2001 Mars Odyssey Mission Design

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Extended Abstract

The 2001 Mars Odyssey Project is part of an ongoing series of robotic missions to Mars within the Jet Propulsion Laboratory's Mars Exploration Program. The Mars Exploration Program goals include the global observation of Mars, to enable understanding of the Mars climatic and geologic history, including the search for liquid water and the evidence of prior or extant life. The 2001 Mars Odyssey orbiter carries scientific payloads that will determine surface mineralogy and morphology, provide global gamma-ray observations for a full Mars year, and study the Mars radiation environment from orbit. In addition, the orbiter spacecraft will serve as a data relay for future landers. The orbiter science mission extends for 917 days. During the science mission, the orbiter will also serve as a communications relay for U.S. or international landers in 2003-2004. The orbiter will continue to serve as a telecommunications asset following the science mission; this relay-only phase extends for 457 days, for a total mission duration of 1374 days, or two Mars years. An additional Mars year of relay operations is planned, as a goal.

The orbiter was launched from Pad 17 at Kennedy Space Center, Cape Canaveral, Florida. The Delta II 7925 launch vehicle injected the orbiter onto a high-declination Type I transfer. The orbiter spacecraft is based upon the MSP'98 Mars Climate Orbiter design. The orbiter will capture propulsively into an elliptical orbit about Mars. Up to three months of aerobraking will be required to adjust the orbit to the desired 400 km circular science orbit altitude.

Six mission phases are defined to describe the periods of activities during the orbiter nominal mission. Definitions of the nominal orbiter mission phases are given in Table 1.

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Table 1. Mission Phase Definitions

Mission Phase	Start of Phase	End of Phase
Pre-Launch	Spacecraft delivery to ETR L – 80 days	Terminal Countdown L – 3 hours
Launch and Initialization	Terminal Countdown L – 3 hours	Initial DSN Acquisition L + 1 to 24 hours
Cruise	Initial DSN Acquisition L + 1 to 24 hours	Mars Orbit Insertion Preparation MOI – 10 days
Orbit Insertion	Mars Orbit Insertion Preparation MOI – 10 days	Period Reduction Maneuver MOI + 48 hrs
Aerobraking	Period Reduction Maneuver MOI + 48 hrs	Aerobraking Completion MOI + ~45 days
Science & Relay	Aerobraking Completion MOI + ~45 days	End Science Mission End Aerobraking + 917 days
Relay-Only	End Science Mission End Aerobraking + 917 days	End of Relay Phase End Science Mission + 457 days (goal of 1144 days)

Pre-Launch

The pre-launch phase extends from delivery of the spacecraft to the Eastern Test Range (ETR) until initiation of the terminal countdown three hours prior to launch. Principal activities performed during this phase included final assembly and checkout of the spacecraft, mating with the launch vehicle third stage, propellant loading, and integration of the spacecraft/third stage stack on the Delta II launch vehicle. In addition, there is an extensive review cycle required prior to launch.

Launch and Initialization

The launch phase extended from the initiation of the terminal countdown until communications were established with the spacecraft by the DSN. The orbiter was launched from Space Launch Complex 17 at Kennedy Space Center. A 21 day launch period was scheduled. Two launch opportunities per day were planned during the launch period, with a separation time of 30 to 90 minutes between opportunities.

The burn of the Delta II first stage and the initial second stage burn placed the vehicle into a near-circular 100 nmi parking orbit. Following a coast phase in the parking orbit, the second stage was restarted, followed by the burn of the solid third stage motor. After third stage burnout (injection), the third stage yo-yo despin system was used to decrease the third stage-spacecraft spin rate to near 0 rpm. Separation occurred approximately 33 minutes after launch. Safe mode entry was triggered nominally on board the spacecraft by the separation event. Following separation, the spacecraft autonomously damped rates and deployed its solar arrays. Attitude knowledge was initialized and the spacecraft slewed to its communication attitude. Safe mode was exited through ground command during the first DSN contact, and the spacecraft was transitioned to its cruise attitude one day after launch.

Cruise

The cruise phase begins with the initial DSN contact and ends at 10 days prior to Mars orbit insertion (MOI) with the initiation of the MOI sequence. The cruise phase is subdivided into three subphases: near-Earth, Earth-Mars transfer, and Mars approach. The near-Earth subphase begins with the initial DSN contact and ends fourteen days after launch. Major activities performed in the near-Earth subphase include checkout of the spacecraft engineering functions, instrument checkouts, THEMIS imaging of the Earth/Moon system, and TCM-1. The Earth-Mars transfer phase begins following the near-Earth phase, and ends 50 days prior to arrival at Mars. Routine spacecraft health checks will be performed during the Earth-Mars transfer, and a UHF test will be performed roughly 60 to 80 days after launch. The Mars Radiation Environment Experiment (MARIE) will take science data during cruise, and the Gamma Ray Spectrometer (GRS) High Energy Neutron Detector (HEND) and Neutron Spectrometer (NS) will operate as well, subject to spacecraft power limitations. A THEMIS star calibration is planned 45 days after launch. A THEMIS image of Mars during the approach subphase is planned as a contingency in the event that Earth/Moon images shortly after launch are not acquired. If the Earth/Moon images are acquired, the Mars approach image will not be taken.

Carefully planned thrusting events will be performed periodically during cruise to calibrate the thrusters and characterize the small forces associated with momentum wheel desaturation events. An "active" thruster calibration will be performed shortly after launch; for the active calibration, the thrust vector will be oriented along the Earth/spacecraft vector for maximum visibility. Passive thruster calibrations, in which high data rate accelerations are recorded during momemtum wheel desaturation events, will occur before and after TCMs.

TCM-2 will be performed 90 days after launch. The Mars approach phase begins 50 days prior to arrival at Mars and includes TCM-3 and TCM-4, scheduled for 40 days and 12 days before arrival, respectively. Continuous tracking by the DSN is required during the approach phase. The approach phase ends at 10 days prior to arrival at Mars, when the orbit insertion phase begins.

<u>Orbit Insertion</u>

The orbit insertion phase begins at 10 days prior to arrival at Mars, and includes TCM-5, Mars Orbit Insertion (MOI) and the subsequent period reduction maneuver (PRM). There are two opportunities to perform TCM-5: TCM-5A is scheduled at 24 hours prior to MOI, and TCM-5B is scheduled at 7 hours prior to MOI. If necessary, both TCM-5A and TCM-5B can be performed.

MOI will be achieved through a bipropellant burn that will end with full oxidizer depletion. Assuming launch at the open of the period, the post-MOI orbit period will be 17 hours. Three revs following MOI, a monoprop PRM will be performed to lower the orbital period to approximately 11 hours. Transition from this elliptical orbit to the desired circular science orbit is accomplished during the aerobraking phase.

<u>Aerobraking</u>

The aerobraking phase begins following the completion of the MOI/PRM burns, and ends when the 400 km circular science orbit is attained. The aerobraking phase begins with a series of walk-in maneuvers which gradually lower periapsis into the atmosphere. Once in the atmosphere, the orbiter solar panels are used as drag surfaces so that the orbit period is reduced with each pass through the atmosphere. As the desired apoapsis altitude is approached, the orbit periapse is gradually raised during a walk-out phase, to maintain a minimum orbit lifetime. The aerobraking phase is completed when an aerobraking termination maneuver is performed to raise the orbit periapsis out of the atmosphere, and a transfer to science orbit maneuver is performed.

<u>Science & Relay Phase</u>

The orbiter science & relay phase begins once the science orbit is achieved, approximately 45 days after the spacecraft is captured into orbit about Mars assuming launch at the open of the launch period. There will also potentially be a spacecraft checkout period of up to a week following the completion of aerobraking, during which science observations will not occur. The primary science phase extends 917 Earth days. During the science phase, THEMIS will determine surface mineralogy using multi-spectral thermal-infrared images, and will also acquire 20 m resolution visible images. The GRS will take global gamma-ray measurements covering all Martian seasons. The MARIE radiation monitor will be operated throughout the science phase. The orbiter will also support lander communications relay during the science mission, as needed.

Relay-Only Phase

The relay-only phase begins at the end of the primary science mission. During the relay-only phase, the orbiter will provide communication support for U.S. or international landers or rovers. No science operations are currently planned during the relay-only phase. At the end of the relay-only phase, maneuvers will be performed to raise the spacecraft's orbit to an altitude of 450 km, to ensure that the orbit lifetime requirements for Mars planetary protection are met.

MISSION OBJECTIVES

The primary objectives of the MSP'01 orbiter are to carry out a global survey of Mars using the GRS, THEMIS and MARIE science instruments, and to provide communications support for the future lander missions. The project has a number of more detailed science objectives, which are listed below.

Science Objectives

The objectives of the GRS are to achieve full planet mapping of elemental abundance on Mars by remote gamma-ray spectroscopy to an accuracy of 10% or better at a spatial resolution of 300 km. Also, full planet mapping of the hydrogen (with depth of water inferred) and carbon dioxide abundances will be obtained by remote neutron spectroscopy. The THEMIS instrument has the following four 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 provide a direct link to the global hyperspectral mineral mapping from the Mars Global Surveyor Thermal Emission Spectrometer by utilizing the same infrared spectral region at high (100m) spatial resolution, (3) to study small-scale geologic processes and landing site characteristics using morphologic and thermophysical properties, and (4) to search for pre-dawn thermal anomalies associated with active sub-surface hydrothermal systems.

MARIE will characterize specific aspects of the near-space radiation environment, to better characterize the radiation-induced risk for human exploration of Mars.

The 2001 Mars Odyssey project is managed at the Jet Propulsion Laboratory in Pasadena, California. The prime contractor for the flight system is Lockheed-Martin Astronautics in Denver, Colorado.

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