```
PDS_VERSION_ID          = PDS3
LABEL_REVISION_NOTE     = "2004-08-09 Joy Crisp"
RECORD_TYPE             = STREAM

OBJECT                  = MISSION
  MISSION_NAME          = "MARS EXPLORATION ROVER"

  OBJECT                = MISSION_INFORMATION
    MISSION_START_DATE  = 2000-05-08
    MISSION_STOP_DATE   = UNK
    MISSION_ALIAS_NAME  = "N/A"
    MISSION_DESC        = "

  Mission Overview
  ================
    The Mars Exploration Rover (MER) mission consisted of two
    spacecraft, MER-2 hardware (including Spirit rover) which was used
    to carry out the MER-A mission, and MER-1 hardware (including
    Opportunity rover) which used for the MER-B mission
    [CRISPETAL2003].  Spirit was launched June 10, 2003, on a Delta
    II 7925 launch vehicle.  Opportunity followed 3 weeks later,
    launching July 7, 2003 on a Delta II 7925 Heavy vehicle.  Each
    spacecraft followed a Type I trajectory from Earth to Mars, with
    Spirit landing in Gusev Crater on January 4, 2004 and Opportunity
    landing in Meridiani Planum on January 25, 2004.  The Earth-Mars
    range was 105 million km at the time of Spirit's landing and 89
    million km at the time of Opportunity's landing.

    The spacecraft design was based on the Mars Pathfinder configuration
    for cruise and entry, descent, and landing.  Each MER spacecraft
    contained a rover which was carried to Mars inside a lander.  The
    lander was packed inside a heatshield and backshell attached to a
    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 trajectory at a velocity of
    5.4 km/s.  The lander velocity was reduced from this high entry
    speed by the application of aerodynamic braking by a parachute and
    aeroshell, propulsive acceleration using small solid rocket motors,
    and inflated airbags to reduce the remaining vertical and horizontal
    velocity components at surface impact (involving significant
    bouncing).  Key engineering status information was collected and
    returned in near real time to the extent possible during entry and
    descent.  In addition, all engineering data obtained during the
    critical entry, descent, and landing phase were recorded for later
    playback during the first week of landed operations.

    The two landing sites were selected because of their science
    potential and safety characteristics [GOLOMBEKETAL2003].  The two
    sites exhibited different types of evidence suggesting past
    liquid-water activity. For Gusev, the evidence was primarily
    geomorphologic (possible crater lake) and for Meridiani, it was
    primarily mineralogic (gray coarse-grained hematite).  The
    navigation team determined the location of the landing sites in
    inertial space, by fitting direct-to-earth (DTE) two-way X-band
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Doppler and two passes of UHF two-way Doppler between each rover and Mars Odyssey. The inertial positions, translated to the MOLA IAU 2000 frame [SEIDELMANNETAL2002] are 4.571892 deg S latitude and 175.47848 deg E longitude for Spirit, and 1.948282 deg S latitude, 354.47417 deg E longitude for Opportunity. The location of the landing sites, with respect to surface features in maps produced in the MOLA IAU 2000 cartographic reference frame, are 14.5692 deg S latitude, 175.4729 deg E longitude for Spirit and 1.9462 deg S latitude, 354.4734 deg E longitude for Opportunity.

Each of the identical rovers was equipped with a science payload consisting of two remote sensing instruments at the top of a rotatable mast to survey the surrounding terrain, a robotic arm capable of placing three instruments and a rock abrasion tool (RAT) on selected rock and soil samples, and several on-board magnets and calibration targets. Engineering sensors and other components on the rovers useful for science investigations included stereo navigation cameras, stereo hazard cameras in front and rear, wheel motors, wheel motor current and voltage, the wheels themselves for digging, gyros, accelerometers, and reference solar cell readings. Mission operations allowed commanding of the rover each martian day, or sol, on the basis of the previous sol's data. Over the 90-sol prime mission lifetime the rovers carried out field geology investigations, exploration, and atmospheric characterization.

Eight mission phases 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 December 2003 special section in the Journal of Geophysical Research - Planets.

Mission Phases

DEVELOPMENT

The development phase began with the start of mission funding in May, 2000. During this phase, the science and technology requirements were developed and analyzed, and the spacecraft and mission were designed. The instruments and spacecraft were fabricated and tested before delivery to Kennedy Space Center. The design of the spacecraft trajectory and mission operations were also determined during this period.

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Spacecraft Id     : MER2
Target Name       : MARS
Mission Phase Start Time  : 2000-05-08
Mission Phase Stop Time           : 2003-06-10
Spacecraft Operations Type        : LANDER

Spacecraft Id     : MER1
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Target Name : MARS
Mission Phase Start Time : 2000-05-08
Mission Phase Stop Time : 2003-07-07
Spacecraft Operations Type : LANDER

LAUNCH

The launch phase for each vehicle began at the final countdown through spacecraft separation from the upper stage. Spirit (MER-2 hardware) was launched June 10, 2003, at 1759 UTC (1359 EDT) from launch complex 17A at Cape Canaveral Air Force Station, Florida. The launch azimuth was 93 degrees. The boost portion of the launch vehicle trajectory took approximately 10 minutes, and was followed by a short coast phase in a parking orbit for approximately 15 minutes. After third stage burnout, the upper stage despun the stack using a yo-yo depin system. Separation of the third stage occurred approximately 36 minutes after launch.

Opportunity (MER-1 hardware) was launched July 7, 2003, at 0318 UTC (1118 EDT) from launch complex 17B at Cape Canaveral Air Force Station, Florida. The launch azimuth was 99 degrees. The boost portion of the launch vehicle trajectory took approximately 9 minutes, and was followed by a long coast phase of approximately 60 minutes in a parking orbit. After third stage burnout, the upper stage despun the stack using a yo-yo depin system. Separation of the third stage occurred approximately 83 minutes after launch.

Spacecraft Id : MER2
Target Name : MARS
Mission Phase Start Time : 2003-06-10
Mission Phase Stop Time : 2003-06-10
Spacecraft Operations Type : LANDER

Spacecraft Id : MER1
Target Name : MARS
Mission Phase Start Time : 2003-07-07
Mission Phase Stop Time : 2003-07-07
Spacecraft Operations Type : LANDER

CRUISE

The cruise phase for each spacecraft began soon after separation from the third stage and ended 45 days before entry into the Mars atmosphere. The duration of cruise phase was 162 days for Spirit and 156 days for Opportunity. The major activities during this phase included: checkout and maintenance of the spacecraft in its flight configuration, monitoring, characterization and calibration of the spacecraft and payload systems, software parameter updates, attitude correction turns, navigation activities for determining and correcting the vehicle's flight path, and preparation for EDL

and surface operations, including EDL X-band communication tests. No science investigations were conducted during cruise, except for instrument health checkouts.

Spacecraft Id : MER2
Target Name : MARS
Mission Phase Start Time : 2003-06-10
Mission Phase Stop Time : 2003-11-19
Spacecraft Operations Type : LANDER

Spacecraft Id : MER1
Target Name : MARS
Mission Phase Start Time : 2003-07-07
Mission Phase Stop Time : 2003-12-10
Spacecraft Operations Type : LANDER

APPROACH

The approach phase was dedicated to the activities necessary to ensure a successful Entry, Descent, and Landing for each spacecraft, beginning 45 days before entry into the Martian atmosphere and ending at the atmospheric entry interface point 3522.2 km from the center of Mars. The main activities during this phase were: acquisition and processing of navigation data to support development of the final trajectory correction maneuvers and activities leading up to the final turn to the entry attitude 70 minutes before entry and separation from the cruise stage 15 minutes before entry.

Spacecraft Id : MER2
Target Name : MARS
Mission Phase Start Time : 2003-11-19
Mission Phase Stop Time : 2004-01-03
Spacecraft Operations Type : LANDER

Spacecraft Id : MER1
Target Name : MARS
Mission Phase Start Time : 2003-12-10
Mission Phase Stop Time : 2004-01-24
Spacecraft Operations Type : LANDER

ENTRY, DESCENT, AND LANDING

The entry, descent, and landing (EDL) phase for each spacecraft mission started six minutes prior to landing, and ended after landing, at which time each lander was on the surface of Mars in a thermally stable, positive energy balance, in a commandable configuration, having completed critical Sol 1 deployments (airbags retracted, lander petals and solar arrays opened). Approximately 20 seconds after parachute deploy, the heatshield separated from each spacecraft, followed approximately 10 seconds later by lander separation on a bridle. This was followed by

radar acquisition of the ground, acquisition of three images by the DIMES (Descent Image Motion Estimation System), airbag inflation, RAD/TIRS rocket firing, bridle cut(6.5 m above the surface for Spirit, 8.5 m for Opportunity), and landing. The landing (first impact) occurred at 04:26 UTC on January 4, 2004 for Spirit (1425 Mars local solar time) and 04:55 UTC on January 25, 2004 for Opportunity (1323 Mars local solar time). Spirit bounced 28 times before coming to rest on the base petal of the lander. After opening the petals, the base petal was oriented at a tilt of 2 degrees. Opportunity bounced 26 times before coming to rest on a side petal (+Y petal) of the lander. After opening the petals, with the base petal down on the surface, the base petal was oriented at a tilt of 5 degrees.

Spacecraft Id : MER2
Target Name : MARS
Mission Phase Start Time : 2004-01-04
Mission Phase Stop Time : 2004-01-04
Spacecraft Operations Type : LANDER

Spacecraft Id : MER1
Target Name : MARS
Mission Phase Start Time : 2004-01-25
Mission Phase Stop Time : 2004-01-25
Spacecraft Operations Type : LANDER

POST-LANDING THROUGH EGRESS

The post-landing through egress phase of each mission began after the lander petals and rover solar panels had been opened. This phase ended 12 Martian 'sols' (each sol being 24.66 hours) after landing for Spirit, and 7 Martian 'sols' for Opportunity, when each rover drove off of the lander directly onto the surface of Mars. Data confirming the egress event for Spirit were received at 01:53 PST January 15, 2004 (09:53, January 15, UTC). Engineers received confirmation that Opportunity's six wheels successfully rolled off the lander and onto martian soil at 03:01 PST, January 31, 2004 (11:01 January 31, UTC).

Spacecraft Id : MER2
Target Name : MARS
Mission Phase Start Time : 2004-01-04
Mission Phase Stop Time : 2004-01-15
Spacecraft Operations Type : LANDER

Spacecraft Id : MER1
Target Name : MARS
Mission Phase Start Time : 2004-01-25
Mission Phase Stop Time : 2004-01-31
Spacecraft Operations Type : LANDER

PRIMARY MISSION

Spirit and Opportunity's primary missions each lasted for 90 Martian 'sols' from time of landing. During this phase and the extended mission phase, a wealth of science and engineering information was collected from the rover and instrument payload. During Spirit's mission, the rover traveled in a primarily northeast direction from its landing site to the 210-meter diameter crater informally called 'Bonneville,' and then headed southeast towards the hills nicknamed 'Columbia Hills,' covering an odometry of 635 meters. During that time, Spirit acquired 23810 Pancam images, 2886 Navcam images, 3980 Hazcam images, and 1872 MI images (these image counts include full frames, subsampled frames, downsampled frames, and thumbnails). During Opportunity's prime mission, the rover spent the first two months investigating the 20-meter diameter crater nicknamed 'Eagle' and then it headed east towards the 130-meter diameter crater nicknamed 'Endurance,' covering an odometry of 772 meters. During the prime mission, Opportunity acquired 22503 Pancam images, 2343 Navcam images, 4421 Hazcam images, and 1395 MI images.

Spacecraft Id : MER2
Target Name : MARS
Mission Phase Start Time : 2004-01-11
Mission Phase Stop Time : 2004-04-06
Spacecraft Operations Type : LANDER

Spacecraft Id : MER1
Target Name : MARS
Mission Phase Start Time : 2004-02-01
Mission Phase Stop Time : 2004-04-27
Spacecraft Operations Type : LANDER

EXTENDED MISSION

The rovers' missions have not yet ended.

Spacecraft Id : MER2
Target Name : MARS
Mission Phase Start Time : 2004-04-06
Mission Phase Stop Time : 2004-xx-xx
Spacecraft Operations Type : LANDER

Spacecraft Id : MER1
Target Name : MARS
Mission Phase Start Time : 2004-04-27
Mission Phase Stop Time : 2004-xx-xx
Spacecraft Operations Type : LANDER"

MISSION_OBJECTIVES_SUMMARY = "

Mission Objectives Overview
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The MER mission had a set of science and technology objectives. The science was closely aligned with the Mars Exploration Program objective of determining the degree to which Mars provided conditions necessary for formation and preservation of prebiotic compounds and whether life started and evolved. This objective can be broadly stated as defining habitability of Mars and providing an understanding of roles of tectonic and climatic processes in possibly providing the conditions that led to life. The presence of water and its interaction with crustal materials is of fundamental importance. Thus, three of the MER objectives focused on exploring for evidence of water in the past: (1) to investigate landing sites which have a high probability of containing evidence of the action of liquid water, (2) to search for and characterize a diversity of rocks and soils that hold clues to past water activity, and (3) to extract clues related to the environmental conditions when liquid water was present and assess whether those environments were conducive for life.

The other MER science objectives were related to the Mars Exploration Program objective of determining the nature and sequence of the various geologic processes that have created and modified the Martian crust and surface: (4) to determine the spatial distribution and composition of minerals, rocks and soils surrounding the landing sites, (5) to determine the nature of local surface geologic processes from surface morphology and chemistry, (6) to calibrate and validate orbital remote sensing data and assess the amount and scale of heterogeneity at each landing site, (7) for iron-containing minerals, to identify and quantify relative amounts of specific mineral types that contain H20 or OH, or are indicators of formation by an aqueous process, and (8) to characterize the mineral assemblages and textures of different types of rocks and soils and put them in geologic context. These are basic field geology objectives that can be carried out at any landing site, but will provide the basis for addressing the first three objectives related to past water and thus habitability.

Three additional objectives for MER were technology related: (9) to demonstrate long- range traverse capabilities by mobile science platforms to validate long-lived, long-distance rover technologies, (10) to demonstrate complex science operations through the simultaneous use of multiple science-focused mobile laboratories, and (11) to validate the standards, protocols and capabilities of NASA-provided and internationally-provided orbiter-based Mars communications infrastructure. These objectives provided experience, lessons-learned, and technology feed-forward to enable improved Mars science missions in the future. While not part of the formal mission objectives, the rovers' remote sensing instruments were also used to make scientific observations of the martian atmosphere.

The objectives of the Extended Mission planned for May through September, 2004, are as follows:

1) Extend investigation of the water history in Gusev Crater by traversing to the Columbia Hills

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    2) Investigate the geologic context of the Opportunity outcrop by
       traversing to other targets (Endurance crater and the etched
       region south of the landing site) and conducting in-situ
       investigations of exposed outcrops

    3) Continue atmospheric measurements at both sites to encompass a
       longer portion of the Martian seasonal cycle

    4) Calibrate and validate orbital remote sensing data for additional
       types of soil and rock deposits

    5) Conduct long range traverses (>1 km) to extend Mars surface
       exploration and demonstrate relevant mobility technologies

    6) Demonstrate long term, sustainable operations of two mobile
       science platforms on remote planetary surfaces

    7) Characterize solar array performance over long durations of dust
       depositions at two different landing sites
"

  END_OBJECT          = MISSION_INFORMATION


  OBJECT              = MISSION_HOST
    INSTRUMENT_HOST_ID = {MER1,MER2}

    OBJECT              = MISSION_TARGET
      TARGET_NAME       = MARS
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  END_OBJECT            = MISSION_HOST

  OBJECT              = MISSION_REFERENCE_INFORMATION
    REFERENCE_KEY_ID = "CRISPETAL2003"
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END_OBJECT            = MISSION

END
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