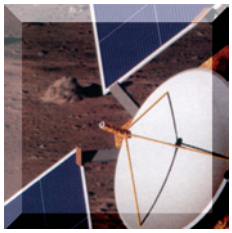

NEAR Shoemaker at Eros: Mission Director's Introduction

Robert W. Farquhar

In 1990, NASA introduced a new program of low-cost planetary missions called "Discovery." A Discovery Science Working Group (DSWG) was established, and in October 1991, the DSWG recommended that "the first mission of the Discovery Program should be a rendezvous with a near-Earth asteroid."[1] In 1991, competitive proposals for the NEAR mission were prepared by APL and the Jet Propulsion Laboratory. After a thorough review of the two proposals by a select panel of experienced project managers, NASA awarded primary management responsibility for the NEAR mission to the APL team. Following the selection, system definition studies were carried out at APL in 1992–1993. The development phase for NEAR began in December 1993, and the spacecraft was shipped to the Kennedy Space Center about 24 months later.

NEAR Shoemaker[2] embarked on its journey to the near-Earth asteroid 433 Eros on 17 February 1996 when the spacecraft was successfully launched by a Delta-2 rocket. One year later, on 18 February 1997, NEAR reached its most distant point from the Sun (2.18 astronomical units), setting a new distance record for a spacecraft powered by solar cells. About 4 months later, on 27 June 1997, NEAR carried out the first reconnaissance of a C-class asteroid (253 Mathilde), obtaining 534 images of this heavily cratered main-belt asteroid.[3] On 3 July 1997, NEAR's large bipropellant rocket engine was fired for the first time, imparting a velocity change of about 269 m/s. This maneuver, which was followed by three smaller propulsive maneuvers using the spacecraft's hydrazine thrusters, targeted NEAR for an Earth gravity-assist maneuver on 23 January 1998. The Earth gravity-assist maneuver substantially reduced the ΔV requirement for an Eros rendezvous by nearly matching the heliocentric orbital inclination and aphelion distance of NEAR and Eros. In addition to changing NEAR's trajectory, the Earth swingby provided an opportunity to obtain spectacular images of Antarctica.[4]

On 20 December 1998, almost 3 years after it was launched, NEAR was ready to begin a sequence of propulsive maneuvers that would culminate with an orbit-insertion maneuver at Eros on 10 January 1999. Unfortunately, the engine burn on 20 December was aborted after firing for less than 1 s, resulting in an unscheduled flyby of Eros on 23 December. Worse yet, the spacecraft wasted almost 30 kg of hydrazine fuel in recovering from the botched rendezvous maneuver. However, NEAR had a forgiving mission design that had planned for adversity.[5] On 3 January 1999, NEAR executed a large propulsive maneuver ($\Delta V \approx 932$ m/s) that reversed the spacecraft's movement away from Eros. This critical event was followed by a clean-up maneuver on 20 January and a midcourse

Table 1. Planetary orbiters: Historic firsts.

4 October	1957	Earth	Sputnik-1	USSR
3 April	1966	Moon	Luna-10	USSR
14 November	1971	Mars	Mariner-9	USA
22 October	1975	Venus	Venera-9	USSR
7 December	1995	Jupiter	Galileo	USA
14 February	2000	Eros	NEAR	USA

correction on 12 August that retargeted NEAR to the vicinity of Eros. The new rendezvous date was 14 February 2000, Valentine's Day.

At 10:47 a.m. EST on 14 February 2000, NEAR executed a 10-m/s orbit insertion maneuver which placed the spacecraft into a 321 × 366 km orbit around Eros. This was the first time that any spacecraft had orbited a small body (asteroid or comet). The accomplishment made NEAR the latest member of a very select club of planetary orbiters (see Table 1).

NEAR's year-long orbital phase at Eros was an unqualified success. The extremely difficult orbital operations were carried out flawlessly. Scientific results at Eros exceeded expectations. However, as NEAR approached the end of its primary mission phase, there was some uncertainty concerning the final disposal of the spacecraft. Should it just be abandoned in its orbit around Eros? Alternatively, could a scientifically useful extended mission be identified? One idea that was brought forward was a bold proposal that NEAR should slowly descend to Eros' surface and attempt a landing.[5] During its descent, the spacecraft would keep its high-gain antenna pointed at Earth to transmit images and other science data as fast as possible. If everything went according to plan, images of Eros' surface with resolutions 10 to 20 times better than anything obtained earlier would be acquired. Because the images would be returned during the descent, success would not depend on the spacecraft surviving the landing impact. The primary goal of the "controlled descent" was to obtain high-resolution images. A secondary goal was to achieve a soft landing (i.e., an impact velocity <3 m/s).

NEAR began its descent to Eros' surface at about 10:30 a.m. EST on 12 February 2001. During its descent, NEAR returned 69 images of Eros, the last one snapped just 125 m above the surface. At approximately 3:02 p.m. EST, NEAR executed an amazingly precise soft landing on the surface of Eros. The estimated impact velocity of 1.5 to 1.8 m/s may be the lowest landing speed ever for a planetary lander.

Media coverage of NEAR's landing on Eros was extensive. In addition to live TV, several Web sites distributed NEAR's final images to an interested public. Approximately 2 million hits were recorded by the APL Web site. There was also considerable coverage by print media throughout the world. An especially perceptive editorial in the *Philadelphia Inquirer* captured the true significance of NEAR's landing operation (see the boxed insert).

NEAR was the first mission in NASA's Discovery Program of low-cost planetary missions. During its 5-year mission, NEAR has racked up an impressive list of "firsts," including the following:

- First spacecraft powered by solar cells to operate beyond Mars orbit (1997)
- First encounter with a C-class asteroid (27 June 1997)
- First encounter with a near-Earth asteroid (23 December 1998)
- First spacecraft to orbit a small body (14 February 2000)
- First spacecraft to land on a small body (12 February 2001)

The final "first" was especially significant because this was the first time that a U.S. spacecraft was first to land on a solar-system body (see Table 2).

Table 2. Planetary landers: Historic firsts.

3 February	1966	Moon	Luna-9	USSR
15 December	1970	Venus	Venera-7	USSR
2 December	1971	Mars	Mars-3	USSR
12 February	2001	Eros	NEAR	USA

INTIMACY WITH EROS

Parallel parking on South Street doesn't seem quite so difficult anymore. Not when you consider the maneuvering done this week by NASA scientists, who landed a spacecraft the size of a car on an asteroid 196 million miles from Earth.

Landing the NEAR (Near Earth Asteroid Rendezvous) Shoemaker spacecraft on the Eros 433 asteroid's surface was a bonus, since the legless craft was built for orbiting the asteroid and collecting information—not for putting down roots. It was a redeeming moment, too, for the space agency, which has suffered a series of bungled missions.

The data from the NEAR Shoemaker undoubtedly will offer ooh-aah revelations about the properties of asteroids. But the contemplative observer will appreciate, too, what the mission uncovered about the properties of humans.

Consider the property of patience scientists exhibited by carefully guiding the craft onto the distant surface at a speed of only 3 m.p.h. Or the property of rising to outer-spatial heights to meet such a challenge. Or the greatest property of all—dreaming that the impossible can be done.

Now, go out and park that car.

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The spectacular success of the NEAR mission was the product of many individual and collective contributions. It was also the result of a highly motivated team that succeeded despite considerable adversity—a team that was willing to accept risks to achieve a prominent place in the history of space exploration.

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