```
PDS_VERSION_ID            = PDS3
LABEL_REVISION_NOTE       = "
      2004-08-23 MER:crisp   Original;
      2004-08-24 RS: simpson Added DSN, ODY, frame definitions"

OBJECT                    = INSTRUMENT_HOST
  INSTRUMENT_HOST_ID      = "MER2"

  OBJECT                  = INSTRUMENT_HOST_INFORMATION
    INSTRUMENT_HOST_NAME  = "MARS EXPLORATION ROVER 2"
    INSTRUMENT_HOST_TYPE  = "SPACECRAFT"
    INSTRUMENT_HOST_DESC  = "
```

Instrument Host Overview

For most Mars Exploration Rover (MER) experiments, data were collected by instruments on the spacecraft. Those data were then relayed directly to stations of the NASA Deep Space Network (DSN) on Earth or indirectly using the Mars orbiters Mars Global Surveyor (MGS) or 2001 Mars Odyssey (ODY). MER Radio Science observations required that DSN and/or ODY hardware also participate in data acquisition. The following sections provide an overview first of the MER spacecraft, then of the DSN ground system, and finally of 2001 Mars Odyssey as each supported MER science activities.

Instrument Host Overview - Rover

The Mars Exploration Rover (MER) mission sent two identical spacecraft to two different landing sites on Mars. The hardware on the first spacecraft is referred to as MER-2 (the rover named Spirit which was sent to Gusev Crater), and the hardware on the second spacecraft is referred to as MER-1 (the rover named Opportunity sent to Meridiani Planum). The spacecraft design owed a lot of its heritage to the Mars Pathfinder configuration for cruise and entry, descent, and landing. For more detailed information on the MER spacecraft, see [CRISPETAL2003].

Spacecraft Configuration for Entry, Descent, and Landing

After separation from the cruise stage, the 840 kg entry vehicle consisted of a backshell and heatshield enclosing the lander. The 550 kg lander had a tetrahedral structure that the air bags were deployed from and surrounded, and that housed the gas generators for the airbags, the RADAR altimeter, motors for the unfolding of the tetrahedron's four sides or 'petals,' and the rover lift mechanism for standing up the rover. On route to Mars, the rover was stowed within the lander, and contained most of the power, computing, and communication electronics for all phases of the mission. The backshell and heatshield provided thermal protection from the hyperbolic entry into the Martian atmosphere through the use of ablating materials. Mounted inside the backshell was the parachute, the deceleration and transverse impulse solid rocket (TIRS) motors, a backshell inertial measurement unit, and thermal batteries for the entry and descent phase. The Entry, Descent, and Landing camera was mounted on the lander radar bracket. The Descent Image Motion Estimation Subsystem (DIMES) gathered the results of a real-time image correlation of surface features contained in three successive Entry, Descent, and Landing camera images of the Martian surface to compute the horizontal velocity of the descending vehicle. TIRS used this horizontal velocity measurement along with measurements of the attitude of the backshell to compute a TIRS rocket firing solution.

Rover on the Surface of Mars

After landing, the instrument host for each spacecraft is just the rover itself, which is a 6-wheeled drive, 4-wheel-steered vehicle 180 kg in mass, including the science package. At its wheel base, the rover is approximately 141 cm long and 122 cm wide. At the height of the solar panel, the rover is approximately 225 cm wide by 151 cm long. In its deployed configuration with the Pancam Mast Assembly (PMA) deployed, the rover is 154 cm tall.

The rocker bogie suspension system gave the rover the ability to drive over obstacles approximately one wheel diameter (26 cm) in size while providing a stable platform for instrument measurements. The distribution of mass of the vehicle allowed the vehicle to be stable even at a 45 degree tilt. Each wheel and steering degree of freedom was independently actuated, which allowed the vehicle to turn in place (turning diameter 1.9 m), to skid steer to a tighter angle (turning diameter as small as 0.9 m), to turn in gradual arcs, or to drag wheels that effectively trench the Martian regolith. When moving on flat terrain, the vehicle could achieve a top speed of 5 cm/s. Under autonomous control using its hazard avoidance system, the rover drove with an average speed of about 1 cm/sec.

The rover was powered by a combination of solar arrays and rechargeable batteries. The solar panel provides 30 strings of triple junction cells (gallium indium phosphorus, gallium arsenide, and germanium) covering 1.3 square meters, which produced about 800 to 900 W hours per sol at the beginning of the MER mission. Each rover had two reference solar cells, one that measures short circuit current and another that measures open circuit voltage. Due to the change in season from late southern summer to early southern autumn, and the degradation in performance due to dust deposition, the energy produced by this array dropped to about 600 W h per sol, 90 sols after landing. Energy was stored in two 8 A h lithium ion rechargeable batteries to provide over 400 W h of energy to support rover peak power operations and provide auxiliary heating and operations overnight.

Temperature-sensitive electronics were housed in the rover warm electronics box (WEB) which is a box built with honeycomb composite material and insulated with 2.5 cm of opacified aerogel.

A combination of radioisotope heater units, waste heat from electronics, and auxiliary heating by survival heaters ensured that the internal electronics were maintained between -40 and +50 degrees C as the external Mars environment cycle ranged from 0 to -97 degrees C. Survival heating in the WEB requires not more than 100 W h of energy during the coldest environment conditions. The rechargeable batteries housed in the WEB supplied this energy.

The rover received commands and transmitted data to the Earth through two distinct systems: a direct-to-Earth X-band system supported by both a low-gain antenna and a steerable high-gain antenna (HGA), and a UHF system supported by a monopole antenna which enables relay communication to orbiters at Mars. Early in the surface mission, the X-band system through the high-gain antenna supported up to 28.8 kbps to a 70 m Deep Space Network (DSN) station. Commands were received through the high-gain antenna at a rate of up to 2000 bps. The X-band system through the low-gain antenna provided a minimum capability of transmitting telemetry at 40 bps and receiving commands at 40 bps throughout the MER missions. The UHF system supported telemetry rates of up to 256 kbps during orbiter passes which lasted up to 8 minutes each. The UHF system also supported a command receipt capability of 8 kbps through Odyssey only.

The computing, command, and data handling functions of the rover were supported by a 20 MHz 32-bit RAD6000 processor housed in a Versa Module Europa (VME) card cage. This radiation hardened processor had access to 128 Mbytes of DRAM and 256 Mbytes of nonvolatile flash memory that supported a multiprocess C-coded software architecture. This system, supported by auxiliary processing functions housed on boards within the VME card cage, had the capability to acquire images from pairs of cameras, drive up to 10 motors simultaneously from 35 motors located on the vehicle, and process data from three spectrometers. The multiprocess architecture allowed communication, image acquisition, and operation of payload elements to proceed simultaneously.

During the surface mission, the rovers communicated on X-band typically once a day, reporting on status and the results of the execution of commands transmitted that day. Data were also relayed through the UHF communication system to the Mars Global Surveyor and Mars Odyssey orbiters. Useful over-flights by these orbiters at the landing site occurred as frequently as twice per day per orbiter.

Each rover carried the Athena Science Payload consisting of two remote sensing instruments that viewed the terrain from the top of a mast 154 cm above the ground, four devices for in-situ analysis on the end of a robotic arm and several magnets and calibration targets. [SQUYRESETAL2003] describes this payload, the mast, the robotic arm, and the plans for science investigation in more detail. Azimuth and elevation actuators permitted the collection of data sets for specific targets, regions, or full 360-degree panoramas from the mast instruments, which are the stereo multispectral Panoramic Camera (Pancam) and Miniature Thermal Emission Spectrometer (Mini-TES). The five degree-of-freedom robotic arm positioned the following devices on rocks and soils for in-situ analysis or rock abrasion: Alpha Particle X-ray Spectrometer (APXS), Moessbauer Spectrometer (MB), Microscopic Imager (MI), and Rock Abrasion Tool (RAT).

In addition, the stereo navigation cameras (Navcams) mounted on the top of the mast and the stereo hazard detection cameras (Hazcams) pointed towards the ground beneath the solar panels in the front and rear of the rover were required for engineering purposes (rover navigation, hazard avoidance, and safe movement purposes and positioning of the robotic arm), but were also used for science analysis [MAKIETAL2003]. [ARVIDSONETAL2003] provides more detail on the use of rover engineering sensors for assessing terrain and soil physical properties, dust accumulation, and other related investigations.

The MER rover coordinate frame is defined as follows:

-- +Zr axis is normal to the rover top deck plane and points down, from the top deck toward the wheels;

-- +Xr axis is parallel to the rover top deck plane and points from the center of the top deck toward the PMA assembly;

-- +Yr completes the right hand frame.

The origin of the MER rover 'navigation' frame is directly above the middle wheels, as shown in the diagram below. A separate MER rover 'mechanical' frame has its origin 29 cm toward the front wheels (in the +Xr direction) but is otherwise identical.

```
          UHF    /\
  HGA            \/ PMA
   .--.    #     ||
  /    \   #     ||
 |      |  #     ||
  \    /=. #     ||
   `--' || #     ||                 Rover
=======================           (deployed)
      |    =o=.    |
      |  .' Yr `.__|o====o
    .===o=== o------> Xr \\
   .-.      .|.    `.-.  ##o###
  | o |    | | |   | o |
   `-'      `|'     `-'
             V Zr
```

Instrument Host Overview - 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).

For more information see [ASMAR&RENZETTI1993].

Instrument Host Overview - 2001 Mars Odyssey
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The 2001 Mars Odyssey (ODY) spacecraft was built by Lockheed Martin Astronautics (LMA). Most spacecraft systems were redundant in order to provide backup should a device fail. In addition to transmitting data collected by ODY instruments and systems, the telecommunications system was used to relay data from Mars surface assets and measure their relative motion radiometrically in the 400 MHz frequency range. For more information, see [JPLD-16303]."

```
END_OBJECT         = INSTRUMENT_HOST_INFORMATION

OBJECT             = INSTRUMENT_HOST_REFERENCE_INFO
  REFERENCE_KEY_ID = "ARVIDSONETAL2003"
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OBJECT             = INSTRUMENT_HOST_REFERENCE_INFO
  REFERENCE_KEY_ID = "ASMAR&RENZETTI1993"
END_OBJECT         = INSTRUMENT_HOST_REFERENCE_INFO

OBJECT             = INSTRUMENT_HOST_REFERENCE_INFO
  REFERENCE_KEY_ID = "CRISPETAL2003"
END_OBJECT         = INSTRUMENT_HOST_REFERENCE_INFO

OBJECT             = INSTRUMENT_HOST_REFERENCE_INFO
  REFERENCE_KEY_ID = "JPLD-16303"
END_OBJECT         = INSTRUMENT_HOST_REFERENCE_INFO
```

```
  OBJECT               = INSTRUMENT_HOST_REFERENCE_INFO
    REFERENCE_KEY_ID = "MAKIETAL2003"
  END_OBJECT           = INSTRUMENT_HOST_REFERENCE_INFO

  OBJECT               = INSTRUMENT_HOST_REFERENCE_INFO
    REFERENCE_KEY_ID = "SQUYRESETAL2003"
  END_OBJECT           = INSTRUMENT_HOST_REFERENCE_INFO

END_OBJECT             = INSTRUMENT_HOST

END
```