# Mars Odyssey Mission Description

## Mission Overview

The Mars Odyssey spacecraft was launched from the Cape Canaveral Air Station in Florida on 2001-04-07 aboard a Boeing Delta II 7925 launch vehicle. At launch Odyssey weighed 729.7 kilograms (1606.7 pounds), including the 331.8 kilogram (731.5 pound) dry spacecraft with all of its subsystems, 353.4 kilograms (779.1 pounds) of fuel and 44.5 kilograms (98.1 pounds) of instruments. The spacecraft traveled more than 460 million kilometers over the course of a 200-day cruise period to reach Mars on 2001-10-24.

Upon reaching Mars, Odyssey fired its main rocket engine for a 19-minute Mars orbit insertion (MOI) burn. This maneuver slowed the spacecraft and allowed the planet's gravity to capture it into orbit. Initially, Odyssey whirled around the red planet in a highly elliptical orbit that took 45 hours to complete.

After orbit insertion, Odyssey performed a series of orbit changes to drop the low point of its orbit into the upper fringes of the Martian atmosphere at an altitude of about 110 kilometers. During every atmospheric pass, the spacecraft slowed by a small amount because of air resistance. This slowing caused the spacecraft to lose altitude on its next pass through the atmosphere. Odyssey used this aerobraking technique over a period of three months to transition from an elliptical orbit into a 400 km nearly circular orbit for mapping.

Mars Odyssey was intended to last for more than 2 full Mars years, or 1374 days. The orbiter had its own science mission and also acted as a relay for landed Mars missions in 2004. The primary mapping mission began in February 2002 and lasted until August 2004 for a total of 917 days. An extended mission then took place through the end of September 2006. The inclination of the science orbit was 93.1 degrees, resulting in a nearly Sun- synchronous orbit (JPLD-16303). The orbit period was just under two hours.

The spacecraft was three-axis stabilized and powered by solar cells. It was built of lightweight composite materials and divided into two sub-assemblies: the equipment module and the propulsion module. The equipment module consisted of two decks - the equipment deck, containing engineering equipment and one science instrument, the Martian Radiation Environment Experiment (MARIE), and the science deck, which housed the remainder of the science instruments and other engineering components.

Mars Odyssey carried three on-board science instruments. The Thermal Emission Imaging System (THEMIS) worked both in the visible and infrared spectral regions. It took multi-spectral thermal-infrared images to determine the surface mineralogy at a global scale and also acquired visible images with a per-pixel resolution of 18 meters (59 feet). The Gamma Ray Spectrometer (GRS) measured gamma rays emitted from the surface of Mars to determine the elemental composition of the surface, including mapping water deposits in water-ice form. It also studied cosmic gamma ray bursts. GRS was actually a suite of three instruments - the Gamma Ray Spectrometer, the Neuron Spectrometer (NS) and the High-Energy Neutron Detector (HEND). GRS and THEMIS could not operate at the same time due to conflicts in the parameters necessary for operation.

The third instrument, the Martian Radiation Environment Experiment (MARIE), was intended to operate continuously throughout the science mission to collect data about the radiation environment of the planet. Flight commanders turned off MARIE on 2001-08-18 because the instrument failed to reset after it did not respond during a downlink session the previous week. It was turned on again in early March 2002 after the mapping orbit had been established. MARIE operated from that time until it was disabled following an intense solar particle event on October 29, 2003. Before being disabled, the instrument showed abnormally high current draw and temperatures. Throughout November and early December of 2003, after the solar event subsided and after Odyssey recovered from entering safe mode, the Odyssey team attempted unsuccessfully to reestablish communication with MARIE.

Two other instruments aboard Odyssey were, like MARIE, sensitive to energetic charged particles. The first instrument was the gamma detector on GRS, which used a large germanium crystal to detects gamma rays coming from the Martian surface. The detection of gamma rays depended on the deposition of energy in the crystal by the incident photons. Charged particles also deposited energy in the crystal. The second non-MARIE instrument aboard Odyssey that was sensitive to charged particles was the scintillation block in the high energy neutron detector (HEND, an element of the GRS suite). The 'external' detector was a cesium-iodide (CsI) scintillator surrounding a stilbene crystal scintillator that was used for high-energy neutron detection. These two detectors were available to continue the monitoring of aspects of the radiation environment at Mars that was conducted by MARIE during Odyssey's cruise and prime mission phases.

The local mean solar time (LMST) at the start of the Odyssey mission was approximately 4:00 p.m. and was later frozen by a maneuver to approximately 5:00 p.m. The local true solar time (LTST) oscillated about 45 minutes around the mean. During the Extended Mission, a small maneuver could be used to eliminate any further drift in LMST. The solar beta angle, which is closely related to the local solar time, had to be maintained at values less than -55 degrees to ensure that GRS radiative cooler was not exposed to the Sun. The Extended Mission orbit had several otable features. In late 2005, the LTST drifted to earlier values, which was favorable for THEMIS daytime infrared imaging. This period also coincided with a minimum in the Earth-Mars range, allowing high downlink data rates, also favorable for THEMIS. A similar favorable geometry occurs in late 2007.

## Mission Phases

Six mission phases were defined for significant spacecraft activity periods. These were the Pre-Launch, Launch and Initialization, Cruise, Orbit Insertion, Aerobraking, and Mapping Phases. The Cruise Phase included three sub-phases: near-Earth, Earth-Mars, and Mars approach.

The final Mapping phase was intended to support the 2003 twin Mars Exploration Rovers and the European Space Agency's Mars Express Beagle II Lander. The rovers began surface operations in January 2004. Beagle II was lost following its landing attempt on December 25, 2003. The Extended Mission, which began in August 2004, had the additional goals of supporting orbit insertion and aerobraking of the Mars Reconnaissance Orbiter in 2006 and landing site reconnaissance for the Phoenix Lander mission.

Prelaunch

The Prelaunch Phase extended from the delivery of the spacecraft to the Eastern Test Range (ETR) until the beginning of the start of the launch countdown at the Kennedy Space Center.

Mission Phase Start Time : 2001-01-04

Mission Phase Stop Time : 2001-04-07

Launch and Initialization

The Launch Phase extended from the start of launch countdown until first contact with the Deep Space Network (DSN) 53 minutes after launch.

Mission Phase Start Time : 2001-04-07

Mission Phase Stop Time : 2001-04-07

Cruise

The Cruise Phase began with initial DSN contact and lasted until 24 hours prior to Mars orbit insertion (MOI). It included 4 trajectory control maneuvers (TCM). The near-Earth subphase included checkout of the spacecraft engineering functions, instrument checkouts, THEMIS imaging of the Earth/Moon system, and TCM-1.

Mission Phase Start Time : 2001-04-07

Mission Phase Stop Time : 2001-10-23

Subphases Dates

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Near-Earth 2001-04-07 to 2001-04-21

Earth-Mars 2001-04-21 to 2001-09-04

Mars Approach 2001-09-04 to 2001-10-17

Orbit Insertion

The orbit insertion phase began 24 hours before spacecraft arrival at Mars. It included the Mars Orbit Insertion (MOI) burn, which achieved an orbit with a 18.6 hour period, making the planned Period Reduction Maneuver (PRM) unnecessary. MOI was achieved through a 19 minute long bipropellant burn.

Mission Phase Start Time : 2001-10-23

Mission Phase Stop Time : 2001-10-27

Aerobraking

The Aerobraking phase began with the completion of the Orbit Insertion Phase and ended with the attainment of the 400 km science orbit. It consisted of brushing through the Martian atmosphere, using the solar panels to create drag and slow down the spacecraft and thus reduce the orbit. The phase also included the deployment of the GRS boom. GRS acquired data throughout the aerobraking phase. Aerobraking concluded with two weeks of transition into the Mapping Phase. The transition included the deployment of the high-gain antenna.

Mission Phase Start Time : 2001-10-27

Mission Phase Stop Time : 2002-02-19

Mapping

The Mapping Phase began once the 400 km science orbit with approximately 5 PM equator crossing was achieved, at 19-Feb-2002 17:14:32 UTC. This time marked the beginning of orbit number 816. The intensive science portion lasted 917 days, with at least one of the three science instruments operating at all times throughout that period.

Mission Phase Start Time : 2002-02-19

Mission Phase Stop Time : 2004-08-24

Extended Mission 1

The first Extended Mission began when the Mapping Phase of the Primary Mission ended, in August 2004. It was to continue for slightly more than one Mars year, about two Earth years. The Extended Mission was designed to address NASA's Mars exploration goals by:

- Significantly enhancing the scientific data sets already acquired, extending their temporal and spatial coverage,

- Enabling new types of observations by operating the instruments and spacecraft in innovative ways,

- Providing operational support for critical phases of future missions, such as communications relay, landing site characterization, and atmospheric monitoring for aerobraking,

- Involving additional students and scientists in data collection and analysis, and

- Establishing Odyssey's role as a long-term asset in the scientific and operational infrastructure at Mars.

Mission Phase Start Time : 2004-08-24

Mission Phase Stop Time : 2006-09-30

Mars Odyssey remains in an extended mission phase as of September 2024.

## Mission Objectives Summary

The 2001 Mars Odyssey Orbiter Mission had 5 detailed science goals each of which was to be addressed by a specific instrument (JPLD-16303).

(1) GRS globally mapped the elemental composition of the surface.

(2) GRS determined the abundance of hydrogen in the shallow subsurface.

(3) THEMIS acquired high spatial and spectral resolution images of the surface mineralogy.

(4) THEMIS provided information of the morphology of the Martian surface.

(5) MARIE characterized the Martian near-surface radiation environment as related to radiation-induced risk to human explorers.

During the Extended Mission, the science teams operated the instruments mostly in their nominal modes, with the scientific objectives of:

(1) Completing coverage,

(2) Improving the signal-to-noise ratio of measurements,

(3) Observing interannual variations and other secular changes,

(4) Acquiring data complementary to those obtained by other spacecraft at Mars.

Each instrument had additional, more specific objectives:

THEMIS

The Thermal Emission Imaging System (THEMIS) had five, more narrowly defined science objectives for the Primary Mission:

(1) To determine the mineralogy and petrology of localized deposits associated with hydrothermal or sub-aqueous environments, and to identify sample return sites likely to represent these environments.

(2) To search for pre-dawn thermal anomalies associated with active sub-surface hydrothermal systems.

(3) To study small-scale geologic processes and landing site characteristics using morphologic and thermophysical properties.

(4) To investigate polar cap processes at all seasons using infrared observations at high spatial resolution.

(5) To provide a direct link to the global hyperspectral mineral mapping from the MGS TES by utilizing the same infrared spectral region at high (100m) spatial resolution.

Additional objectives in the Extended Mission:

(6) To complete the global mapping of surface mineralogy.

(7) To build global mosaics.

(8) To monitor polar-cap growth, retreat, volatile exchange, and energy balance.

(9) Monitor the temporal and spatial variability of dust and water ice aerosols.

GRS

The Gamma Ray Spectrometer (GRS) had the following more specific science objectives (JPLD-16303) for the Primary Mission:

(1) To determine quantitatively the elemental abundances of the martian surface to an accuracy of 10% or better at a spatial resolution of 300 km.

(2) To map the abundances of CO2 and hydrogen (with water depth inferred) over the entire planet.

(3) To determine the depth of the seasonal polar ice caps and their variation with time.

(4) To study the nature of cosmic gamma-ray bursts.

Additional objectives in the Extended Mission:

(5) To map additional elements.

(6) To monitor seasonal and interannual variations.

(7) To simultaneously observe the atmosphere with the Mars Climate Sounder on the Mars Reconnaissance Orbiter.

(8) To locate gamma-ray bursts.

*MARIE*

The Martian Radiation Environment Experiment (MARIE) had the following more specific science objectives:

(1) To measure radiation from the Sun and from sources beyond the solar system that could cause cancer or damage the central nervous system.

(2) To measure for the first time the radiation environment outside the Earth's protective magnetosphere.

(3) To predict anticipated radiation doses that might be experienced by future astronauts and help determine possible effects of Martian radiation on human beings.

Radio Science

Although not a recognized science objective of the 2001 Mars Odyssey mission, improvement of models of the Mars gravity field was supported by collection and archiving of spacecraft radio tracking data by the Planetary Data System.

Extended Mission Themes

Several themes were common to the extended mission science plans. First was the opportunity to collect data for an additional Mars year, to observe and evaluate interannual variability. The Odyssey instrument complement could observe many aspects of the Martian annual cycle, including volatile deposition and sublimation in polar regions, dust storm occurrence, and cloud and aerosol phenomena. Second, for the Gamma Ray Spectrometer (GRS), the increased temporal coverage allowed monitoring of the Martian environment as the solar cycle approached its minimum. This affected the radiation environment, and the increased flux of galactic cosmic rays increased the production of secondary neutrons and gamma rays, providing an enhanced signal for the GRS instruments' studies of the Martian surface. Finally, additional observations also increased the quality of many of the Odyssey data sets. For GRS, the added accumulation time of observation allowed the team to reduce the uncertainties on the elemental abundances, to generate higher resolution maps of many of the elements, and to derive abundances for elements that were not previously mappable. For THEMIS, the extended mission provided the time and bandwidth to obtain early time-of-day infrared data for much of the planet and to complete high-resolution visible image mosaics.

## References

Mars Surveyor 2001, Mission Plan, Revision B (MSP 722-201), JPL Document D-16303, Jet Propulsion Laboratory, Pasadena, CA, 2000.