Mission Overview

The Mars Pathfinder Project was one of the first of the NASA Discovery class missions. Discovery Program missions are defined as low cost missions, (with a $150M FY'92 development cost cap), and a fast schedule (less than 3 years development period). They have focused, but significant, science objectives.

Mars Pathfinder placed a single vehicle on the surface of Mars, the Mars Pathfinder Lander, which then deployed a microrover, called variously 'Sojourner', the 'Microrover Flight Experiment', or the 'Mars Pathfinder Rover'. Several instruments were included on the two spacecraft. The Sojourner carried three cameras, (two black & white cameras on the front and one color camera in the rear), and the Alpha Proton X-Ray Spectrometer (APXS). Sojourner's mobility provided the capability of 'ground truthing' a landing area over hundreds of square meters on Mars. The Lander investigated the surface of Mars with two additional science instruments, a stereoscopic imager with spectral filters on an extensible mast (Imager for Mars Pathfinder or IMP), and the Atmospheric Structure Instrument / Meteorology package (ASI/MET). Mars Pathfinder paved the way for a cost effective implementation of future Mars lander missions as part of a comprehensive Mars exploration program augmented by additional Discovery Program missions.

The launch occurred December 4, 1996 on a McDonnell Douglas Delta II 7925 launch vehicle. The Earth-Mars trajectory was a Type 1 transfer with a Mars arrival date of July 4, 1997. The landing site for Mars Pathfinder was in the Ares Vallis region of Chryse Planitia at 19.17 degrees North latitude, 33.21 degrees West longitude. (See [GOLOMBEKETAL1997B] for specifics.) The Earth elevation angle at landing was 11 degrees and rising, and the Sun was 30 degrees below the local horizon and rising. The Earth-Mars range at arrival was 191,000,000 km (and increasing).

Required guidance, navigation, attitude control, telemetry, and power generation functions during the 7 month cruise were provided by the cruise stage. At Mars arrival, the cruise stage was jettisoned from the entry capsule. The entry capsule entered the Martian atmosphere directly from the Earth-Mars transfer orbit at a velocity of 7.6 km/s. The lander velocity was reduced from this high entry speed through the sequential application of aerodynamic braking by a Viking heritage aeroshell and parachute, propulsive deceleration using small solid tractor rockets, and airbags to nullify the remaining vertical and horizontal velocity components at surface impact. Key engineering status information was collected and returned in near real time to the extent possible during entry and descent. In addition, all engineering and science data obtained during the critical entry, descent, and landing phase were recorded for playback at the initiation of lander surface operations.

The principal surface operations activities were return of engineering data characterizing the performance of the lander system in the Martian environment, return of science data obtained from the imaging, meteorology, and spectroscopy instruments, and operation of the rover to deploy instruments and conduct science and technology experiments.

Seven mission phases, including the extended phase, were defined to describe the periods of activity during the mission. Brief summaries of the activities in each phase are described below.

The mission has been described in many papers including a February, 1997 special issue of the Journal of Geophysical Research and a December, 1997 special issue of Science. Sometime in the latter half of 1998 there will be another special issue of the JGR discussing the results of the mission.

Mission Phases

DEVELOPMENT

The development phase began with the start of mission funding in 1993. During this phase, the science and technology requirements were analyzed and the spacecraft and its components were designed. The instruments and spacecraft were fabricated and tested before delivery to the Eastern Test Range. The spacecraft trajectory and mission operations were also determined during this period.

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Spacecraft Id                 : MPFL
Target Name                   : MARS
Mission Phase Start Time      : 1993-11-01
Mission Phase Stop Time       : 1996-08-12
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PRELAUNCH

The prelaunch phase extended 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 Payload Assist Module-D (PAM-D), propellant loading, and integration of the spacecraft/PAM-D stack on the Delta. In addition, there was an extensive review cycle required prior to launch.

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Spacecraft Id                 : MPFL
Target Name                   : MARS
Mission Phase Start Time      : 1996-08-12
Mission Phase Stop Time       : 1996-12-04
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LAUNCH

The launch phase extended from the initiation of the terminal countdown through spacecraft separation from the upper stage. Mars Pathfinder was launched December 4, 1996, at 6:58 am UTC (1:58 am EST) from launch complex 17B at Cape Canaveral, FL. The launch azimuth was 95 degrees. The boost portion of the launch vehicle trajectory took approximately 10 minutes. Injection occurred about one hour later after an extended coast phase. After third stage burnout, the upper stage despun the stack using a yo-yo despin system. Separation occurred approximately 75 minutes after launch.

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Spacecraft Id                 : MPFL
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Target Name : MARS
Mission Phase Start Time : 1996-12-04
Mission Phase Stop Time : 1996-12-04

CRUISE

The cruise phase started when the spacecraft separated from the upper stage and ended twelve hours prior to entry. The cruise phase was subdivided into three subphases: near Earth, Earth-Mars transfer, and Mars approach. The near Earth subphase started at separation and ended the day after the first Trajectory Correction Maneuver (TCM), which occurred on January 10, 1997. Major activities performed in this subphase were initial link acquisition, initiation of the nominal cruise attitude profile, checkout of the spacecraft engineering functions, rover and instrument health checks, and TCM-1. The Earth-Mars transfer subphase started at the end of the near-Earth subphase and extended through May 20, 1997 (45 days prior to arrival). Activities carried out during this subphase included routine spacecraft health and performance monitoring, tracking data acquisition for navigation, and the second and third TCM's (performed on February 3 and May 7, respectively). The Mars approach subphase started on May 21, 1997 and ended twelve hours prior to entry on July 4, 1997. TCM-4 (on June 25), the entry attitude turn (where the spacecraft was placed into the desired entry attitude), and preparations for Mars atmospheric entry were completed during this subphase.

Because the instruments were all enclosed within the folded-up lander, no science investigations were conducted during cruise, except for instrument health checkouts.

Spacecraft Id : MPFL
Target Name : MARS
Mission Phase Start Time : 1996-12-04
Mission Phase Stop Time : 1997-07-04

ENTRY, DESCENT, AND LANDING

The entry, descent and landing (EDL) phase of the mission started 12 hours prior to entry. The spacecraft was in the autonomous EDL control mode during this period. This phase ended when the airbags were fully retracted, the petals were deployed, and the lander transitioned from the EDL mode to sequence control. This occurred 87 minutes after landing. The EDL phase was divided into three subphases: entry, terminal descent, and EDL surface.

The entry subphase extended from the start of the EDL phase through parachute deployment. The exact time of parachute deployment was calculated from on-board accelerometer measurements, and occurred at 4:54:41 pm UTC (9:54:41 am PDT) on July 4, 1997. Activities in this period included cruise stage separation, peak aerodynamic heating and deceleration, acquisition of engineering and science accelerometer data, and parachute deployment.

The terminal descent subphase started at parachute deployment and ended when the lander rolled to a stop on the surface of Mars. The landing occurred at 4:56:55 pm UTC (9:56:55 am PDT) July 4, 1997; the

true local time at the landing site on Mars was 2:58 am. The lander rolled for about two minutes before finally coming to rest about 19 kilometers southwest of its targeted landing spot. It rested on the surface at a very slight tilt of about 2.5 degrees. Heatshield separation, bridle deployment, radar altimeter data acquisition, airbag inflation, RAD (rocket assisted descent) motor ignition, and impact were the key activities of this subphase.

The EDL surface subphase covered the time period required for the deflation and retraction of the airbags and deployment of the lander petals. The spacecraft landed on its base petal, obviating the need for righting itself. At 6:24 pm UTC (11:24 am PDT), engineering data indicated that Pathfinder had fully deployed its petals and was awaiting sunrise on Mars to power up.

Spacecraft Id : MPFL
Target Name : MARS
Mission Phase Start Time : 1997-07-04
Mission Phase Stop Time : 1997-07-04

LANDER SURFACE MISSION

Mars Pathfinder's surface, or primary, mission phase began when its lander petals were fully unfolded and the lander switched to a sequence of computer commands that controlled its functions. This phase ended 30 Martian 'sols' (each sol being 24.6 hours) after landing. During this and the extended phases, a wealth of engineering and science information was collected from the lander and the instrument packages mounted on it. The IMP camera alone acquired 16,661 images.

Spacecraft Id : MPFL
Target Name : MARS
Mission Phase Start Time : 1997-07-04
Mission Phase Stop Time : 1997-08-03

ROVER SURFACE MISSION

The Rover's primary mission lasted for seven Martian 'sols' from the time of landing. One of the lander's airbags did not fully retract, and was initially draped over the edge of the rover's petal. The petal had to be partially closed and then reopened. This resulted in a slight delay in the deployment of the rover, which occurred at 5:37 am, July 6, 1997 UTC, (10:37 pm, July 5, PDT). During the Rover's primary and extended mission phases, the Rover traveled in a clockwise direction around the lander. It acquired over 600 images and deployed the APXS instrument at a number of rock and soil sites.

Spacecraft Id : MPFR
Target Name : MARS
Mission Phase Start Time : 1997-07-04
Mission Phase Stop Time : 1997-07-11

LANDER EXTENDED MISSION

The Lander's extended mission ended with the last receipt of science

data from the surface on September 27, 1997. It is believed that a combination of a dead battery and the increasing cold of approaching Martian winter crippled the spacecraft's ability to communicate with Earth.

Spacecraft Id : MPFL
Target Name : MARS
Mission Phase Start Time : 1997-08-03
Mission Phase Stop Time : 1997-09-27

ROVER EXTENDED MISSION

The Sojourner rover was continuing to function at the time the Lander ceased communicating with Earth. Upon loss of communication, the Rover presumably acted on its stored commands, which directed it to return to the Lander.

Spacecraft Id : MPFR
Target Name : MARS
Mission Phase Start Time : 1997-07-11
Mission Phase Stop Time : 1997-09-27"

MISSION_OBJECTIVES_SUMMARY = "

Mission Objectives Overview
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The primary objective of the Pathfinder Project was to develop and deliver a single flight system successfully to the Martian surface. This would demonstrate the entry, descent, and landing design by successfully acquiring and returning EDL engineering data and a panoramic image of the Martian surface. The project had a number of secondary programmatic, engineering, science, and technology objectives which are listed below:

Programmatic Objectives

- Complete the development phase within a cost cap of $171M (excluding the rover)
- Complete the mission operations and data analysis phase within a cost cap of $14M (excluding the rover)
- Complete the development and operations of the rover within a cost cap of $25M
- Establish management approaches and practices applicable for fixed price, quick reaction, low cost projects.

Engineering Objectives

- Demonstrate simple, reliable, low cost cruise, entry, descent, and landing systems.
- Monitor and evaluate lander performance in the Martian environment.
- Provide significant inheritance to future Mars lander missions.
- Demonstrate the use of a rover surface vehicle as an instrument deployment and operation mechanism.

Science Objectives

- Obtain data on the structure of the Martian atmosphere along the entry and descent trajectory.
- Characterize the landing site surface geology and morphology at sub-meter scale.
- Monitor meteorological conditions at the landing site.
- Investigate the elemental composition of rocks and surface materials at the landing site.
- Constrain models of the interior of Mars by determining its rate of precession.

Technology Objectives

- Investigate Mars' terrain feature classes.
- Investigate basic Martian soil mechanics parameters.
- Assess the performance of dead reckoning navigation sensors and path reconstruction capabilities.
- Investigate the sinkage of rover wheels in Martian soil.
- Acquire all measurable rover engineering parameters during surface operations.
- Monitor rover thermal behavior during surface operations.
- Assess performance of the rover imaging sensors.
- Investigate the effectiveness of UHF communications links on Mars.
- Measure the abrasive qualities of Martian soil and dust.
- Assess the adherence of Martian dust to surfaces."