Mars Reconnaissance Orbiter (MRO) Project

Data Archive Generation, Validation, and Transfer Plan

Version 1.1

Raymond E. Arvidson
Stephen J. Noland
Susan Slavney

Approved:

____
Richard Zurek, MRO Project Scientist

____
Gerald Keating, Accelerometer Team Leader

____
Michael Malin, MARCI Principal Investigator; CTX Facility Team Leader

____
Daniel McCleese, MCS Principal Investigator

____
Alfred McEwen, HiRISE Principal Investigator

____
James Graf, MRO Project Manager

____
Scott Murchie, CRISM Principal Investigator

____
R. Seu, SHARAD Team Leader

____
Maria Zuber, Gravity Team Leader

____
Edwin Grayzeck, Planetary Data System Manager

____
R. Stephen Saunders, MRO Program Scientist

26 January 2006

Jet Propulsion Laboratory
California Institute of Technology

CHANGE LOG

DATE	SECTIONS CHANGED	REASON FOR CHANGE	REVISION
3-16-02	2 – Mission Overview	Refined information	Draft
3-16-02	3.1 Principal Investigator	Clarified roles	Draft
3-16-02	Table 1. MRO Payload	Updated key parameters	Draft
5- 5-02	2.0, 3.1, Tables 1,2 & CI => CTX throughout	Updated to make consistent with latest MRO plans.	Draft
5-6-02	Table 2 – Std. Data Prod.	Updated CRISM standard products, volumes	Draft
5-16-02	1.4 Applicable Documents	Update MEP DMP information	Draft
5-16-02	Table 2 – Std. Data Prod.	Updated based on DARWG discussion	Draft
6-2-02	Added new Table 2	Telemetry allocations for each instrument; added std. product volumes	Draft
6-5-02	Updated Table 3	Revised information	Draft
6-18-02	Updated Table 3	New information	Draft
7-23-02	Updated Table 3	Corrected CRISM info	Draft
1-31-03	Updates/Edits throughout	Revised Information	Draft
2-6-03	2. Mission Overview, Table 7, Table 8	New mapping mission dates from Project, new data product volumes from CRISM	Draft
2-18-03	Updated Table 2	New % allocations for HiRISE and CRISM	Draft
6-25-03	Updated Tables 4, 8	Revised data volumes for HiRISE	Draft
8-19-03	Signature page	Added Steve Saunders, Program Scientist	Draft
8-19-03	TBD Items	List updated	Draft
8-19-03	4.1 Generation	Added special products, calibration data, cartographic standards	Draft
8-19-03	4.2 Validation	SIS documents govern archive contents	Draft
8-19-03	4.4 Distribution	Generalized description of tools	Draft
8-19-03	5. Schedules	Exceptions to 6-month delivery schedule	Draft
8-19-03	Tables 1 and 4	Updated HiRISE information	Draft
8-19-03	Table 5	Added table of special products	Draft
8-19-03	Table 9	Updated chart showing data volume over time	Draft
9-03-03	Table 4	Added new CRISM EPF product	Draft

10-07-03	4.1 Generation	Added Interface Control Document information. Added IAU 2000 standard requirement for cartographic products	Draft
10-07-03	4.2 Validation	Added PDS peer review information	Draft
10-07-03	Table 4	Updated HiRISE product information	Draft
10-07-03	Table 9	Updated table	Draft
10-07-03	2. Mission Overview, Table 1, Table 3	Added Optical Navigation Camera information	Draft
11-11-03	Table 3	Added Imaging/JPL as node for ONC	Draft
01-13-04	Tables 3 - 10	Renumbered tables after insertion of new table 3	Draft
01-13-04	Table 3	New table	Draft
01-13-04	New Table 5	Adjusted CRISM data volumes	Draft
01-13-04	3.1 MRO Project	Added text per MRO/PDS agreement of 12/22/03.	Draft
01-13-04	3.2 PDS	Added text per MRO/PDS agreement of 12/22/03.	Draft
01-13-04	4.3 Transfer	Added table of PSP product transfer methods.	Draft
01-20-04	4.3 Transfer	Merged Transfer Methods Table into Table 5 and added PDS ingest timeliness requirement.	Draft
01-20-04	Table 3	Revised volume estimates per recent PI inputs.	Draft
01-20-04	Table 5	Changed to Landscape, added product counts and transfer methods	Draft
04-07-2004	Table 5	Update products, product counts and transfer methods	Draft
03-01-2005	Final edits for first signature version	Update products, product counts, other minor edits	Final
06-14-2005	Revisions to signature version	Update products, product counts, Special Products	Final
07-26-2005	Revisions to signature version	Update MARCI/CTX products, Signatures	Final
09-21-2005	Revised Table 5, Table 6	Update Accelerometer products, quantities.	Final
01-26-2006	Revised Table 9	Added data archive release dates for Accelerometer data, see releases 0 and 1.	Version 1.1

TBD ITEMS

SECTION	DESCRIPTION
Table 8	Are these the correct components for the Engineering Data Archives?
Tables 4	Add Interface Control Document IDs

CONTENTS

1. INTRODUCTION 1
1.1. Purpose 1
1.2. Scope 1
1.3. Contents 1
1.4. Applicable Documents and Constraints 1
2. MISSION OVERVIEW 2
3. ROLES AND RESPONSIBILITIES 3
3.1. MRO Project 4
3.2. Planetary Data System 4
3.3. National Space Science Data Center 5
4. ARCHIVE GENERATION, VALIDATION, TRANSFER, AND DISTRIBUTION 5
4.1. Generation 5
4.2. Validation and Peer Review 6
4.3. Transfer 7
4.4. Distribution 8
5. ARCHIVE GENERATION, VALIDATION AND RELEASE SCHEDULES 8

TABLES

Table 1. MRO Payload 9
Table 2. MRO Data Allocation 11
Table 3. Estimated Science Data Product Volumes 12
Table 4 Data Provider – PDS Interfaces 13
Table 5. MRO Standard Data Products 14
Table 6. MRO Special Products 18
Table 7. Definitions of Processing Levels for Science Data Sets 20
Table 8. Components of MRO Archives 21
Table 9. MRO Nominal Release Schedule for Standard Products 22
Table 10. Volume of Data Delivered to PDS over Time 23

ACRONYMS

CTX	MRO Context Imager
CRISM	Compact Reconnaissance Imaging Spectrometer for Mars
DARWG	Data and Archive Working Group
EDR	Experiment Data Record
FOV	Field of View
GDS	Ground Data System
HiRISE	High Resolution Imaging Science Experiment
JPL	Jet Propulsion Laboratory
MARCI-WA	Mars Color Imager - Wide Angle Camera
MCS	Mars Climate Sounder
MIT	Massachusetts Institute of Technology
MMO	Mission Management Office
MRO	Mars Reconnaissance Orbiter
MSSS	Malin Space Science Systems
NAIF	Navigation and Ancillary Information Facility
NSSDC	National Space Science Data Center
ONC	Optical Navigation Camera
PDS	Planetary Data System
RDR	Reduced Data Record
SHARAD	Shallow Radar
SIS	Software Interface Specification
SPICE	Spacecraft, Planet, Instrument, C-Matrix, and Event kernels (historical acronym for navigation and ancillary data)
TBD	To Be Determined
TBR	To Be Resolved

1. INTRODUCTION

1.1. Purpose

The purpose of this document is to provide a plan for generation, validation, and transfer to the Planetary Data System (PDS) of archives from the Mars Exploration Program 2005 Mars Reconnaissance Orbiter (MRO) Mission. The archives will contain raw and reduced data compliant with PDS standards, documentation, and algorithms or software to process the data to higher-level reduced data products. Also included in the plan is an overview of how the archives will be made available to the communities served by the PDS.

1.2. Scope

The plan covers archiving and distribution of raw and reduced data sets and related information to be produced during the MRO mission.

Specific aspects addressed in this plan are:

- Generation of high-level mission, spacecraft and instrument documentation, instrument calibration reports, and documentation of algorithms and/or software used to produce reduced data records.
- Generation and validation of experiment data records (EDRs) and reduced data records (RDRs) as standard products, with associated documentation that determines when and where the data were acquired and for what purpose.
- Generation and validation of SPICE archives for use with software from the Jet Propulsion Laboratory's Navigation and Ancillary Information Facility (NAIF) and instrument team or facility team supplied algorithms and software.
- Generation and validation of logical and physical archive volumes containing telemetry data, EDRs, RDRs, software, algorithms, documentation, and ancillary information.
- Delivery to the PDS of validated MRO archives.
- Model for distribution of data by the PDS both during and after the Project lifetime.

1.3. Contents

This plan begins with an overview of MRO mission phases, followed by a summary of roles and responsibilities for organizations and personnel associated with generation, validation, archiving, and distribution of MRO data. The document then discusses the flow of archiving processes and ends with specific archiving schedules.

1.4. Applicable Documents and Constraints

This Archive Generation, Validation, and Transfer Plan is responsive to the following documents:

1. Mars Exploration Program Data Management Plan, R. E. Arvidson, S. Slavney, and S. Nelson, Rev. 3.0, March 20, 2002.
2. Mars Reconnaissance Orbiter Project Plan, MRO-11-109, JPL D-22205, 28 Aug 2002.
3. Mars Reconnaissance Orbiter Mission Plan, MRO-31-201, JPL D-22239, 28 May 2003.
4. Memorandum of Understanding Between the Planetary Data System and the Mars Reconnaissance Orbiter Project, J. Graf, R. Zurek, and L. Hall, February, 2003.

The plan is consistent with the principles delineated in the following reports:

5. Data Management and Computation, Volume 1, Issues and Recommendations, 1982, National Academy Press, 167 p.
6. Issues and Recommendations Associated with Distributed Computation and Data Management Systems for the Space Sciences, 1986, National Academy Press, 111 p.
7. Report of the IAU/IAG working group on cartographic coordinates and rotational elements of the planets and satellites: 2000, Seidelmann, P.K., et al., Celestial Mechanics and Dynamical Astronomy, 82, 83-111, 2002.

The plan is also consistent with the following Planetary Data System documents:

8. Planetary Data System Archive Preparation Guide, January 20, 2005, Version 0.050120, DRAFT, JPL D-31224.
9. Planetary Data System Data Standards Reference, August 1, 2003, Version 3.6, JPL D-7669, Part 2.

Finally, the plan is meant to be consistent with:

10. The contracts negotiated between the MRO Project, Principal Investigators and Facility Team Leaders in which experiment data records (EDRs), reduced data records (RDRs), software and algorithms, and documentation (including calibration) are explicitly defined as deliverable products,
11. Agreements between the Project and PDS for delivery of data to the community served by the PDS, and
12. The Interface Control Documents that will be generated between the Project/Principal Investigator/Team Leaders and the PDS and that cover in detail archive generation, validation, and transfer plans.

2. MISSION OVERVIEW

The Mars Reconnaissance Orbiter will be launched in August 2005 and be inserted into Mars orbit in March 2006. Aerobraking will be used from orbit insertion until September 2006, when propulsion maneuvers will terminate aerobraking and place the orbiter into the primary science orbit (PSO) during October 2006, prior to solar conjunction. The Primary Science Mission (PSM) includes global mapping, regional survey and targeted observations and will be accomplished between November 8, 2006, and November 8, 2008, for a total of 731 days spanning slightly more than one Mars Year. An additional six-month period (from November 2008 thru May 2009) is provided for final processing and delivery of MRO data products to the PDS. During its Primary Science Mission, MRO will also provide relay for U. S. spacecraft launched in the 2007 opportunity. MRO will continue to serve as a relay for future landed missions to Mars until December 2010, with the possibility of extended science instrument operations during this period. End of mission is currently slated for December 31, 2010, with a possibility for extended operations depending upon the health of the orbiter.

The MRO Mission will recover science objectives lost with the 1998 Mars Climate Orbiter by including the Mars Climate Sounder (MCS), an updated version of the Pressure Modulator Infrared Radiometer (PMIRR). In addition, the wide-angle component of the Mars Color Imager (MARCI-WA) will be flown, replacing the MARCI-WA lost on the Climate Orbiter. MRO will include two new remote sensing imaging systems, the High Resolution Imaging Science Experiment (HiRISE) camera and the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM). CRISM covers both visible and near-infrared wavelengths. A Context Imager (CTX) will be flown as a facility instrument, in part to provide extended area views of the locales covered in detail by HiRISE and CRISM observations. The CTX will provide regional surveys, which can be used to target the other MRO instruments, in addition to scientific observations. A radar system designed to probe the structure and nature of the shallow subsurface (SHARAD) will also be included. An Accelerometer Science Team will use data acquired by the spacecraft accelerometers during aerobraking to infer upper atmosphere properties and a Gravity Science Team will use radio tracking to refine models of the gravity field and to better understand subsurface structure and dynamics. An Optical Navigation Camera will acquire images during the final 30 days of the approach to Mars. Table 1 summarizes the MRO payloads, along with Principal Investigator and Team Leader designations.

Assuming that the MRO Primary Science Mission extends for 2 Earth years and is supported by two nominally 8 hour X Band 34 m DSN passes per day and three 70m passes per week, the spacecraft is capable of returning a total of up to 34 terabits (Tbits) of data, transmitting at rates which vary throughout the mission from 20 to 100 and back to 20 gigabits (Gbits) of data per day. The lowest data rates occur at the start of the Primary Science Mission when the Earth-Mars range is greatest, and the highest data rates occur when the range is small, a period extending from late October 2007 to June 2008. Table 2 shows telemetry data volumes allocated to each instrument, based on full mission success criteria of 26 Tb data downlinked for all instruments combined. It is expected that 34.5 Tb as opposed to 26 Tb of data will be downlinked. Additional data may be transmitted using X Band 70 m DSN coverage, particularly early in the mission when data rates are otherwise low. MRO also carries a Ka Band demonstration package, which can be used on additional DSN passes to augment the nominal science data return. Additional data would also be acquired during any extended missions. Table 3 shows estimated science product volumes for several data return cases.

The generation of EDRs and RDRs from telemetry data typically results in a data volume expansion of at least an order of magnitude. Thus, archiving MRO data will be challenging indeed since at least several hundred terabits of data will be produced, validated, and placed on hard media for safe-keeping, and made available through the PDS.

3. ROLES AND RESPONSIBILITIES

In this section the roles and responsibilities for personnel and organizations involved in generation, validation, transfer, and distribution of MRO archives are summarized.

3.1. MRO Project

The Project has overall responsibility for generation and validation of PDS-compliant archives for release to the PDS. To accomplish these tasks the Project will ensure that instrument telemetry data, SPICE files, and any other ancillary information needed to process relevant data sets to EDRs and RDRs are made available in a timely manner to Principal Investigators and Team Leaders to pull to their home institution processing facilities.

The Principal Investigators and Team Leaders will direct the generation, validation and release of PDS-compliant archives for their instruments or investigations, working with the appropriate PDS Discipline Nodes (Table 4). They will also ensure archive transfers to the PDS according to the plans specified in this document and in detail in relevant Interface Control Documents (Table 4).

In preparation for the delivery of archive products, the Project will conduct two Trial Data Deliveries. Each instrument and investigation team that will be delivering products to the PDS archives will prepare sample archive volumes and deliver them to their respective PDS nodes. The first delivery (contingent on Project approval of early imaging, i.e. prior to start of aerobraking) will be scheduled for early in the aerobraking phase. The second will be scheduled shortly prior to the start of the Primary Science Phase. These Trial Deliveries will reduce risk by allowing the Teams to exercise and debug their archival product production capabilities.

During the Primary Science Phase, higher-level data products archived in the PDS will not be routinely reprocessed. Calibrated data files needed to reprocess previously delivered EDRs will be delivered or low-level RDRs will be generated, depending on data volume, in the event that calibration files and data processing algorithms change. After the PSP, all products will be reprocessed using the final versions of calibration files, ancillary data, and processing algorithms, and these products will form the final MRO delivery to PDS.

MRO teams will deliver final versions of all archive data products 6 months after end of the Primary Science Phase observations. These final versions will be delivered according to PDS requirements. Currently, this requires (3 copies) on hard media.

Coordination and oversight of the implementation of this Archive Plan and relevant Interface Control Documents is accomplished in part through a Subgroup of the Project Science Group, specifically the Data and Archive Working Group (DARWG). The DARWG will consist of members of instrument teams and facility teams who are cognizant of, and involved in archive preparation, together with relevant Project and PDS personnel.

3.2. Planetary Data System

The PDS is the designated point of contact for the Project, including Principal Investigators and Team Leaders, on archive-related issues.

The PDS is the interface between the Project and the National Space Science Data Center (NSSDC).

The PDS will work with Project Personnel, Principal Investigators, and Team Leaders through DARWG and through bilateral discussions to ensure that the MRO archives are compatible with PDS standards and formats. These deliberations will be formalized through generation and approval of Interface Control Documents that specify procedures and institutional arrangements for transfer of validated archives to the PDS (Table 4).

The PDS is responsible for accepting validated, PDS-compliant archives from the MRO Project or designates (i.e., Principal Investigators and Team Leaders) and making the archives available to the research and other communities, according to the plans specified in this document.

Currently, the PDS will accept three (3) copies of hard copy digital media versions of MRO Archives. One copy will be deposited for deep storage at NSSDC and two will be deposited at different sites within the PDS. The PDS will undertake a study of data delivery technology that can reasonably deal with the MRO data volume, and will provide the MRO Project with updated requirements before the start of the Primary Science Phase (October 2006, TBR).

The PDS will distribute MRO archives through its distributed Discipline Nodes, the Imaging Node, NAIF Node, and perhaps through use of short term Data Nodes, using an interface or set of interfaces that allow(s) users to access the archives by time, orbit, location, instrument, data type, and other relevant parameters.

3.3. National Space Science Data Center

The NSSDC will maintain a deep archive of MRO data for long-term preservation and for filling large delivery orders to the science community and other customers.

4. ARCHIVE GENERATION, VALIDATION, TRANSFER, AND DISTRIBUTION

4.1. Generation

MRO science operations will be geographically distributed, with a Project-controlled central database at JPL, containing telemetry data, SPICE files, and other information needed by Principal Investigators and Team Leaders to generate EDR and RDR standard products. The Project will implement a system that meets the timeliness requirements associated with operations and archiving that allows the Principal Investigators and Team Leaders to access the data and information and to transfer the files to their home institution facilities. Specifically, HiRISE data will be transferred to the HiRISE processing facility at the University of Arizona, CRISM data will be transferred to the CRISM processing facility at the Applied Physics Laboratory, MARCI-WA and CTX data will be transferred to the MSSS facility, and MCS data to the team facility at JPL. SHARAD data will be made available to the SHARAD science team for transfer to the Rome University facility. Radio science data will be transferred to the Gravity Team's facilities at MIT (Team Leader institution), and accelerometer data to the George Washington University/Langley Research Center facility (Team Leader institution).

An Interface Control Document (ICD) will exist for each relationship between a facility that provides data and the PDS node that receives it. This document will describe the management interface between the two entities, roles and responsibilities of each side, and policies and procedures that govern the flow of data from provider to PDS. Each type of data product to be delivered to PDS will be described in a Data Product Software Interface Specification (SIS), which may be included as an Appendix to the ICD. The SIS will include an example of the PDS label for the data product. In addition, an Archive Volume SIS will describe the contents and organization of the complete archive to be delivered to PDS, including data products, indices, documentation, software, and other supporting materials. The Archive Volume SIS may also be appended to the ICD.

The raw data, SPICE files, and other required data sets will be used at the home facilities to generate EDR and RDR standard products for use by team members and for use in archiving. A list of standard data products (both EDRs and RDRs) to be generated is provided in Table 5.

It is noted that a number of special products are under discussion within some teams. These products will be produced and delivered on a ‘best efforts’ basis to the PDS. These products are listed in Table 6. Definitions of processing levels for standard and special products are provided in Table 7.

EDRs and RDRs are but two components of PDS-compliant archives. Other elements are summarized in Table 8, including archives to be supplied by the Project, and Table 9 summarizes the archive schedule.

The archives are intended to preserve observational data that support instrument calibration as well as science observational data. Calibration data acquired during cruise and in orbit will be archived in the same manner as science observations. Calibration data acquired pre-flight will be treated as a PDS "saved" data set, archived for safekeeping with minimal documentation.

The archives associated with instrument data and facility investigations will be assembled at relevant Principal Investigator and Team Leader institutions, using archive volume SISs that define the elements of archives and the associations among the elements. Archive volume SISs will pertain both to online archives and to the physical volumes that must be made and transferred to the PDS. Archives produced by the Project, namely telemetry files, SPICE files, engineering data sets, and any other relevant information, will follow the same procedures that are designated for the science archives.

MRO cartographic data products will conform to a Project-determined set of cartographic standards. All map-projected data will use planetocentric coordinates and east-positive longitudes, according to the IAU 2000 standard [see Applicable Document 7].

4.2. Validation and Peer Review

DARWG will provide oversight and coordination of validation of archives. The validation process includes the following components:

1. A quality control activity is built in as part of the generation of EDR and RDR products by the Principal Investigators and Team Leaders, using SPICE and other data from the Project.
2. Scientific analysis of the derived products constitutes another form of validation since problems will be uncovered during the course of work.
3. Home institution processing facilities, and the Project, as relevant, will check the products for conformance to SIS documents. The data product SIS and volume SIS serve as the definitive documents for defining the contents, structure, and organization of the data deliveries.

4. Assembly into archive volumes and checking for conformance to Archive Volume SIS documents is an additional validation step performed by each processing facility and by the PDS node that receives the data.

Generation of products and volumes, together with validation, should occur within the defined validation period, the period between receipt of data and release to the PDS (nominally six months).

PDS requires data sets to be peer reviewed before they can be accepted as PDS archives. A typical PDS peer review includes a committee of a few scientists who are knowledgeable about the type of data under review, along with representatives from the data provider and the PDS. The committee is asked to review the data set for completeness and scientific utility. The result of a peer review is a list of liens against the data set that must be resolved before PDS can accept it.

For data products from ongoing missions that are delivered periodically, the peer review takes place as follows.

1. Before data production begins, the committee reviews a representative sample of data products along with associated documentation, software, and other ancillary files that will make up the archive to be submitted to PDS. This is done early to allow time for the data provider to make any necessary changes to the product design, and to ensure that sufficient ancillary materials are provided so that the typical user can access and interpret the data (e.g., software).
2. The committee also reviews the data "pipeline"; that is, the procedures that the provider will use to generate standard products during the mission. The idea is that with the reviewers' approval of a sample of the product and the method for generating it, the PDS can be reasonably sure that future products generated in the same way will be equally valid.
3. Reviewers have an opportunity to view revised products and supporting materials to ensure that the liens have been resolved. Data Product SIS documents are updated as necessary to describe the revised products.
4. With each delivery of data products, the appropriate PDS node performs a standard set of validation procedures to ensure that products conform to the Data Product and Archive Volume SISs. As long as the product design and processing steps do not change, no further peer review is necessary.

4.3. Transfer

A large volume of data will be acquired from the MRO Spacecraft and an even larger volume of derived products and associated information will be generated for analyses and release to the PDS (Table 5). Transfer of the raw observations to the Principal Investigators and Team Leaders is the responsibility of the Project. Transfer of EDRs, RDRs, and associated files to the Co-Investigators and Team Members is the responsibility of the relevant Principal Investigators and Team Leaders, working with the Project to ensure that access is made available. The likely transfer modes will be electronic in some cases, together with some shipments on such media as optical and magnetic disks. Each home institution processing facility will have processing, storage, and transfer capabilities necessary to access raw data, process the data, and allow Team

Members and Co-Investigators to access relevant files to conduct science analyses focused on instrument and facility science objectives.

Transfer of archive products to the PDS during the Primary Science Phase shall be by means described in Table 5. The PDS must be able to ingest data volumes given in this plan within the two-week delivery-to-release window.

Transfer also includes movement of the archive volumes to the PDS using appropriate processes and media and as a set of three hard copy digital media [TBR] designed for deep archival storage.

Designated PDS Nodes for the archives are shown in Table 4.

4.4. Distribution

Once released to the PDS, the MRO archives will be available on-line through a set of PDS search and retrieval tools that will provide access to data from all Mars missions. The user will be able to search for and retrieve data that meet criteria such as a specific time range, instrument, or location on the planet. Map-based searches will also be supported as appropriate. Data will be made available via electronic transfer and as custom volumes generated on digital media. The NSSDC will be responsible for replication of large volumes of data on appropriate digital media.

5. ARCHIVE GENERATION, VALIDATION AND RELEASE SCHEDULES

The release schedule for MRO standard product archives is presented in Table 9. It is based on a nominal six-month period for archive generation, validation, and delivery to the PDS, on three-month intervals, of EDR and RDR standard products. Some RDR products may require longer than six months to produce; therefore exceptions to the nominal six-month release period may be negotiated on a per-product basis.

Special products differ from standard products in that (a) they are not required as part of the agreement between the Principal Investigator and the Project, but are generated on a best-efforts basis, and that (b) in some cases they are not planned ahead of time, but are produced as the need arises. Special products will be released as soon as they have been produced and validated.

The volume of data to be released as a function of time is shown in Table 10.

Table 1. MRO Payloads

Instrument	Type	Investigator	Key Parameters
Principal Investigator Instruments			
HiRISE	High spatial resolution imaging system	Alfred McEwen, University of Arizona	Ultra-high resolution imager. 30 cm/pixel ground sampling 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	Scott Murchie, Applied Physics Laboratory, Johns Hopkins University	Targeted hyperspectral imaging spectrometer in 0.4 – 3.96 µm wavelength range. 20 m/pixel resolution, 10 km swath from 300 km. Survey mode with about 60 bands and 200 m/pixel resolution. Acquires data at multiple emission angles, including for atmospheric survey.
MARCI (WA)	Wide Angle imaging system with 7 spectral bands.	Michael Malin, Malin Space Science Systems	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.	Daniel McCleese, Jet Propulsion Laboratory	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).
Facility Investigations			
Accelerometer	Accelerometer measurements of upper atmosphere	Gerald Keating, George Washington University (LaRC)	Accelerometers coupled with other engineering measurements provide in situ atmospheric density profiles above 100 km
CTX	Context imaging system	Michael Malin, Malin Space Science Systems	Panchromatic (minus blue); 6 m/pixel resolution, 30 km swath from 300 km. Context imaging for targeting and for independent science.

Instrument	Type	Investigator	Key Parameters
Gravity	Use radio tracking to map gravity field	Maria Zuber, MIT	Radio science tracking of spacecraft to improve estimates of gravity field and understanding of internal processes.
SHARAD	Shallow Radar Sounder	R. Seu, Rome University	20 MHz (10 MHz bandwidth) frequency, probing subsurface to depths < 1 km at 10-15 m resolution.
Technology Demonstration			
ONC	Optical Navigation Camera	Steve Synnott, JPL (Mars Technology Program)	High accuracy optical navigation with a camera an order of magnitude smaller than on previous missions

Table 2. MRO Data Allocation

Instrument	Percent allocated with 26 Tb	26 Tb allocation data volume (Tb)
HiRISE	35%	9.1
CRISM	30%	7.8
CTX	13%	3.5
SHARAD	15%	4.0
MARCI	7%	1.4
MCS	1%	0.2

Table 3. Estimated Science Data Product Volumes

Data Type	26 Tb Mission	34 Tb Mission	50 Tb MOS Rqmt (includes margin)
RSDS	26	34	50
EDRs	35.4	48	65
RDRs	363.7	491	645
Total (less RSDS)	399.1	539	710
Total (incl. RSDS)	425.1	573	760

Table 4 Data Provider – PDS Interfaces

Instrument / Principal Investigator	PDS Representative	Interface Control Document ID
HiRISE, Alfred McEwen	PDS Imaging Nodes at JPL and/or USGS, Flagstaff	TBD
MARCI-WA, Michael Malin	PDS Imaging Nodes at JPL and/or USGS, Flagstaff	TBD
CTX, Michael Malin	PDS Imaging Nodes at JPL and/or USGS, Flagstaff	TBD
CRISM, Scott Murchie	PDS Geosciences Node at Washington University in St. Louis	TBD
SHARAD, R. Seu	PDS Geosciences Node at Washington University in St. Louis	TBD
Gravity, Maria Zuber	PDS Geosciences Node at Washington University in St. Louis	TBD
MCS, Daniel McCleese	PDS Atmospheres Node at New Mexico State University	TBD
Accelerometer, Gerald Keating	PDS Atmospheres Node at New Mexico State University	TBD
SPICE and telemetry files	PDS NAIF Node at JPL	TBD
ONC, Steve Synnott	PDS Imaging Node at JPL	TBD

Table 5. MRO Standard Data Products

Instrument	Product	NASA Level	*Delivery Frequency	Volume (Gb) 26Tb Mission	Number of Products 26Tb Mission	Transfer Medium during PSP
HIRISE	EDR: Raw image data	0	Nominal	12,100	12,000	Internet Transfer & Hard media at EOM
	Binned Panchromatic images	1C		24,200	10,000	Same as above
	Binned color images	1C	Nominal, + EOM + 6 months	3,200	5,000	Same as above
	Full-resolution panchromatic images	1C	Nominal (low jitter selected) + EOM + 6 months	30,300	4,000	Same as above
	2x2 binned stereo images	1C	EOM + 6 months	1,900	1,000	Same as above
	Digital Elevation Models	3	EOM + 6 months	1,000	[TBD]	Same as above
CRISM	EDR: Raw spectral cubes with pointing, time planes	0	Nominal	12,800	282,940	Data brick
	DDRs and part of TRDRs: calibrated targeted and EPF spectra cubes with pointing, geometric, physical properties data.	1A & 3	Nominal & EOM + 6 months	59,000	111,902	Data brick
	CDRs: In-flight calibration files	4 & 6	Nominal, & EOM + 6 months	1,000	133,630	Data brick
	Ground Calibration Files	2	Orbit Insertion	220	200	Data brick
	Spectral library	2	Orbit Insertion	1	10,000	Data brick

Instrument	Product	NASA Level	*Delivery Frequency	Volume (Gb) 26Tb Mission	Number of Products 26Tb Mission	Transfer Medium during PSP
SHARAD	EDR: Raw data	1A	Nominal	5,000	23,000	DVD
	RDR: Filtered, compressed, calibrated profiles	1B	Nominal	3,200	23,000	DVD
	DDR: Radargrams	2	Best Effort	1,600	23,000	DVD
	MDR: Radargrams	3	Best effort	TBD	TBD	DVD
CTX	EDR: Raw image data with calibration data and ancillary information	0	Nominal	3,380	24,000	DVD or internet
MARCI	EDR: Raw image data with calibration data and ancillary information	0	Nominal	1,300	8500	DVD or internet
MCS	EDR: Unpacked telemetry data	1A	Nominal	640	4386	Internet
	RDR: Calibrated radiances	1B	Nominal	1280	4386	Internet
	DDR: Atmospheric profiles	2	3 mo. Chunks, no less frequent than every three months beginning 18 mo. after 1st three mo. of data, final delivery by EOM + 6 mo.	320	731	Internet
Accelerometer	EDR: Raw telemetry data	0	Nominal	0.2		
	Density	2	1st delivery 6 mo. after A/B (Mar ’07) and 3 mos. thereafter.	1		
	Density Scale Height	2	1st delivery 6 mo. after A/B (Mar ’07) and 3 mos. thereafter.			
Gravity	TRK-2-34 files	0	Nominal	6.4		

Instrument	Product	NASA Level	*Delivery Frequency	Volume (Gb) 26Tb Mission	Number of Products 26Tb Mission	Transfer Medium during PSP
	Coefficients for the harmonic expansions of the gravity field			0.08		
	Error covariance models for expansions			48		
	Maps showing field expansions (free air, areoid, Bougher anomaly) (note: assume 1 set from JPL and 1 set from GSFC)			0.12		
	Angular momentum desat files			0.0144		
	Weather data files			0.0272		
NAIF / SPICE	SPK kernels for spacecraft, Mars, Sun, Phobos/Deimos		Nominal	24		
	CK (orientation) for spacecraft, high gain antenna, solar arrays		Nominal			
	FK (coordinate frame specifications)		Nominal			
	IK (instrument field-of-view geometry)		Nominal			
	SCLK (spacecraft clock coefficients)		Nominal			
	PcK kernels for times of interest		Nominal			
	LSK (leap seconds)		Nominal			
	ESQ (commands and related sequence items)		Nominal			
	ENB (experimenter’s notebook) perhaps not for MRO		Nominal			

Instrument	Product	NASA Level	*Delivery Frequency	Volume (Gb) 26Tb Mission	Number of Products 26Tb Mission	Transfer Medium during PSP
	ORBNUM file		Nominal			
Engineering Data	Engineering Archive Data Record	0	Nominal	TBD		
RSDS	CFDP Safed Data Files	0	Nominal	26,000	TBD	DVD
* Nominal delivery frequency means 6 months after receipt of data, delivered on 3-month centers.						

Table 6. MRO Special Products

Instrument SIS ID	Product	NASA Level	Delivery Frequency	Volume (Gb) 26Tb Mission
HiRISE	Figures from publications	tbd	Coincident with publications	tbd
	Full resolution merged color images	1C	EOM + 6 months	30,300
	Corrupted images: The estimated ~5% of HiRISE observations that cannot be processed via automated procedures will be “manually” corrected and processed on a best-effort basis.	1C	EOM+ 6 months	1,500
	RDRs for ridealong images	2	EOM + 6 months	1,900
CRISM	Map-projected multispectral spectral cubes (calibrated radiances, surface spectra, spectral indices in map projected, tiled cubes)	1B	6 months with 6 month centers + EOM + 6 months	88,600
	Part of TRDRs: Summary Products	1A & 3	Up to once every 3 mo. After 6 mo. Validation, & EOM + 6 mo.	6,000
	Selected targeted observations reduced to surface spectral image cubes and presented as map projections (approximately 50 sites)	3	Coincident with publications + EOM + 6 months	2,000
	Selected surface spectral image cubes from targeted and global observations	2	Coincident with publications + EOM + 6 months	1,500
SHARAD	Figures from publications	tbd	Coincident with publications	tbd
CTX	Figures from publications	tbd	Coincident with publications	tbd
MARCI	Figures from publications	tbd	Coincident with publications	tbd
MCS	Figures from publications	tbd	Coincident with publications	tbd
	Daily brightness temperature “images”, 3 spectral bands	1C	Nominal	5
	Daily temperature “images” for 4 altitude levels, incl. surface.	2	3 mo. of data ,<= once per 3 mo.,	7

Instrument SIS ID	Product	NASA Level	Delivery Frequency	Volume (Gb) 26Tb Mission
			complete by EOM + 6 mo.	
	Daily column-integrated dust and water “images”	2	3 mo. of data ,<= once per 3 mo., complete by EOM + 6 mo.	3.5
	[Mars] monthly 1x1 degree, mapped surface temperature	3	3 mo. of data ,<= once per 3 mo., complete by EOM + 6 mo.	<1 Gb
	[Mars] monthly 1x1 degree broadband solar reflectance maps	3	3 mo. of data ,<= once per 3 mo., complete by EOM + 6 mo.	<1 Gb
	[Mars] monthly 2x2 degree maps of surface thermal inertia	3	3 mo. of data ,<= once per 3 mo., complete by EOM + 6 mo.	<1 Gb
	Polar maps of depth to ice	3	EOM + 6 mo.	< 1 Gb
Accelerometer	Temperature	3	Tbd	tbd
	Pressure	3	Tbd	tbd
	Pressure scale height	3	Tbd	tbd
	1.26 Nanobar Pressure Heights	3	Tbd	tbd
	Zonal Winds	3	Tbd	tbd
Gravity	Figures from publications	tbd	Coincident with publications	tbd

Table 7. Definitions of Processing Levels for Science Data Sets

NASA	CODMAC	Description
Telemetry data	Raw – Level 1	Telemetry data stream as received at the ground station, with science and engineering data embedded.
Level 0	Edited - Level 2	Instrument science data (e.g., raw voltages, counts) at full resolution, time ordered, with duplicates and transmission errors removed.
Level 1A	Calibrated - Level 3	Level 0 data that have been located in space and may have been transformed (e.g., calibrated, rearranged) in a reversible manner and packaged with needed ancillary and auxiliary data (e.g., radiances with the calibration equations applied).
Level 1B	Resampled - Level 4	Irreversibly transformed (e.g., resampled, remapped, calibrated) values of the instrument measurements (e.g., radiances, magnetic field strength).
Level 1C	Derived – Level 5	NASA Level 1A or 1B data that have been resampled and mapped onto uniform space-time grids. The data are calibrated (i.e., radiometrically corrected) and may have additional corrections applied (e.g., terrain correction
Level 2	Derived - Level 5	Geophysical parameters, generally derived from Level 1 data, and located in space and time commensurate with instrument location, pointing, and sampling.
Level 3	Derived - Level 5	Geophysical parameters mapped onto uniform space-time grids.

Table 8. Components of MRO Archives

Component	Contents	Supplier
SPICE Archives	SPICE Kernel Software Interface Specification Documents SPICE Kernels SPICE Toolkit	MRO Project
Science Data Archives	High-level mission, spacecraft, instrument, and data set descriptions for the PDS Catalog Software Interface Specification (SIS) Documents Archive Volume Software Interface Specification Documents Processing Descriptions, Algorithms, and Software (to use in understanding reduced data product generation) Instrument Calibration Reports and associated data needed to understand level 1 product generation Experiment Data Records and Reduced Data Records, containing standard products, with PDS Labels	Instrument Teams
Engineering Data Archives	Software Interface Specification Documents Uplink sequences and notebook entries Telemetry data	MRO Project

Table 9. MRO Nominal Release Schedule for Standard Products

Date	Event
August 10-31, 2005	Launch window
March 2006	Mars orbit insertion
November 8, 2006	Start of mapping
December 8, 2006	30 days of mapping
February 8, 2007	3 months of mapping
March 8, 2007	**Release 0: Accelerometer data acquired during first 90 days of aerobraking**
May 8, 2007	6 months of mapping
June 8, 2007	**Release 1: data acquired during first 30 days of mapping, and all remaining aerobraking data**
August 8, 2007	9 months of mapping
September 8, 2007	**Release 2: data acquired between day 31 and 3 months of mapping**
November 8, 2007	12 months of mapping
December 8, 2007	**Release 3: data acquired between 3 and 6 months of mapping**
February 8, 2008	15 months of mapping
March 8, 2008	**Release 4: data acquired between 6 and 9 months of mapping**
May 8, 2008	18 months of mapping
June 8, 2008	**Release 5: data acquired between 9 and 12 months of mapping**
August 8, 2008	21 months of mapping
September 8, 2008	**Release 6: data acquired between 12 and 15 months of mapping**
November 8, 2008	24 months of mapping; end of primary mission
December 8, 2008	**Release 7: data acquired between 15 and 18 months of mapping**
March 8, 2009	**Release 8: data acquired between 18 and 21 months of mapping**
May 8, 2009	**Release 9: data acquired between 21 and 24 months of mapping (EOM)**
TBD	Further releases every 3 months in case of an extended mission
Note: Data releases occur every 3 months. A release contains data acquired 6 to 9 months previously.	

Table 10. Volume of Data Delivered to PDS over Time