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. 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 Martian Radiation Environment Experiment (MARIE) was intended to operate continuously throughout the science mission to collect data about the radiation environment of the planet, but the instrument failed to respond and was shut off 2001-08-18.

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. Both missions were expected to conduct surface operations in 2004.

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.

Flight commanders turned off the Martian Radiation Environment Experiment (MARIE) on 2001-08-18 because the instrument failed to reset after it did not respond during a downlink session the previous week.

Mission Phase Start Time: 2001-04-07
Mission Phase Stop Time: 2001-10-23

Subphases	Dates
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 an 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 "

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.

Each instrument had additional, more specific objectives:

THEMIS - The Thermal Emission Imaging System (THEMIS) had five, more narrowly defined science objectives:
(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.

GRS - The Gamma Ray Spectrometer (GRS) had the following more specific science objectives [JPLD-16303]:
(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.

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.

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."

Spacecraft Overview

For most Mars Odyssey experiments, data were collected by instruments on the spacecraft. Those data were then relayed via the telemetry system to stations of the NASA Deep Space Network (DSN) on the ground. Radio Science observations (such as radio tracking) required that DSN hardware also participate in data acquisition. The following sections provide an overview first of the spacecraft and then of the DSN ground system as both supported Mars Odyssey science activities.

Spacecraft

The Mars Odyssey spacecraft was built by Lockheed Martin Astronautics (LMA). The spacecraft structure was divided into two modules: the equipment module and the propulsion module. The shape was not uniform but can be approximated by envisioning a box 2.2 x 1.7 x 2.6 meters. The framework was composed of aluminum and titanium. Most spacecraft systems were redundant in order to provide backup should a device fail. For more information, see [JPLD-16303].

Command and Data Handling

This subsystem handled all computing functions for Mars Odyssey. It ran the flight software and controlled the spacecraft through interface electronics. The system was based around a RAD6000 computer with 128 megabytes of random access memory (RAM) and 3 megabytes non-volatile memory, which allowed data to be maintained by the system in the event of a power failure. The interface electronics were computer cards that communicated with external peripherals. The cards fit into the computer's main board. There were two identical sets of the computer and interface electronics for back up in case one failed. One card was not redundant. It was a one gigabyte mass memory card that was used to store imaging data.

Telecommunications

The telecommunication subsystem was composed of two parts. first was a radio system that operated in the X-band microwave frequency range. It was used for communications between Earth and the spacecraft. The other system operated in the ultra high frequency (UHF) range for communications between future Mars landers and Odyssey.

Communication between the spacecraft and Earth occurred through the use of three antennas. The high-gain antenna was a dish with 1.3 meter diameter (4.25 feet). It was used during the late Cruise and Science and relay phases of the mission when data rates were high. It simultaneously received commands from Earth and transmitted science data to Earth. The medium-gain antenna was a 7.1 cm (2.8 inch) wide rectangular horn antenna that protruded through the high-gain dish. The low-gain antenna was 4.4 cm (1.75 inches) and provided wide- angle communications in emergencies or when the high-gain antenna was not pointed directly at Earth.

Electrical Power

A 7 square meter (75 square feet) solar panel containing an array of gallium arsenide cells generated power for the spacecraft. The power distribution and drive unit sent power to the electrical loads of the spacecraft through a system of switches.

Guidance, Navigation and Control

This subsystem used three redundant pairs of sensors to determine the spacecraft's attitude. A star camera was used to look at star fields and a sun sensor detected the position of the Sun in order to back up the star camera. The inertial measurement unit collected spacecraft orientation data between star camera updates. The reaction wheels along with the thrusters operated to control the attitude. There were four reaction wheels - three primary and one for backup. Odyssey was a three-axis stabilized spacecraft.

Propulsion

The propulsion system comprised a main engine, which aided in placing Odyssey in orbit around Mars, and sets of small thrusters, which performed attitude control and trajectory correction maneuvers. The main engine produced a thrust of about 695 Newtons (156 pounds of force). Each of the four attitude controlling thrusters produced a thrust of 0.9 Newtons (0.2 pounds of force) and the four spacecraft turning thrusters produced a force of 22 Newtons (5 pounds of force). The propulsion system also included one gaseous helium tank used to pressurize the fuel and oxidizer tanks, miscellaneous tubing, pyro valves, and filters.

Structures

The spacecraft was composed of two modules - propulsion and equipment. The propulsion module contained tanks, thrusters, and associated plumbing. The equipment module consisted of the equipment deck, which supported the Mars Radiation Environment Experiment (MARIE), and engineering components. The other component of the equipment module was the science deck which housed the Thermal Emission Imaging System (THEMIS), Gamma Ray Spectrometer (GRS), High-Energy Neutron Detector (HEND), Neutron Spectrometer (NS), and star cameras on top and engineering components and the GRS central electronics box on the underside.

Thermal Control

A combination of heaters, radiators, louvers, blankets, and thermal coatings maintained each spacecraft component's temperature within its allowable limits.

Mechanisms

Odyssey functioned via several mechanisms, many of which were associated with the high-gain antenna. The antenna was locked down during launch, cruise, and aerobraking through three 'retention and release devices,' or latches. The antenna was released and deployed with a motor-driven hinge once the science orbit around Mars was attained. A two-axis gimbal assembly controlled the position of the antenna. The solar array used four latches which folded together and locked down the panels during launch. After deployment, a two-axis gimbal assembly controlled the solar array. The last mechanism was a latch for the deployment of the 6-meterGRS boom.

Flight Software

Odyssey received commands from Earth via radio and then translated them into spacecraft actions. The flight software had the capability to run many sequences concurrently in addition to executing received commands immediately.

The data collection software was quite flexible. The science and engineering data were collected and then put in a variety of holding bins called Application Identifiers (APIDs). Ground commands could easily modify the data routing and sampling frequency.

A number of autonomous spacecraft performance functions were part of the flight software. The spacecraft ran routines to control attitude and orientation without commands sent from Earth. The software also executed fault protection routines to determine if any internal problem occurred. If a problem was found, a number of automatic preset actions would occur to resolve the problem and put the spacecraft into a standby mode until ground controllers provided further direction.

DSN

The Deep Space Network is a telecommunications facility managed by the Jet Propulsion Laboratory of the California Institute of Technology for the U.S. National Aeronautics and Space Administration (NASA).

The primary function of the DSN is to provide two-way communications between the Earth and spacecraft exploring the solar system. To carry out this function it is equipped with high-power transmitters, low-noise amplifiers and receivers, and appropriate monitoring and control systems.

The DSN consists of three complexes situated at approximately equally spaced longitudinal intervals around the globe at Goldstone (near Barstow, California), Robledo (near Madrid, Spain), and Tidbinbilla (near Canberra, Australia). Two of the complexes are located in the Northern Hemisphere while the third is in the Southern Hemisphere.

Each complex includes several antennas, defined by their diameters, construction, or operational characteristics: 70-m diameter, standard 34-m diameter, high-efficiency 34-m diameter (HEF), and 34-m beam waveguide (BWG)."

Instrument Overview

During aerobraking, the accelerometers measure the change in velocity of the spacecraft due to aerodynamic forces. The dominant force is along the spacecraft y-direction. The spacecraft y-axis is approximately into the wind. Data are provided at 1 second intervals and recorded in units of m/s^2.

Scientific Objectives

Accelerometer data were used to characterize the nature of the atmosphere, to determine the effect of the atmosphere on each orbit, and to predict the effect of the atmosphere on future orbits.

Calibration

The instrument was calibrated on each orbit to determine drift in instrument bias. Bias is determined by monitoring the accelerometer instrument during periods of inactivity before and after entering the atmosphere. The bias acceleration is then estimated over the entire pass by trending the data from the pre- and post-atmospheric entry periods. The pre- and post-atmospheric periods were defined by instrument turn-on and turn-off times and a lower limit on the altitude of data used for calibration, typically 250 km.

Operational Considerations

The instrument readings are affected by changes in temperature. The instrument is mounted in the inertial measurement unit (IMU) and the temperature of the IMU is by temperature sensors.

Operational Modes

The data from the accelerometer are passed to the telemetry deck during an aerobraking pass from the time the s/c reaches aerobraking orientation until the s/c returns to nominal orbit attitude.

Measured Parameters

An accelerometer is an instrument that measures the acceleration of the case of the sensor due to external forces. All accelerometers have a 'proof mass' and it is the tendency of the proof mass to move relative to the case that is a measure of the acceleration of the case. Early accelerometers produced output that was directly related to acceleration; but modern sensors integrate the internally measured signal to reduce noise and the output is proportional to the change in velocity over the integration time. In high precision accelerometers, like those on ODY, the proof mass is an electronically floating mass. The electromagnetic field is varied to keep the proof mass stationary relative to the case. The current required to accomplish this is proportional to the acceleration. The accelerometers on ODY are sensitive to acceleration of the center of mass (c.m.) of the s/c, pseudo-accelerations (i.e. centrifugal) due to rigid motion of the s/c about the c.m., and differences in gravitational force at the proof mass and the c.m. of the s/c (gravity gradient).