Mars Global Surveyor Project Archive Generation, Validation, and Transfer Plan

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MARS GLOBAL SURVEYOR PROJECT
Archive Generation, Validation, and Transfer Plan

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CHANGE PAGES

Rev. 5/20/96

1. Added statement that PIs are required to deliver a complete, validated data archive to PDS by the end of mission (page 2).
2. Changed delivery schedule to reflect deliveries to PDS every six months instead of every three months, with the last delivery at end of mission (9/30/01) to be consistent with new funding schedule (page 5, Fig. 1, Table 10).

Rev. 8/23/96

1. Changed Figure 3 to show correct delivery volumes corresponding with Figure 1 and Table 10.
2. Added note to caption of Figure 1 stating that one of the deliveries is not shown in the figure.

Rev. 6/9/97

1. Section 1.2, second sentence changed to "Data acquired before mapping phase… may be included in archives of mapping phase data."; i.e., it is not mandatory. In third sentence, deleted reference to Russian landed missions.
2. Section 1.4: Updated versions of Planetary Data System documents.
3. Section 2.1, last paragraph, changed to "…each PI and TL is obligated to deliver to the PDS a complete, validated archive…". (Added the words "and TL".)
4. Section 3.0, first paragraph: added level 0 radio science data to list of archive collections, and grouped level 0 science packets and engineering data together as one archive collection, explicitly listing the science instruments.
5. Section 3.1, first paragraph: Explicitly stated the archiving responsibilities of Data Administration and the Radio Science Team.
6. Section 3.2, second paragraph, first sentence changed to "The Science Validation Team will consist of … and a representative from each Science Team." (formerly stated as "a Science Team Representative"). Last paragraph, third sentence changed to "A fundamental aspect of the release schedule is that level 0 science packets…" (added the words "level 0").
7. Sections 4.1 and 4.2: Replaced references to DARWG with SDVT.
8. Section 4.1, second paragraph, added "The Radio Science Team Leader will produce the Radio Science level 0 archive collection."
9. Section 4.3: Added "The PDS will deliver copies of MGS archive volumes to NSSDC."
10. Section 5.2, third paragraph, first sentence changed to "…standard products (and associated raw data and SPICE files) will be delivered to the PDS…" (formerly stated as "will be included in archive volumes for delivery"). Fourth paragraph, second sentence: changed to "…each delivery containing up to 16 mapping cycles worth of data" (formerly "about 16 mapping cycles").
11. Updated Figure 2 to show Data Administration generating level 0 science and engineering data and SPICE, and to show Radio Science generating level 0 Radio Science archives, all to be delivered to NAIF.
12. Removed Figure 3.
13. Table 4: Updated data volumes for Radio Science data with new values from R. Simpson; adjusted totals accordingly.
14. Table 5: Updated list of standard data products for MOLA and TES.

15. Table 6: Added "Data Product Software Interface Specification Documents" to list of components of Engineering and Level 0 Science Data Archive Collections; added list of components for Radio Science Level 0 Data Archive Collection.
16. Table 8: Under responsibilities for NAIF, changed "ancillary engineering data sets" to "level 0 science instrument data packets and engineering data, including DSN monitor data, and Radio Science level 0 archive collection".
17. Table 9: Changed data level for product SPAE034 from 1C to 3.
18. Table 9: Deleted old MOLA data products (MOLA-IARR, MOLA-EPDR, MOLA-CEPDR, MOLA-CEGDR, and MOLA-FEGDR) and replaced with new (MOLA-PEDR and MOLA-IEGDR). MOLA-AEDR and MOLA-MEGDR remain the same.
19. Table 9: Combined products SPAE052 (TES-CR) and SPAE053 (TES-ADF) into one product, SPAE052 (TES-OBS). Total data volume does not change.
20. Appendix I: Revised definitions of archive collection, archive volume, data product, standard data product, data set, and reduced data record.
21. Deleted Appendix III, Archive Volume Software Interface Specification Outline for Instrument-Related Data, and a reference to it in Section 4.1. Renamed Appendix IV to Appendix III and changed all references to it accordingly.
22. Updated Table 9 and Appendix II with correct MGS interface ID for MOLA-AEDR: SPAE067.
23. Appendix II: Replaced descriptions of TES data products TES-CR and TES-ADF with description of new combined product TES-OBS.
24. Appendix II: Deleted descriptions of MOLA data products MOLA-IARR, MOLA-EPDR, MOLA-CEPDR, MOLA-CEGDR, and MOLA-FEGDR, and replaced them with descriptions of new products MOLA-PEDR and MOLA-IEGDR. MOLA-AEDR and MOLA-MEGDR remain the same.

Rev. 6/23/97

1. Changed list of names on signature page.
2. Replaced references to Mission Operations Assurance Team (MOAT) with Data Administration.

Rev. 7/3/97

1. In Table 7, under Spacecraft Team, changed "Contributions to E kernel" to "Spacecraft Status Report and Mission Controllers Real-Time Operations Log". Removed Mission Control category. Changed "Planning and Sequencing Team" to "Mission Planning and Sequencing Team", and changed their contribution to "Predicted Events File as input to the E Kernel and Sequence of Events File as input to the E Kernel".

Rev. 7/15/98

1. Changed Patricia Rogers to John Grant on signature page.
2. Updated 1.2 to include archiving of data acquired during Circularization Phase of Mission.
3. Updated 2.1 to include discussion of Circularization Subphases, e.g., SPO-1.
4. Updated 5.2, Figure 1 to include MGS Sampler CD and SPO-1, SPO-2 archive deliveries.
5. Updated tables to say they refer to standard products produced from Mapping Phase observations, and updated Table 10 to be consistent with new 6 month deliveries.
6. Added Table 1, Mission Phases, renumbered other tables, and corrected references to them.

Rev. 7/29/98

1. Changed Figure 2 to include NSSDC.
2. Added accelerometer data archive information.

Rev. 8/9/98

1. Changed dates of mission phases and data deliveries based on Mapping Phase beginning 1999-04-01.

Rev. 2/11/99

1. Changed names and dates of mission phases based on definitions provided by R. Springer.
2. Changed processing levels for MOLA AEDR and PEDR products in Table 9.

TABLE OF CONTENTS

1.0 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 Mars Global Surveyor (MGS) archives containing raw and reduced data, documentation, and algorithms/software. A second purpose is to delineate plans for posting on the Internet a subset of derived data and documentation that shows interesting and timely results.

1.2 Scope

The plan covers archiving of raw and reduced data sets and related information to be acquired or derived during the MGS circularization and mapping mission phases. Data acquired before these phases (i.e., during cruise and orbit insertion) may be included in archives of mapping and circularization phase data. Data archive generation will continue after the mapping phase into the analysis phase of the mission, ending in September 2001. A plan for an extended relay mission for the Mars Surveyor Program will be prepared later as needed. Finally, addenda to this Plan will be published at a later date if products generated by MGS Interdisciplinary Scientists (e.g. global circulation model output) are deemed appropriate for archiving.

Specific aspects addressed in this plan are:

1. Generation of high-level mission, spacecraft and instrument documentation, instrument calibration reports, algorithms, and documentation of software used to produce Levels 1 to 3 reduced data records.
2. Reduction of science packet data (i.e., packetized level 0 data) to reduced data records, including generation of data sets expressed in geophysical units, with associated documentation that determines when and where the data were acquired and for what purpose.
3. Generation of SPICE archives for use with software from the Jet Propulsion Laboratory's Navigation and Ancillary Information Facility (NAIF).
4. Generation and validation of archive volumes containing MGS data, software, algorithms, documentation, and ancillary information.
5. Delivery to the PDS of validated MGS archives.

1.3 Contents

This plan begins with a summary of MGS mission phases and an overview of the ground data system. This section is followed by a description of the roles and responsibilities for organizations and personnel associated with generation, validation, and archiving of MGS data. The document ends with specific plans for archiving and for posting of subsets of data for outreach and educational purposes. For reference, Appendix I is a glossary of selected terms used in this document.

1.4 Applicable Documents and Constraints

The MGS Archive Generation, Validation, and Transfer Plan is responsive to the following Mars Global Surveyor documents:

Project Plan (Doc. 542-10, Dec. 1994).

Mission Plan (Doc. 542-405, Jul. 1995).

Investigation Description and Science Requirements Document (Doc. 542-300, Feb. 1995, JPL D-12487).

Project Data Management Plan (Doc. 542-403).

Science Data Management Plan (Doc. 542-310).

Mission Operations (Doc. 542-409, vol. 1-12).

The plan is consistent with the principles delineated in the following National Academy of Sciences reports:

Data Management and Computation, Volume 1, Issues and Recommendations, 1982, National Academy Press, 167 p.

Issues and Recommendations Associated with Distributed Computation and Data Management Systems for the Space Sciences, 1986, National Academy Press, 111 p.

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

Planetary Science Data Dictionary Document, July 15, 1996, JPL D-7116, Rev D.

Planetary Data System Data Preparation Workbook, February 1, 1995, Version 3.1, JPL D-7669, Part-1.

Planetary Data System Data Standards Reference, July 24, 1995, Version 3.2, JPL D-7669, Part-2.

Finally, the plan is meant to be consistent with the contracts negotiated between the MGS Project and each Principal Investigator (PI), Team Leader (TL), and Interdisciplinary Scientist (IDS), in which reduced data records and documentation are explicitly defined as deliverable products.

2.0 OVERVIEW OF MARS GLOBAL SURVEYOR MISSION

2.1 Mission Overview

The MGS spacecraft was launched from Cape Canaveral, Florida, on 1996-11-07, aboard a Delta-2/7925 rocket. The 1062 Kg spacecraft, built by Lockheed Martin Astronautics, traveled nearly 750 million km over the course of a 300-day cruise to reach Mars on 1997-09-11 (Figure 1). Upon reaching Mars, MGS entered the Orbit Insertion Phase of the mission by firing its main rocket engine for a 25-minute Mars orbit insertion (MOI) burn. This maneuver slowed the spacecraft and allowed the planet's gravity to capture it into orbit. The initial MGS orbit was highly elliptical with a period of approximately 45 hours. MGS performed a series of orbit changes to drop the low point of its orbit (i.e., periapsis) into the upper fringes of the Martian atmosphere at an altitude of about 110 km. During the periapsis atmospheric passes, the spacecraft velocity was slightly reduced because of drag. This, in turn, reduced subsequent apoapsis altitudes.

MGS was to use aerobraking over a period of four months to lower the highpoint of its orbit from 56,000 km to near 400 km in altitude. However, at the low point of orbit 15, 1997-10-08, the spacecraft experienced difficulties later diagnosed as due to excess vibrations of one of the solar panels. The problem was associated with a fracture of a panel damper arm [Albee et al., Mars Global Surveyor mission: Overview and status, *Science*, 279, 1998]. While an evaluation of the solar array problem was underway, periapsis was raised to about 172 km on 1997-10-13 and remained near that altitude until 1997-11-07 (orbits 19 through 36). During this 26-day period the spacecraft instrument panel was pointed towards Mars during close approaches (i.e., near periapsis) and the first extensive set of science observations from MGS was collected. Orbits 19 through 36 are known as the assessment orbits, and the time period is known as the Aerobraking Hiatus of the Orbit Insertion Phase. The science observations were acquired during the descending leg of each orbit; that is, as the spacecraft moved from north to south.

Aerobraking was restarted on 1997-11-08 (orbit 37), but with a periapsis approximately 10 km higher than that previously used. As of this writing, the mission plan is to conduct aerobraking at about 1/3 the rate originally planned and to place the spacecraft in a 2 AM Sun-synchronous mapping orbit in March 1999 rather than the planned 2 PM mapping orbit in March 1998. The 2 PM orbit meant that the spacecraft would have crossed the equator in the descending leg of the orbit -- north to south -- at 2 PM, a desirable time for data collection for some instruments. This orbit could not be achieved given the new orbital characteristics. However, a 2 AM orbit is satisfactory because if the descending leg of the orbit crosses the equator at 2 AM, it means that the ascending leg, south to north, will cross the equator at the desired time of 2 PM.

Another aerobraking hiatus began on 1998-03-27, extending through 1998-09-23. This period, termed the Science Phasing Orbits of the mission, was necessary to ensure that the final two hour circular orbit has an equatorial crossing time of 2 AM. After a final period of aerobraking beginning in September, 1998, the Mapping Phase of the mission will begin in April 1999. During mapping operations, the spacecraft will orbit Mars with a period of 118 minutes, at an average altitude of 400 km. For 687 Earth days (one Mars year), MGS will utilize this orbital vantage point to collect scientific data on a continuous basis.

Six mission phases are defined for significant spacecraft activity periods. These included Pre-Launch, Launch, Cruise, Orbit Insertion, Mapping, and Relay Phases. The Cruise Phase includes both Inner and Outer Cruise components. The Orbit Insertion Phase includes the Aerobraking Phases, the Assessment Subphase, and the Science Phasing orbits. During the Mapping Phase, the spacecraft will approximately retrace its ground track once every seven Martian sols; these 88-orbit intervals are known as repeat cycles. Table 1 lists the mission phase dates. Note that dates for events after 1998-09-24 are planned but have not yet occurred as of this writing. Note that the end of the data analysis phase of the mission is 2001-09-30 and corresponds to the last delivery of archive data to the Planetary Data System.

The MGS Mission has objectives that pertain to geosciences and atmospheric sciences. The primary geoscience objectives include the global definition of the topography and the gravitational field, global determination of the mineralogical character of surface materials, and determination of the nature of the magnetic field around Mars. The primary climatology objectives are the determination of the time and space distribution, abundances, sources and sinks of volatile material and dust over a seasonal cycle, as well as the delineation of atmospheric structure and dynamics. MGS objectives require mapping and result in raw and derived data sets that have both spatial and temporal dimensions. The intent is to generate a suite of products that depict atmospheric, surface, and subsurface characteristics as a function of latitude, longitude, altitude (as appropriate), and time.

Table 2 shows instruments on MGS, measurements to be made, and investigators responsible for the instruments. Table 3 lists the Interdisciplinary Scientists and their planned activities. For reference, Table 4 is a summary of raw data to be acquired by each instrument over the course of the Mapping Phase.

Through extensive discussions within the Mars Observer (MO) Data and Archives Working Group, a set of standard products were compiled for each MO experiment. The products are now to be generated from data acquired during the Mapping Phase of the MGS mission. The list is shown in Table 5 and descriptions are given in Appendix II. The products consist of documentation/ancillary data, time sorted vectors (e.g., TES along track spectral radiances), and gridded products (e.g., digital elevation maps from MOLA).

A fundamental tenet of the Mars Surveyor Program and MGS is that each PI and TL is obligated to deliver to the PDS a complete, validated archive of his data by the end of the data analysis portion of the mission, September 30, 2001.

2.2 Ground Data System

The MGS ground data system will involve a centralized mission operations component at JPL and a distributed component located at home institutions of the Principal Investigators, the Radio Science Team Leader, Interdisciplinary Scientists, Team Members, Co-Investigators, and Participating Scientists. Science Operations Planning Computer (SOPC) workstations located at Principal Investigator, Team Leader, and Interdisciplinary Scientist home institutions will be electronically connected via NASCOM and ethernet links to a Project Data Base at JPL. Personnel at JPL and those with SOPC workstations will use the Project Data Base to coordinate observation planning. Level 0 science data in packetized form, SPICE files, and relevant engineering data will be placed in the PDB for access by Principal Investigators and the Radio Science Team Leader. These files will be transferred to the relevant home institutions for examination and generation of reduced data records.

Each Principal Investigator and the Radio Science Team Leader is responsible for getting the products to his respective team members and to interdisciplinary scientists and participating scientists, under the guidelines of data use outlined in the MGS Science Data Management Plan. It is expected that ftp transfers, use of CD-WOs, and other transfer mechanisms will be used to get data to the relevant individuals. This science part of the ground data system will be based on existing systems and/or purchases for science use and will not formally be part of the MGS ground data system. Finally, each Principal Investigator and the Radio Science Team Leader should maintain an on line data collection, accessible over Internet, that contains recent reduced data of general interest, together with documentation explaining the products and their relevance to MGS and Mars science. These postings are to be generally available to Internet users for outreach and educational purposes.

3.0 OVERVIEW OF ARCHIVING FUNCTIONS

Standard products form the core of the archives to be produced by MGS and released to the PDS for distribution to the science community. These products and associated raw data, SPICE files, and ancillary information will be placed on archive volumes for validation and transfer to the PDS. A logical grouping of volumes is termed an archive collection (Appendix I). Table 6 lists the key elements associated with archive collections and Table 7 lists suppliers of data and information for MGS archive collections. There will be one archive collection (and associated volumes) for each instrument, one for accelerometer data, one for SPICE files, one for level 0 science packets for MOC, MOLA, TES, and MAG/ER, together with engineering data, and one for level 0 radio science data, for a total of 9 archive collections (and associated volumes). Accelerometer data collected during aerobraking will also be archived.

In the following section we discuss the processes and schedules for generation and validation of standard products and archive volumes and ingestion by the PDS. Figure 2 shows the flow of components through the various stages of archive volume generation, validation, transfer to the Planetary Data System, and distribution of products to the science community. Also shown is posting of timely results on Internet for education and outreach.

3.1 Generation

Generation of archive volumes of level 0 spacecraft instrument science packets, spacecraft engineering packets, DSN monitor packets, and SPICE files is the responsibility of Data Administration. Generation of archive volumes of raw radio science data is the responsibility of the Radio Science Team

The Science Operations Team, which consists of the Instrument Teams and Interdisciplinary Scientists and is led by the Science Manager, will be responsible for the generation of reduced data records (as standard data products), documentation, algorithms or software to generate levels 1 to 3 products. Archive volumes will be assembled under Principal Investigator and Radio Science Team Leader auspices.

3.2 Validation and Delivery

Validation of level 0 science packets and SPICE files will be an intrinsic part of standard product generation. Validation of standard products will be done in part during analysis of the data. However, a key additional requirement is the validation of archive volumes for integrity of scientific content, file structures (e.g., do the files conform to Software Interface Specification documents?), directory structures, compliance with PDS standards, and integrity of the physical media used to transfer the data set collections. This validation will be overseen by the Science Operations Team through its Science Data Validation Team.

The Science Data Validation Team will consist of a Team Chief, the Interdisciplinary Scientist for Data and Archives, Experiment Representatives, PDS Mission Interface Team Representative, the Multimission Ground Data System Data Base Administrator, and a representative from each Science Team. These personnel will work with the Principal Investigators and the Radio Science Team Leader, examining volumes and generating reports that delineate problems.

The Science Operations Team will have veto power on whether given archive volumes are ready for transfer to the PDS. Errors, if minor, may simply be documented. Large errors would require corrections and regeneration of the respective volumes. If given volumes pass validation, then the Principal Investigator or Radio Science Team Leader would transfer the archives to the PDS, based on the release schedule given in Section 5 of this Plan.

Final validation will take place under PDS auspices as a check of archive volumes before release to the planetary community. Problems due to obvious errors in science, missing files, and inadequate documentation will be referred back to the MGS Project for correction, although it is expected that such referrals will be highly unusual because of the work of the Science Teams and the Science Data Validation Team. A fundamental aspect of the release schedule is that level 0 science packets, SPICE files, and algorithms/software generating levels 1 to 3 data products are released at the same time as reduced data records generated from the relevant science packet data.

4.0 ROLES AND RESPONSIBILITIES

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

4.1 Mars Global Surveyor

The Project Scientist and the Project Science Group (Project Scientist, Team Leaders, Principal Investigators, and Interdisciplinary Scientists) provide an oversight function for implementation of the Archive Generation, Validation, and Transfer Plan. The MGS Interdisciplinary Scientist for Data and Archives, with input from the SDVT and the MGS Project Science Group, will advise the Project with regard to archiving and will work with MGS and the PDS to help ensure that detailed plans are in place for generation of Planetary Data System-compatible products and associated documentation, and that archive volumes are generated, validated, and transferred to the Planetary Data System.

MGS Data Administration will compile archive volumes containing engineering, level 0 science packets from spacecraft instruments, DSN monitor data, and SPICE files. The Radio Science Team Leader will produce the Radio Science level 0 archive collection. Principal Investigators are responsible for generation of reduced science data records, documentation, algorithms/software to generate levels 1 to 3 products, and archive volumes containing standard products and supporting information. The Radio Science Team Leader will not supply reduction software, but will instead provide documentation to explain how the processing is carried out. Table 7 lists the suppliers for each component of the archive collections. The author of each archive collection (and associated volumes) is responsible for publishing a Software Interface Specification document that delineates the format and content of the respective volumes. These SISs are due in final form by the time of orbit insertion. Generally, the relevant SIS is included on the archive volume.

Each Principal Investigator and the Radio Science Team Leader will also be responsible for posting a subset of reduced data (and relevant documentation) on a system accessible via the Internet for public access.

As discussed in Section 3.2, the Science Data Validation Team (SDVT) will be responsible for reviewing the initial archive volumes. Note that the Data and Archives Working Group (DARWG) discussed in the MGS Science Data Management Plan has been replaced by the SDVT.

The MGS Project will provide funds for production (e.g., premastering of CD-ROMs) and distribution of archive volumes for use by the MGS community.

4.2 Planetary Data System

The PDS is the designated point of contact for MGS on archive-related issues. The interfaces between the MGS teams and elements of the Planetary Data System are summarized in Table 8. The PDS is also the interface between MGS and the NSSDC.

The PDS, through its Mission Interface Team and with help from its Discipline Nodes, will work with the SDVT and other MGS elements to ensure that the MGS archives are compatible with PDS standards and formats. The PDS will provide funds for generation, distribution, and maintenance of MGS archives volumes for the NASA-supported science community after the volumes have been released by MGS.

4.3 National Space Science Data Center

The National Space Science Data Center will maintain a "deep archive" of MGS data for long-term preservation and for filling large delivery orders to the science community. The PDS will deliver copies of MGS archive volumes to NSSDC.

5.0 ARCHIVE GENERATION, VALIDATION, AND RELEASE SCHEDULES

5.1 Postings for Outreach and Education

It is expected that each Principal Investigator and the Radio Science Team Leader will develop a World-Wide Web site for his instrument or experiment. This site will be operational by the time of launch and will have pointers to the MGS Project Web site and to the other MGS instrument/experiment sites. Within a month after start of mapping operations, each of the instrument/experiment Web sites will provide access to reduced data and documentation that illustrate exciting results from the observations. Updates to the postings of reduced data and documentation will be done at least once per week when new data are being acquired.

For MOC, a large subset of images will be posted. For TES, selected spectra will be displayed, along with maps depicting derived parameters such as composition of the surface. MOLA postings will include along track elevation data and maps depicting surface elevations. MAG/ER postings will be similar in form to those for MOLA. The Radio Science postings will include atmospheric temperature, pressure profiles and gravity vector and map-oriented presentations.

5.2 Archive Volumes for Science Community Use

As discussed above, standard products will be generated in systematic manners during the course of the Mapping Phase of the mission. These products will be used for analyses and some will be posted for education and outreach. A final and important purpose for the standard products is to provide the research community with the best derived data for their analysis. Table 9 lists the standard products, the number of cycles worth of data to be included in the products, the number of times the products will be issued, and data volumes for the Mapping Phase. Also included are the processing levels for each product, using level definitions provided in Appendix III.

The standard products are the core data sets for archive volumes to be delivered to the PDS. Further, all raw data and SPICE files used to generate the standard products will be released to the PDS at the same time that the standard products are released.

In the MGS Science Data Management Plan it is assumed that standard products (and associated raw data and SPICE files) will be delivered to the PDS six months after receipt of the last raw data used in generating the standard products. For the Mapping Phase of the mission the instrument teams will follow this six month guideline (Figure 1).

An MGS Sampler archive volume was generated and released to the PDS on 1998-07-01, largely using data sets acquired during the Assessment Subphase of the Orbit Insertion Phase of the mission. This volume, published as a CD-ROM, contains a mix of special and standard products and is meant to provide the community with initial data sets for use in planning proposals and research efforts.

Data acquired up to and including the first period of Science Phasing Orbits (SPO-1) will be archived with the PDS by approximately 1998-12-01 and data acquired through the end of SPO-2 will be archived by approximately 1999-04-01. Accelerometer data from Aerobraking Phase 2 will be archived by 1999-07-01 (see figure 1 for details). The intent is to produce, validate, and release standard products generated from observations acquired during each of these phasing periods.

The first delivery of archives to the PDS from the Mapping Phase will take place approximately six months after start of mapping (i.e. six months after 1999-04-01). This will be followed by a delivery every six months. The last data acquired at the end of the mapping phase will be delivered at the end of the analysis phase, 2001-09-30. Using this schedule and the data given in Table 9, it is possible to generate size estimates for delivery of archive volumes to the PDS (Table 10).

During the period between receipt of data and delivery of archive volumes to the PDS, standard products will be generated and validated, archive volumes will be assembled and placed on relevant media (e.g., CDs), and the volumes will be validated.

MGS Mission Timeline

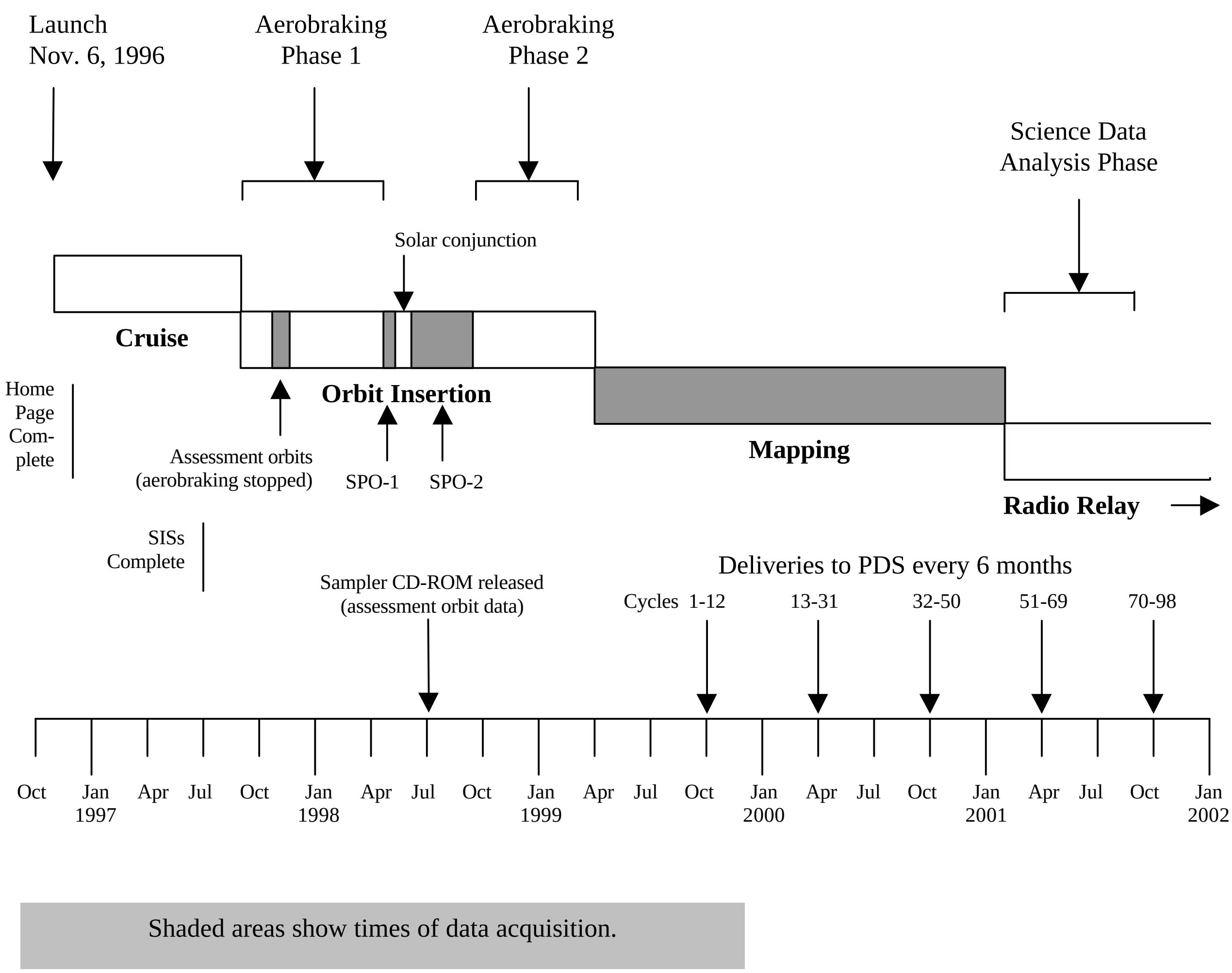

Figure 1. Timeline showing MGS mission activities and archive volume deliveries to the PDS. The first delivery of data from the Mapping Phase will be six months after start of mapping and will consist of data from the first 12 mapping cycles. Deliveries will then take place every six months and consist of data from subsequent mapping cycles. The last delivery will occur on September 30, 2001, at the end of the Science Data Analysis Phase. After the Mapping Phase of the mission, MGS acts as a radio relay for lander missions until January 1, 2003, the nominal end-of-mission.

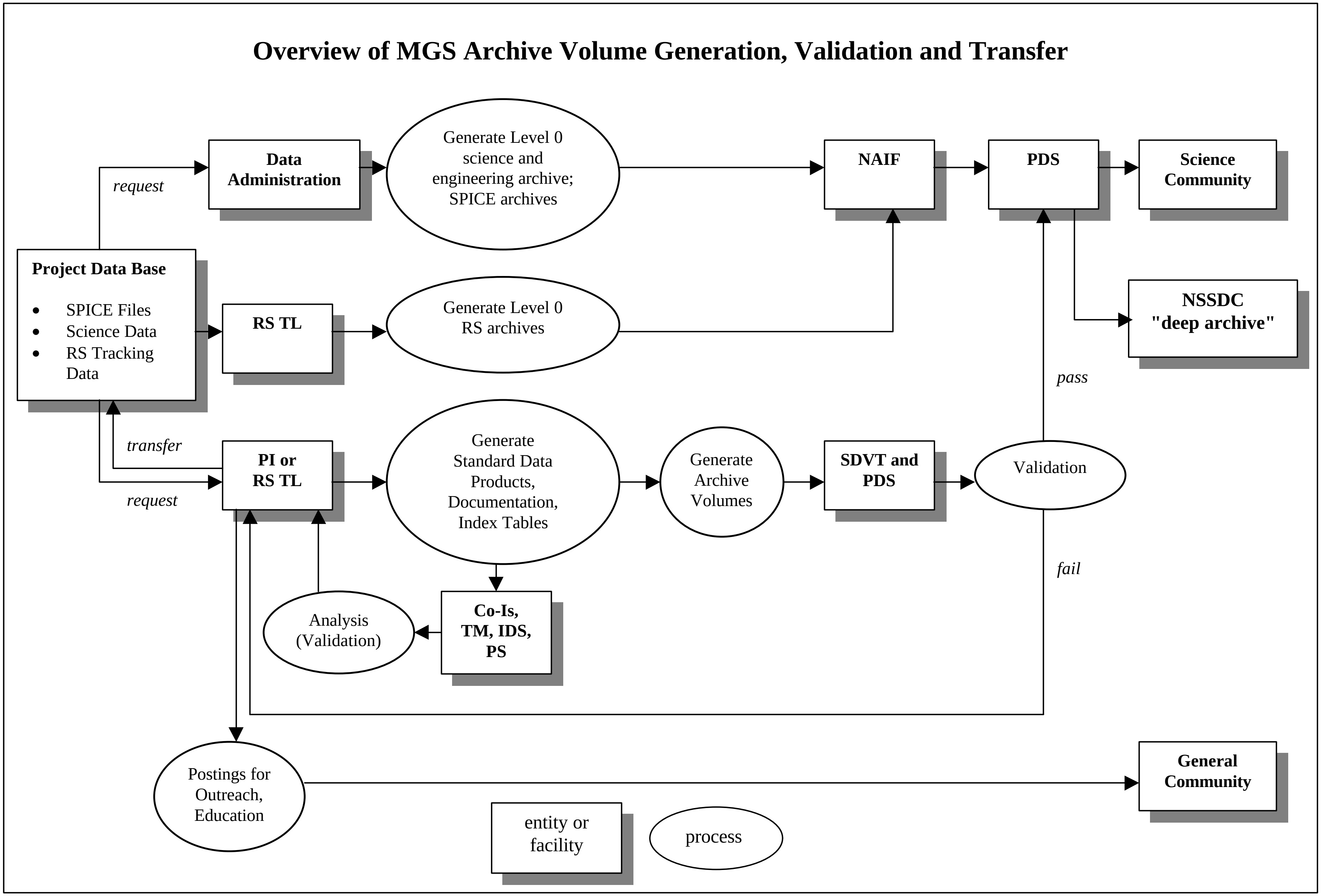

Figure 2. Flow of MGS archive volume generation, validation, and transfer. Also shown is posting of reduced data for outreach and education.

TABLE 1. MGS Mission Phases

Phase Name	**Start date**	**End date**	**Start orbit**	**End orbit**
Prelaunch Phase	1994-10-12	1996-11-06		
Launch Phase	1996-11-06	1996-11-07		
Cruise Phase	1996-11-07	1997-09-12		
Inner Cruise Subphase	1996-11-07	1997-01-09		
Outer Cruise Subphase	1997-01-09	1997-09-12		
Orbit Insertion Phase	1997-09-12	1999-02-08	1	TBD
Aerobraking Phase 1A	1997-09-12	1997-10-12	1	18
Aerobraking Hiatus	1997-10-13	1997-11-07	19	36
Aerobraking Phase 1B	1997-11-08	1998-03-27	37	201
Science Phasing Orbit 1 (SPO-1)	1998-03-27	1998-04-28	202	268
Solar conjunction	1998-04-29	1998-05-27	269	328
Science Phasing Orbit 2 (SPO-2)	1998-05-28	1998-09-23	329	573
Aerobraking Phase 2	1998-09-24	1999-02-08	574	TBD
Transition to mapping	1999-02-09	1999-03-31		
Mapping Phase (687 days)	1999-04-01	2001-02-16		
Radio Relay Phase	2001-02-16	2003-01-01		

TABLE 2. Mars Global Surveyor Instruments

NASA MAG/ER (Magnetometer/ Electron Reflectometer)	Up to 16 magnetic field vectors per second. Electron reflectometer will determine electron pitch angle distribution, field strength, altitude dependence of field. Continuous operation.	Mario Acuña, Goddard Space Flight Center
MOC (Mars Orbital Camera)	Wide angle imaging able to generate global map in one Sol with 7.5 km/pixel resolution. Wide angle for regional imaging with 250 m/pixel resolution at nadir. Global imaging using blue or red filters. Narrow angle (NA) cross track widths with 1.4 m/pixel. NA images are accompanied by simultaneously acquired WA context images.	Michael Malin, Malin Space Science Systems, Inc.
MOLA (Mars Orbital Laser Altimeter)	Distances from spacecraft to nadir surface locations with vertical resolution of several meters. Surface reflectivity at 1.06 micrometer from backscattered power. Operates continuously at 10 pulses/second.	David Smith, Goddard Space Flight Center
TES (Thermal Emission Spectrometer)	Emitted radiance from 6.25 to 50 micrometer from surface and atmosphere with 10 cm^{-1} (apodized) resolution; Solar radiance from 0.3 to 3.9 micrometers; Broadband radiance from 0.3 to 100 micrometers. Three kilometer field of view at nadir. Nadir observations; fore and aft surface observations to vary emission angle; limb observations.	Philip R. Christensen, Arizona State University
RS (Radio Science)	Radio occultation measurements of polar atmosphere to obtain profiles of refractive index, number density, temperature, and pressure for lowest several scale heights. Atmospheric scintillation measurements will also be obtained. Radio tracking of spacecraft for information on gravitational field. Orbital decay due to air drag by analysis of spacecraft orbital evolution.	G. Leonard Tyler, Team Leader, Stanford University
ACCEL (Accelerometer)	Atmospheric density measurements obtained during aerobraking.	G.M. Keating, George Washington University at NASA Langley Research Center

TABLE 3. Interdisciplinary Scientists

R. E. Arvidson Washington University	Data Management and Archiving
M. Carr United States Geological Survey	Geosciences
A. Ingersoll California Institute of Technology	Polar atmospheric science
B. Jakosky University of Colorado	Surface-atmospheric science
R. Haberle Ames Research Center	Climatology
L. Soderblom United States Geological Survey	Surface processes and geomorphology

TABLE 4. Total Data Volume per Instrument to be acquired during mapping phase of mission

Data Returned (S&E 1) in Gbits	
MAG/ER	50.6
MOLA	36.7
TES	70.9
MOC	315.1
Data Returned (S&E 2) in Gbits	
TES	25.1
MOC	147.3
Radio Science Data in Gbits	
Occultations	330
Tracking	66
Totals	
MAG/ER	50.6
MOLA	36.7
TES	96.0
MOC	462.4
RS	396
ACCEL.	0.4
Total	1042.1 or approximately 130.3 Gbytes

Notes: Sum equivalent to approximately 200 CD-ROMs

RS data estimate from Richard Simpson, Stanford University

Other data from MGS Project 9/19/95

S&E = science and engineering

TABLE 5. Standard Data Products To Be Produced From Mapping Phase Observations

Magnetometer/ Electron Reflectometer	Time Series Data (MAG-TSD) Orbital Map (MAG-OM)
Mars Orbital Camera	Narrow Angle Standard Data Product (MOC-NA-SDP) Wide Angle Standard Data Product (MOC-WA-SDP) Global Map Image (MOC-GMI)
Mars Orbital Laser Altimeter	Aggregated Experiment Data Record (MOLA-AEDR) Precision Experiment Data Record (MOLA-PEDR) Initial Experiment Gridded Data Record (MOLA-IEGDR) Mission Experiment Gridded Data Record (MOLA-MEGDR)
Radio Science	Occultation Summary File (RS-OCCSUM) Atmospheric Temperature-Pressure Profiles (RS-TP) Intensity Power Spectra From Atmospheric Scintillations (RS-IPS) Line-of-sight Acceleration Profiles (RS-LOSAPDR) Spherical Harmonic Models of Gravity Field (RS-SH) Radio Science Digital Maps (RS-DM)
Thermal Emission Spectrometer	Observational Parameters (TES-OBS) Global Derived Surface Property Maps (TES-GDSPM)
Accelerometer	Raw and derived products produced from data acquired during Aero-braking mission phases. Pertains to atmospheric parameters.

TABLE 6. Components of Mars Global Surveyor Archive Collections

SPICE Archive Collections

- SPICE Kernel Software Interface Specification Documents
- SPICE Kernels
- NAIF Software

Science Data Archive Collections

- High-level catalog mission, spacecraft, instrument, and data set collections, data set templates
- Software Interface Specification Documents
- Processing Descriptions, Algorithms, and Software (to use in understanding reduced data record generation)
- Instrument Calibration Reports and associated data needed to understand level 1 product generation
- Standard Data Products
    - Labels
    - Data Objects

Engineering and Level 0 Science Data Archive Collections

- Archive Collection and Volume Software Interface Specification Document
- Data Product Software Interface Specification Documents
- Science Packet Data Products
    - Labels
    - Data Objects
- Engineering Data Products
    - Labels
    - Data Objects

Radio Science Level 0 Data Archive Collection

- High-level catalog files
- Archive Collection and Volume Software Interface Specification Document
- Data Product Software Interface Specification Documents (as available)
- Original Data Stream Files
    - Labels
    - Data Objects
- Archival Tracking Data Files
    - Labels
    - Data Objects
- Orbit Data Files
    - Labels
    - Data Objects
- Ancillary Files

TABLE 7. Mars Global Surveyor Archive Collection Component Suppliers

Science Operations Team (SOT)

- Planetary Data System high-level catalog templates
- I Kernels
- E Kernel contributions---instrument specific
- Reduced Data Records
  - Standard Data Products
  - Special Data Products
  - Detailed-level catalog information in label keywords
  - Processing algorithms and software to go from level 0 to level 1 products
- Instrument calibration reports and associated data

Data Administration

- E Kernels
- Science packet data
- Engineering packet data
- Monitor data [RTOT(DSO)]
- SPICE file archives
- Engineering data archive files

Spacecraft Team (SCT)

- C Kernels
- Spacecraft Status Report
- Mission Controllers Real-Time Operations Log

Navigation Team (NAV)

- SP Kernels

Mission Planning and Sequencing Team (PST)

- Predicted Events File as input to the E Kernel
- Sequence of Events File as input to the E Kernel

Radio Science [SOT(RS)]

- Radio Science Files

All Teams

- Software Interface Specification documents

TABLE 8. Planetary Data System Responsibilities for Archiving Mars Global Surveyor Data

Planetary Data System Organization	Responsibility
Central Node/Mission Interface Team	Overall coordination with Mars Global Surveyor Project, including joint planning efforts.
Geosciences Node	Archive TES, MOLA, and RS gravity volumes.
Atmospheres Node	Archive RS occultation volumes, TES atmospheric volumes; Accelerometer volumes
Image Node	Archive MOC volumes.
NAIF Node	Archive SPICE Kernels; NAIF Toolkit; level 0 science instrument data packets and engineering data, including DSN monitor data; and Radio Science level 0 archive collection.
Plasma Interactions Node	Archive MAG/ER volumes.

TABLE 9. Types and Sizes of Standard Data Products To Be Produced From Mapping Phase Observations

MGS I/F ID	Description and Acronym	Data Type†	Data Level	Number of 7-sol cycles in product grouping	Size of product grouping (Mbytes)	Data set size (Mbytes)
SPAE017	Time Series Data (MAG-TSD)	TOV	1A	4	258.4	6,330.0
SPAE018	Orbital Map (MAG-OM-P)	GP	3	49	2.0	2.0
	Orbital Map (MAG-OM-F)	GP	3	98	2.0	2.0
SPAE020	Narrow Angle Standard Data Product (MOC-NA-SDP)	GP	1A	4	1,179.6	28,900.0
	Wide Angle Standard Data Product (MOC-WA-SDP)	GP	1A	4	1,179.6	28,900.0
SPAE023	Global Map Image (MOC-GMI)	GP	3	4	217.1	5,320.0
SPAE067	Aggregated Experiment Data Record (MOLA-AEDR)	TOV	0	4	218.7	5,359.0
SPAE026	Precision Experiment Data Record (MOLA-PEDR)§	TOV	1A	4	962.0	23,570.0
SPAE027	Initial Degree Experiment Gridded Data Record (MOLA-IEGDR)	GP	3	4	1.8	44.0
	Mission Experiment Gridded Data Record (MOLA-MEGDR)	GP	3	98	311.0	311.0
SPAE034	Atmospheric Temperature-Pressure Profiles (RS-TP)	TOV	3	4	242.0	5,928.0
SPAE070	Occultation Summary File (RS-OCCSUM)	TOV	N/A	4	0.6	14.0
SPAE038	Intensity Power Spectra (RS-IPS)	TOV	N/A	4	109.1	2,674.0
SPAE041	Radio Science Gravity Models, Spherical Harmonic Models (RS-SH)	GP	3	49	90.0	90.0
	Final Radio Science Gravity Models, Spherical Harmonic Models (RS-SH-F)	GP	3	98	90.0	90.0
SPAE044	Radio Science Digital Maps (RS-DM)¥	GP	3	49	6.0	6.0

MGS I/F ID	Description and Acronym	Data Type†	Data Level	Number of 7-sol cycles in product grouping	Size of product grouping (Mbytes)	Data set size (Mbytes)
	Final Radio Science Digital Maps (RS-DM-F)¥	GP	3	98	6.0	6.0
SPAE049	Line-Of-Sight Acceleration Profiles (RS-LOSAPDR)	TOV	2	4	45.5	1,114.0
SPAE052	TES Observational Parameters (TES-OBS)	TOV	1A	4	4,700.5	115,162.0
SPAE055	Global Derived Surface Property Map (TES-GDSPM)	GP	3	12	4.0	4.0
	Final Global Derived Surface Property Map (TES-GDSPM-F)	GP	3	98	50.0	50.0
	Total					247,869.0

† TOV: Time Ordered Vector; GP: Gridded Product; DAI: Documentation, Ancillary Information
§ Multiple versions will be produced; the final version will be in the permanent archive.
¥ Some Radio Science map products will have fewer cycles than shown in a product grouping.

Note: Level descriptions can be found in Appendix III.

TABLE 10. Summary of Archive Sizes (in Mbytes) For Each Delivery to the PDS

PDS Delivery	Delivery Date	Mapping Cycles	MAG/ER	MOC	MOLA	RS	TES	Total per Delivery
1	1999-9-30	1-12	775.7	7,728.9	6,522.8	1,215.1	14,108.1	30,350.7
2	2000-3-31	13-31	1,228.2	12,237.4	10,327.8	1,923.9	22,337.9	48,055.2
3	2000-9-30	32-50	1,228.2	12,237.4	10,327.8	1,923.9	22,337.9	48,055.2
4	2001-3-31	51-69	1,228.2	12,237.4	10,327.8	1,923.9	22,337.9	48,055.2
5	2001-9-30	70-98	1,874.6	18,678.2	15,763.5	2,936.5	34,094.6	73,347.5
Total			6,334.8	63,119.4	53,269.9	9,923.4	115,216.3	247,863.8

APPENDIX I — GLOSSARY OF SELECTED TERMS

Archive collection — A group of related data sets, supplemental data, software, and documentation that are logically linked to facilitate their use and administration. An example of an archive collection is the MGS MOLA Science Data Archive Collection.

Archive volume, **archive volume set—** A volume is a single unit of media on which one or more data sets are stored; e.g., one CD-ROM. When the data span multiple volumes, the group of volumes is called a volume set. The media supported by PDS are CD-ROMs and magnetic tape. Within each volume is a directory structure listing the subdirectories and files contained on that volume. Magnetic tapes have a "virtual" directory structure provided in a directory and file map included on the volume.

Data product, standard data product — A data product is a labeled grouping of data resulting from a scientific observation, usually stored in a single file. A product label identifies, describes, and defines the structure of the data. A standard data product is a reduced data record generated in a standard or predefined way using well-understood procedures, processed in "pipeline" fashion. Examples of a standard data product are a MOC narrow angle image, a Radio Science intensity power spectrum, and a MAG time series table. Data products that are generated in a nonstandard way are sometimes called special data products.

Data set- A logical grouping of data products; e.g., the set of all MOC narrow angle images, all RS power spectra, or all MAG time series tables.

High-level catalog — High-level descriptive information about mission, spacecraft, instrument, data sets, and related items. Catalog inputs derived from templates expressed in Object Description Language (ODL) which are suitable for loading into a catalog.

Reduced data record — A data product generated by processing raw science data to some level (see Appendix III for definitions of processing levels).

Science packets — Level 0 (raw) data for a given instrument in packetized form.

APPENDIX II — DESCRIPTIVE SUMMARY OF STANDARD DATA PRODUCTS

Below are brief descriptions of each of the MGS Standard Data Products. Each Standard Data Product is identified first by a MGS interface ID and is followed by a product acronym.

SPAE017 MAG-TSD

Vector magnetic field as a function of time along spacecraft orbit.

SPAE018 MAG-OM

Orbital altitude map of average magnetic field (components and magnitude). Plans include initial and final versions.

SPAE022 MOC-WA-SDP

Wide-angle image data of the following types of observations: regional mapping; limb observation; global mapping; or narrow angle context image.

SPAE020 MOC-NA-SDP

Narrow-angle image data containing high-resolution sampling or targeted narrow angle image.

SPAE023 MOC-GMI

Global map images. Plans include initial and final versions.

SPAE067 MOLA-AEDR

The MOLA Experiment Data Records (EDR) including both science and maintenance mode data packets aggregated by Mars Global Surveyor orbit.

SPAE026 MOLA-PEDR

Time series, along track MOLA data science mode data in geophysical units. A record contains range, orbit data (time, latitude, longitude, areocentric distance), elevation, relative pulse energy, and match filter number. Includes engineering and housekeeping data.

SPAE027 MOLA-IEGDR

Initial MOLA corrected profile data mapped to a 5x5-degree grid. The cells shall contain elevation, height variance, and relative reflectivity. Also, a data density per grid cell shall be given.

SPAE027 MOLA-MEGDR

MOLA corrected profile data for the entire mission, mapped to a 0.25 x 0.25-degree grid. The cells shall contain elevation, height variance, and relative reflectivity. Also, a data density per grid cell shall be given.

SPAE070 RS-OCCSUM

Occultation summary file covering approximately one-month periods of observations. Will include observing conditions, temperature, pressure, occultation radius, column content, and pointer back to T-p profile files, i.e., to RS-TP files.

SPAE034 RS-TP

(a) Atmospheric temperature and pressure vs. altitude near each occultation point at approximately 200 m vertical resolution over 0-100 km.

(b) Atmospheric temperature and pressure vs. altitude near each occultation point at approximately 10-20 m vertical resolution over 0-100 km.

SPAE038 RS-IPS

Intensity power spectra from spectral analysis of atmospheric scintillations in radio occultation data.

SPAE049 RS-LOSAPDR

Line of sight acceleration profiles, giving the component of spacecraft acceleration along Earth-Mars line as a function of spacecraft position in its orbit.

SPAE041 RS-SH

Spherical harmonic expansions of gravity field:

(a) ASCII files containing coefficients

(b) Binary file equivalents, with covariance terms

SPAE044 RS-DM

Maps showing Bouguer, isostatic, and free air anomalies

SPAE052 TES-OBS

Raw, calibrated and atmosphere corrected radiance observations produced by the TES instrument, stored in time series format. Includes up to 143 spectrometer channels, plus 1 solar albedo channel and 1 thermal bolometric channel for each IFOV. Also included for each observation are the instrument state parameters and observing geometry. Where it is possible to derive them, the following surface and atmospheric properties are also included: surface radiance, surface temperature, surface pressure, thermal inertia, atmospheric opacity, single scattering albedo, dust column density and pressure-temperature profile.

SPAE055 TES-GDSPM

TES derived surface properties maps, including principal component unit maps, surface composition based on Project-agreed algorithm, thermal inertia, albedo, rock abundance, and surface frost occurrence. Plans include initial and final versions.

SPAE061 ACCEL

Raw data include accelerometer counts, quaternions, rates, and thruster on times. Derived products include the following areophysical parameters at 1 second resolution: atmospheric density, latitude, longitude, local solar time, altitude and I_S. Reports from the Thruster are at an 8 second resolution. Additional derived products include inbound and outbound density at constant altitude and the corresponding quantities: density scale height, estimated temperature, estimated pressure and standard deviation of fit. Also included are periapsis density and maximum density with corresponding quantities: dynamic pressure, scale height, temperature and standard deviation of fit.

APPENDIX III — DEFINITION OF PROCESSING LEVELS FOR SCIENCE DATA SETS

LEVEL 0 — Instrument science packets (e.g., raw voltages, counts) at full resolution, time ordered, with duplicates and transmission errors removed. Corresponds to Space Science Board's Committee on Data Management and Computation (CODMAC) Edited Data (see National Academy press, 1986).

NOTE: Following levels correspond to Reduced Data Records and may correspond to Standard or Special Data Products.

LEVEL 1A — Level 0 data which 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). Corresponds to CODMAC Calibrated Data.

LEVEL 1B — Irreversibly transformed (e.g., resampled, remapped, calibrated) values of the instrument measurements (e.g., radiances, magnetic field strength). Corresponds to CODMAC Resampled Data.

LEVEL 1C — Level 1A or 1B data, which 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). Corresponds to CODMAC Derived Data.

LEVEL 2 — Geophysical parameters, generally derived from Level 1 data, and located in space and time commensurate with instrument location, pointing, and sampling. Corresponds to CODMAC Derived Data.

LEVEL 3 — Geophysical parameters mapped onto uniform space-time grids. Corresponds to CODMAC Derived Data.