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PDS_VERSION_ID            = PDS3
RECORD_TYPE                      = STREAM
OBJECT                    = INSTRUMENT
  INSTRUMENT_HOST_ID      = {MER1, MER2}
  INSTRUMENT_ID           = IMU

  OBJECT                  = INSTRUMENT_INFORMATION
    INSTRUMENT_NAME       = "INERTIAL MEASUREMENT UNIT"
    INSTRUMENT_TYPE       = "ACCELEROMETER"
    INSTRUMENT_DESC       = "

  Instrument Overview
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  Each MER entry capsule contained two LITTON LN-200S Inertial
Measurement Units (IMU).  One IMU was located within the rover, with the
other
IMU located on the backshell. The IMU within the rover was not
located at the rover's center of mass, and the IMU within the backshell
was not located at the backshell's center of mass. Neither of the two
IMU's within the entry capsule was located near either the entry shell's
center of mass nor the entry shell's spin axis. The entry shell consisted
of the heat shield and backshell inside of these two joined components.

  The four LN-200S units employed in the mission were selected from a
larger population for improved stability.

  These LN-200S IMU's provide three-axis rotation rate and acceleration
measurements. The rotation rate is provided by a Fiber Optic Gyro (FOG)
sensor, while the accelerations are provided by silicon accelerometers.
Each IMU contains three FOGs and three accelerometers, oriented
orthogonally
to provide measurements in three dimensions simultaneously. The resultant
measurements from each of the accelerometers and each of the FOGs is
spatially
transformed to the center of the IMU prior to being output by the
instrument.

  Each IMU has a mass of 0.75 kg (1.65 pound weight), is ~9 cm by 9 cm in
size, and is operated at 12 watts.  These LN-200S IMU's have space flight
heritage, having been successfully flown on the Clementine mission.

  The accelerometers within each IMU had a dynamic range of 80g (where g
here represents Earth's standard surface gravitational acceleration of
9.80665 meters per second per second) and a resolution
of 2.4 milli g's, with a noise level of 1.6 milli g's when sampled at 400
Hz
(the nominal instrument sampling rate). The spacecraft could not handle
400 Hz
sampling, so the IMU data were summed over 50 measurements,
resulting in an 8 Hz sampling by the spacecraft. This summing
has the effect of reducing the the effective noise to 300 micro g's,
with an effective resolution of 50 micro g's.  These instrument
attributes are clearly discussed in [CRISPETAL2003].
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Atmospheric entry occurred at a nominal height of 128 km above the Mars surface at a nominal atmospheric relative velocity of 5400 m/s. The frictional drag of the atmosphere upon the entry vehicle results in a reduction in the speed of the entry vehicle. This deceleration is measured by the accelerometers within the IMU, while the orientation of the entry vehicle is provided by the gyroscope measurements.

The FOGs also provided relative orientation information for both the backshell and the lander after parachute deployment, which occurred approximately 240 seconds after entry at an altitude approximately 8.5 kilometers above the surface. The lander separated from the backshell and descended on a tether approximately 30 seconds after parachute deployment. Subsequent simultaneous backshell and lander (rover) IMU measurements in this tethered condition allow for the 'swing' of the lander on the tether to be determined. This enabled removal of this motion from the accelerometer measurements, permitting a determination of the net motion of the lander toward the surface. This allows for atmospheric profile reconstruction while the lander is still attached to the parachute. These measurements (as well as the descent imaging) also served as part of the guidance for the horizontal motion reduction system which was included to minimize lander horizontal motion upon initial impact with the surface. The bridle connecting the lander to the backshell was severed approximately three seconds prior to surface impact. The backshell IMU measurements ceased upon the severing of this connection.

Platform Mounting Description

Each entry assemblage included two IMUs. One IMU was included within the rover while the other was included on the backshell. Neither of these was located at either the center of mass of its parent entry vehicle component nor the center of mass of the entire entry vehicle.

Principal Investigator

No Science Team was selected for the IMU/EDL aspect of the MER mission, thus there is no Principal Investigator. The IMU system was part of the engineering instrumentation and was selected, configured, installed, and operated by members of the engineering team. They provided entry vehicle deceleration and position and orientation information that was used for tracking EDL and triggering EDL events on the entry vehicle (parachute deployment, lander and backshell relative attitudes, retro-rocket firing, etc.).

Scientific Objectives

The IMUs were not science instruments and thus nominally there was no science objective for their inclusion on the spacecraft. The measured deceleration values provided by the IMU, as a function of time (which needs to be used to determine the height above the surface). the surface, can be employed to deduce the vertical structure of density and pressure, and ultimately temperature of the atmospheric column traversed by the lander as it descended through the atmosphere.

Operational Considerations

The nominal data rate provided by the IMUs was 400 Hz, a rate faster than the on-board spacecraft processing could deal with. The 400 Hz rate was reduced to 8 Hz via averaging of 50 consecutive measurements (measurements 1-50, 51-100, ...) and it was these 8 Hz data that were ingested into the onboard software and from which the accelerations and rotation rates were calculated. It is these on-board calculated values of accelerations (or velocity change) and rotation rates (or quaternion elements) that are included in this archive.

EDL is a mission critical phase (if EDL fails, the mission is completely lost) and thus the IMU data collection/processing needed to adapt to the EDL and mission requirements. Furthermore, since the IMUs were a key component (as an active sensor) of the EDL process, their operational characteristics were driven by EDL engineering considerations. This included the amount and type of in-flight processing to the IMU data, the sampling frequency, and the data collection rate. These choices have, in some ways, limited the scientific return of the instruments.

Calibration

The IMUs were delivered with a 'factory calibration' based upon individual unit testing after assembly. Based upon later testing, this is good, but not perfect. Among other issues, it does not account for unit aging and instrument drift. It is only intended to ensure the instrument remains within the formal specifications as they (the IMUs) performed their critical tasks during EDL.

The onboard calculated parameters (the TRANSFORMED dataset) are based upon the IMU output and nominal (not measured) entry-vehicle parameters (IMU position and orientation, etc.). There was no laboratory testing of the IMU performance and quality while in the entry configuration.

A more accurate calibration based upon prelaunch measurements, cruise observations, as well as EDL data themselves is in progress. It is anticipated that this calibration effort will result in an improved IMU EDL dataset.

Operational Modes

From the time of IMU turn on throughout the total EDL process (atmospheric entry through the cessation of bouncing and rolling), IMU data were provided at 400 Hz and integrated to 8 Hz measurements used by the on-board software.

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 There were no gain changes or offset changes throughout this time
period.
 The interval between saved samples (and whether or not the HIGHRATE data
 were collected) varied over the course of EDL. This was based partly
upon
 absolute time and partly upon spacecraft events.
 One anomaly was a periodic resetting to a value of zero of the
accumulated
 velocity change (in each of the three axes) of the Rover IMU.

"
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  REFERENCE_KEY_ID               = "CRISPETAL2003"
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END_OBJECT           = INSTRUMENT

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