Mars Reconnaissance Orbiter (MRO) - From Downlink to Archive

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Introduction

In an orbit of 300 kilometers above the Martian surface, MRO will spend four Earth years in Mars orbit. Two years will be dedicated to science observations. MRO will carry a payload of six international scientific instruments and additional experiments with meter scale imaging, 20 meter resolution mineralogical mapping, and 6 meter ground sampling context imaging (Table 1). MRO will seek to characterize Mars seasonal cycles, global atmospheric structure and upper atmosphere, gravity field, transport and surface changes. MRO will search sites for evidence of aqueous and/or hydrothermal activity, and study the Martian ice caps to profile the upper crust while searching for subsurface water and ground ice. MRO will map and explain in detail the stratigraphy, geologic structure, and composition of Mars surface features.

Instrument	Type	Description
HiRISE	High spatial resolution imaging system	Ultra-high resolution imager. 30 cm/pixel ground resolution with 6 km swath width (central 1.2 km swath in 3 colors) from 300 km. Stereo by re-imaging targets.
CRISM	Multiple emission angle hyperspectral imaging system	Targeted hyperspectral imaging spectrometer in 0.4 – 4.05 µm wavelength range. 20 m/pixel resolution, 10 km swath from 300 km. Survey mode with up to 64 bands and 100 m/pixel resolution. Acquires data at multiple emission angles, including for atmospheric survey.
MARCI (WA)	Wide Angle imaging system with 7 spectral bands.	0.6 to 10 km/pixel resolution from 300 km. Daily global monitoring of Martian weather and surface change.
MCS	Atmospheric IR sounding system and solar radiation monitor.	Atmospheric profiling of T, dust, water vapor and ice at ~5km vertical resolution using IR (12-50 µm); monitor reflected light in solar band (0.3 –3.0 µm).
CTX	Context imaging system	Panchromatic (minus blue); 6 m/pixel resolution, 30 km swath from 300 km. Context imaging for targeting and for independent science.
SHARAD	Shallow Radar Sounder	20 MHz (10 MHz bandwidth) frequency, probing subsurface to depths < 1 km at 10-15 m resolution.

Table 1

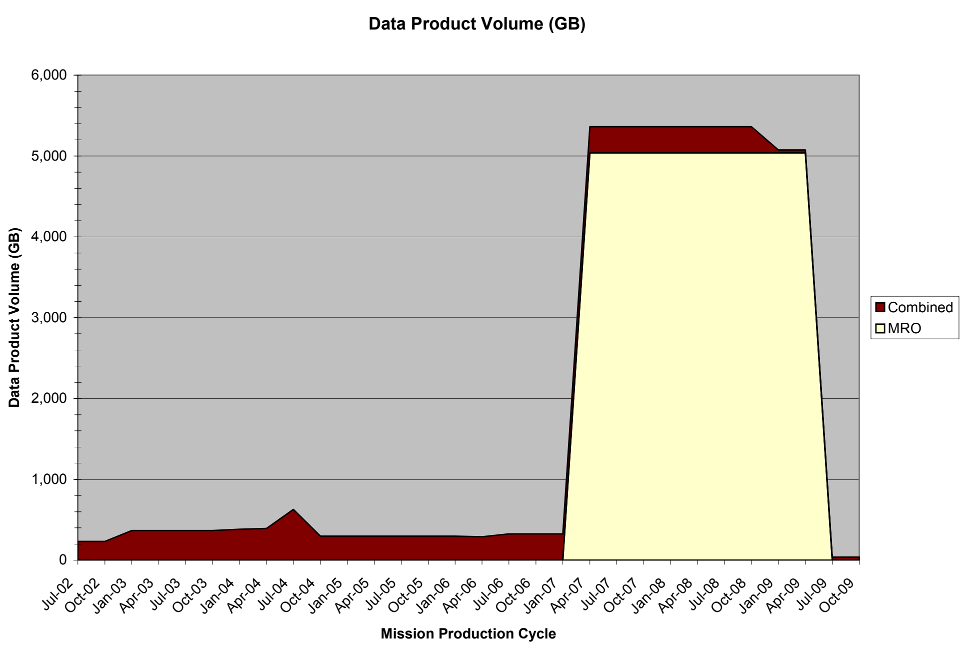
Planetary mission, such as MRO, are characterized by the need to receive, process, archive, and transmit remotely sensing data to geographically extended science and engineering teams. Science and Engineering Team members are located in industry, academic, and government centers all over the world.

JPL operates the Deep Space Network (DSN), a global set of large antennas to provide continuous monitoring of the signals from Space Science Missions. The data collected from MRO will be sent from the DSN to JPL. Spacecraft are designed to operate with only a few hours of power margin. Mission Science and Engineering teams must receive constant updates on instrument health, pointing, and data. The MRO mission requires that the Science and Engineering teams have their data 24 hours after receipt at the DSN. There is then a six month window during which the data are processed for archive and distribution to the planetary science community at large.

MRO will return in excess of 51Tb of data (Figure 1). This enormous amount of data requires new paradigms for all aspects of CCSDS File Delivery Product (CFDP) generation, Science Product Delivery, and Archive. Future NASA Solar System Missions will use the paradigms established for MRO to increase their science data return.

In this paper, we describe the pipeline being developed to provide MRO instrument health, pointing, and science data in a cost effective, reusable fashion that maximizes the use of automation, parallel processing, and data subscription services. The elements of this system include: 1. CFDP Product Generation, 2. Raw Science Data Server (RSDS), 3. Visualization and Analysis Test-bed (VAT), 4. File Exchange Interface (FEI), and 5.Planetary Data System (PDS).

Figure 1. Data Product Volume Profile (Across All NASA Missions)



CCSCS File Delivery Protocol (CFDP)

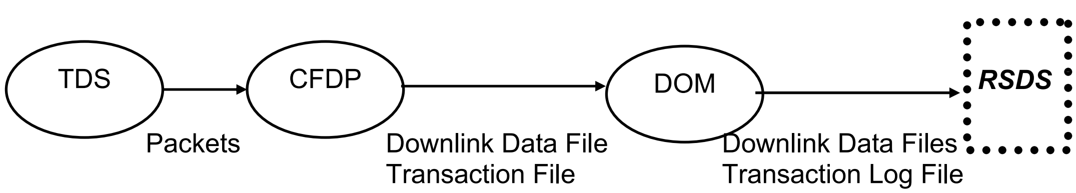
Product Generation

Traditionally, spacecraft science data was received at the DSN from planetary mission as a stream of telemetry data. Data received on the ground became part of the Telemetry Data System (TDS). Previous planetary missions needed to have TDS data organized into files, such as image files, on the ground using mission specific Telemetry Processing Software. Each mission was unique as was the telemetry data. Thus, each new mission required individual software. Telemetry processing software, “telemprocs”, from one mission was used as the basis for another mission. The software development process for a new “telemproc” was long and costly.

CFDP is a protocol developed for use in planetary missions. CFDP builds data files on the spacecraft. These files are complete when the reach the DSN and no further telemetry processing need be done before the CFDP files are sent to the instrument science teams.

The MRO adaptation to the CFDP protocol will generate CFDP files on the ground. The decision to use the CFDP protocol was made after the flight software was created. This is a valid CFDP protocol mode. Turbo Unpacking will be used in the Telemetry Input Subsystem (TIS). The TIS will use the Turbo Unpacking algorithm to un-pack bits rom the encoded telemetry stream. As with the telemetry processing software, the Turbo Unpacking algorithm is mission specific. Two files are generated in the CFDP file generation process – the CFDP Product file which contains instrument data, and a metadata file called the Transaction Log File.

Upon completion of the MRO CFDP file generation, the science data will be put on the JPL Mission Management Office (MMO) Distributed Object Manager (DOM) database.



The Raw Science Data Server

Data Receipt

The RSDS will ingest CFDP files from the DOM. The DOM is the staging area for uplink requests to NASA spacecraft and will be the downlink repository for MRO CFDP image and pointing files (SPICE). Ancillary data, such as spacecraft health and safety information, will be down linked to the Telemetry Data System (TDS). Once CFDP data is received in the DOM from the DSN it is automatically sent to the RSDS. Upon receipt at the RSDS, the RSDS: 1. Places the CFDP Product and Transaction Log files into the RSDS Sybase database; and, 2. Sends the CFDP Transaction Log File to the Instrument team whose data was received in the DOM. 3. Generates a PDS Label for the . From the CFDP Transaction Log File, the instrument team selects the files it wishes to receive and requests these files from the RSDS.

Visualization and Analysis Test-bed (VAT)

Planetary Data System (PDS) File Format

PDS files consist of an ASCII label and data. The PDS label may be attached to the file or detached. This label contains data in “Keyword” = “Value” format and provides descriptive metadata information concerning a specific file. Keywords vary as a function of the mission. Typical orbiter “Keywords” include: file name, record type, record length, spacecraft name, instrument id, and many more. Due to the large size of some of the instrument data files (a Hi-Rise data files can be up to 28 MB), the MRO PDS science data file was designed with a PDS detached label followed by the data.

RSDS Products Generated on the VAT

The VAT is one of the several Beowulf clusters used to support the processing activities of the Solar System Visualization (SSV) Project. The SSV Project provides NASA missions with a team data processing and visualization specialists. This hardware will be used to generate PDS labels for requested MRO science data.

A PDS label is generated for all CFDP data files. A CFDP Transaction Log File will be fed into one of the VAT Beowulf nodes. A Java script will be invoked and information from this file will be extracted to generate a PDS compliant label. Multiple files can be processed on the VAT nodes simultaneously. The generated PDS label is placed in the RSDS database.

Life of Mission Storage

All instrument science and SPICE files ingested from the DOM will be stored for the life of the MRO mission. A primary and shadow repository will be maintained in the JPL Multimission Image Processing Laboratory (MIPL) on Redundant Array of Inexpensive Disks (RAID) to assure data safety and availability. Each of these repositories currently has 5 TB of storage. In the MRO data acquisition time frame, this capacity on the VAT will be increased to over 10 TB. Additionally, data will be backed up regularly onto tape and stored in a fireproof facility outside of JPL. In the event of a catastrophic loss of data (such as a fire or earthquake) at an MRO science instrument site, it is required that data will be restored within 24 hours.

The File Exchange Interface (FEI)

FEI Capabilities

The MIPL File Exchange Interface (FEI) service provides secure file transaction, store, transport, and management services. FEI is a client-server application that uses standard input/output to interact with the file system to enable portable support across various file systems. FEI client and server code are developed with pure Java 2 technology in order to maximize its portability among popular operating systems. Current client OS supports: Sun Solaris – 7,8; Red Hat Linux – 7.x , 8.0, 9.0; Mac OS X – 10.2x; and Microsoft Windows, NT, 2000, XP. The version that will serve MRO enables a “Resume Transfer”. This capability allows clients to resume the acquisition of a file in the event communication was severed before file transfer completes. This capability is critical for large files such as those collected by Hi-Rise and CRISM.

FEI is a push / pull subscription service. When data type subscribed to becomes available at the server, the client is sent the requested data. For MRO, the RSDS will push the Transaction Log File from the RSDS FEI server. The Science Instrument teams will use FEI to pull the CFDP files and associated PDS labels required.

Science Site Connections

MRO science operations will be geographically distributed. Located at JPL in MIPL, the Raw Science Data Server (RSDS) will be the single point of distribution of instrument and experiment data to the MRO science teams. MRO will provide each science instrument team with a computer system for raw science data receipt. These computers will be connected to JPL and the VAT via two T1 communications lines. Science teams that are connected by Internet 2 lines may receive their data by this route.

Data Archive – The Planetary Data System (PDS)

Data Generation

Raw science data and SPICE files will be distributed to the Instrument Science Teams from the JPL Raw Science Data Server (RSDS). A Project-controlled central database will be maintained at JPL and will contain telemetry data, and other information needed by Principal Investigators and Team Leaders. The raw data, SPICE files, and other required data sets will be used at the home facilities to generate Electronic Data Records (EDRs) and Reduced Data Records (RDRs) for use by team members and for use in archiving. The Data Product Software Interface Specification (SIS) document will be written and will describe all EDR and RDR data product formats produced by each of the MRO instruments and experiments.

Data Validation

The validity of science data products must be assured. The validation process begins at the Principal Investigators home institution. Here, EDR and RDR data products are generated and checked against the Data Product SIS. Anomalies are identified and corrected. The Archive Volume SIS details the manner in which the EDR's and RDR's will be assembled for delivery to the PDS. Again, data is checked for conformance to the Archive Volume SIS. Data is now ready for transfer to the PDS. When data arrives at the Discipline Nodes, once again the data is validated. Discipline node personnel check the data to assure it has arrived in the proper format while checking against the Archive Volume and Data Product SIS's, and is scientifically correct. Any errors encountered in this process are brought to the attention of the Principal Investigator. If necessary, data will be reprocessed by the Instrument Science Team and redelivered to the PDS.

Data Archive / Distribution

The MRO Archive Plan details EDR and RDR science data deliveries that begin six months after the start of the PSM. The first PDS data delivery will be June 1, 2006 and continue every three months until the end of the PSM.

MRO science data will be maintained on-line through the PDS distributed Data System. This data system was initially developed for the Mars Odyssey orbiter. Currently, both Odyssey and SPICE data are available through this system. The PDS Data System provides a web based, form driven interface. This interface provides the user with forms to specify data search criteria. Information from the forms will be used to select and retrieve MRO science data. Once selected, data can be retrieved electronically or on digital media.

Data Availability

As well as the PDS Data System, MRO archived data will be available to the science and academic sectors at various Planetary Data System Discipline Nodes (Geosciences, Imaging, Atmospheres) and, at the proposed University of Arizona data sub-node. The public can access MRO data via JPL's on-line Planetary Image Atlas and Photojournal.

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