of July 4, 2005, struck the nucleus at a closing velocity of 10.2 kilometers per second. The collision released kinetic energy equivalent to about 4.8 tonnes of TNT, excavated a crater, and threw a plume of interior material into space where the Flyby craft, passing within 500 kilometers minutes later, could image and analyze it. It was, by design, the most publicized moment in comet science: the impact was observed by the Hubble Space Telescope, by ESA's Rosetta spacecraft from about 80 million kilometers away, and by professional and amateur astronomers on Earth.

The mission's Principal Investigator was the astronomer Michael A'Hearn of the University of Maryland, leading a science team drawn from Cornell, Arizona, Brown, Hawaii, JPL, and Ball Aerospace, which built the spacecraft. The questions they set out to answer were fundamental: what a comet's interior is made of, how the surface layer differs from the material beneath it, and what

the ice and dust locked inside preserve about the origin of the solar system.

The answers surprised nearly everyone. The excavated material was finer and dustier than expected; the comet proved fluffier and less dense than models had predicted, and beneath the stale crust lay water ice and organic molecules. Whatever a comet looked like from the outside, the inside told a different story, one that upended the dirty-snowball picture in favor of something more like a porous, layered dustball.

The mission did not end at Tempel 1. After an Earth flyby on December 31, 2007, the still-healthy Flyby craft was retasked as EPOXI, a dual-purpose extended mission: observing extrasolar planets as they transited their stars, and steering toward a second comet, 103P/Hartley 2, whose November 4, 2010 flyby found jets driven by carbon dioxide rather than water. Contact was lost in 2013, and the mission was formally concluded. What follows in this book is the full story: the comet, the spacecraft, the impact, and what the interior of a comet told us about how the solar system was built.

Chapter 1: The Discovery of Deep Impact

The story of Deep Impact begins with a small, faint smudge spotted from a rooftop observatory in Marseille on the night of April 3, 1867. Ernst Wilhelm Tempel, a brewer's son who had taught himself astronomy and ground his own lenses, found the object while sweeping for comets, and the new visitor proved to be a periodic one, circling the Sun roughly every six years. It was eventually designated 9P/Tempel 1: the ninth comet recognized as periodic, and the first of Tempel's discoveries to earn a permanent place in the catalog. Observations over the following decades showed a Jupiter-family comet, its orbit shaped and shortened by the giant planet's gravity, one that had been recycling the same ice and dust through the inner solar system for millennia.

A century later, the comet's reliable orbit and moderate activity made it a natural target when planetary scientists began to ask a question that no mission had ever answered: what is a comet like on the inside? Flybys had shown the surfaces of nuclei, but the surface is the part of a comet most altered by the Sun, baked into a crust that hides the pristine material below. Only an excavation could reach it. A mission to excavate a comet, engineers realized, would need to hit it hard enough to dig, fast enough to arrive, and precisely enough to strike a specific point on a target millions of kilometers away, arriving at a specific hour.

That precision was the audacious part. The Impactor would have to navigate itself, in real time, into the path of an object about 6 kilometers across traveling at tens of kilometers per second, with no help from Earth, because commands would take more than seven minutes each way. Skeptics called the plan too ambitious; the mission's designers answered by building the Impactor as a smart, autonomous spacecraft in its own right, a strategy that ultimately proved the doubters wrong on the night of July 4, 2005.

At 05:45 UTC on July 4, 2005, with the confirmation reaching Earth at 05:52, the Impactor successfully collided with the comet's nucleus.

The impact excavated debris from the interior of the nucleus, forming an impact crater. Photographs taken by the spacecraft showed the comet to be more dusty and less icy than had been expected. The impact generated an unexpectedly large and bright dust cloud, obscuring the view of the impact crater. Previous space missions to comets, such as Giotto, Deep Space 1, and

Stardust, were fly-by missions.

These missions were able to photograph and examine only the surfaces of cometary nuclei, and even then from considerable distances. The Deep Impact

mission was the first to eject material from a comet's surface, and the mission garnered considerable publicity from the media, international scientists, and amateur astronomers alike. Upon the completion of its primary mission, proposals were made to further utilize the spacecraft.

The Deep Impact mission was planned to help answer fundamental questions about comets, which included what makes up the composition of the comet's nucleus, what depth the crater would reach from the impact, and where the comet originated in its formation. By observing the composition of the comet, astronomers hoped to determine how comets form based on the differences between the interior and exterior makeup of the comet.

The mission's Principal Investigator was Michael A'Hearn, an astronomer at the University of Maryland.

He led the science team, which included members from Cornell University, University of Maryland, University of Arizona, Brown University, Belton Space Exploration Initiatives, JPL, University of Hawaii, SAIC, Ball Aerospace, and Max-Planck-Institut für extraterrestrische Physik. The spacecraft consists of two main sections, the 372-kilogram (820 lb) copper-core "Smart Impactor" that impacted the comet, and the 601 kg (1,325 lb) "Flyby" section, which imaged the comet from a safe distance during the encounter with Tempel 1.

The Flyby spacecraft is about 3.3 meters (10.8 ft) long, 1.7 meters (5.6 ft) wide and 2.3 meters (7.5 ft) high. It includes a solar panel, a Whipple debris shield, and several science instruments for imaging, infrared spectroscopy, and optical navigation to its destination near the comet. The spacecraft also carried two cameras, the High Resolution Imager (HRI), and the Medium Resolution Imager (MRI).

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ABOUT THE AUTHOR

Aira Astralis is a science writer specializing in astronomy and space exploration. Her work spans the full breadth of humanity's relationship with the cosmos -- from the earliest naked-eye observations to the engineering marvels of modern space missions.

Her books are built on a foundation of primary sources: peer-reviewed research, mission archives, and direct engagement with the scientific community. She writes for readers who want to understand not just what we know about the universe, but how we came to know it.

She believes that the most important frontier is not out there but in the gap between what scientists discover and what the public understands. Her books exist to close that gap.