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Mars Program

Mars Science Laboratory Mission 2009 Landed Science Payload

DRAFT

Proposal Information Package

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1. INTRODUCTION AND DOCUMENT OVERVIEW

This document describes the current best estimate of the capabilities and resources the Mars Science Laboratory (MSL) landed mission intends to provide to science instrument payloads, and supplies science instrument proposers that data necessary to propose viable payloads for this mission. The information in this document is based on conceptual designs (at this writing, approximately two years prior to the project preliminary design review (PDR)). To be considered viable for this rover opportunity, proposed payloads should meet the technical and programmatic constraints and requirements described herein. This document describes the science instrument payload interfaces and spacecraft capabilities for International and NASA Code S (Space Science), Code U (Office of Biological and Physical Research) and Code M (Human Exploration and Development of Space) Science Instrument Payloads. Proposers should appreciate that actual capabilities of the landed mission may ultimately be less than or greater than described here. The MSL science instrument accommodations described in this document conform to the programmatic constraints specified in the Announcement of Opportunity. Should there be an inadvertent conflict between this Proposal Information Package (PIP) and the Announcement of Opportunity (AO), the AO shall take precedence.

1.1 POTENTIAL USE OF RADIOISOTOPE POWER SUPPLIES

Radioisotope Power Supplies (RPS) are being considered as a power system option for the MSL mission. Even though the final decision will not be made until after Science Investigation selection, investigations proposed against this opportunity must accommodate environmental requirements implied by such selection.

The system designs presented herein represent a pre-decisional draft mission option that is being considered by the Project at this time. For the purpose of creating investigation concepts in response to this Solicitation, these systems designs should be assumed.

1.2 DOCUMENT STRUCTURE

Section 2, General Mission Description, provides a general overview of the mission and spacecraft, and gives the mission context in which Payload activities will occur.

Section 3, Accommodations & Constraints Imposed by Mission and Rover Design, describes the payload resources and constraints imposed by the mission and spacecraft design.

Section 4, Mission Scenarios, describes what is to be done.

Section 5, Mission Operations Systems, describes how it will be done.

Section 6, Ground Data Systems, describes what tools will be used to get it done.

Section 7, Science/Payload Management describes the science and payload management responsibilities, schedules, reviews and deliverables for the science instruments and investigations.

Section 8, Mission Assurance, describes Mission Assurance and Quality Assurance (QA) requirements.

Section 9, Post-Delivery Hardware Support, describes Assembly, Test and Launch Operations (ATLO), including testbed facilities and activities.

Section 10, Cost Guidelines, describes cost guidelines and reserve strategy.

1.3 MISSION PURPOSE AND SCOPE

The Mars Science Laboratory (MSL) will launch a rover to a single location on Mars in the October - November 2009 launch opportunity as a part of the National Aeronautics and Space Administration (NASA) Office of Space Science (OSS) Mars Exploration Program. MSL will conduct a Mars Habitability investigation, with habitability defined as the "capacity of the environment to sustain life", i.e., the potential of a given environment to support life at some time, past or present. The specific objective and investigations are:

Objective:

Explore and quantitatively assess a potential habitat on Mars.

Investigations:

(A) Assess the biological potential of at least one target environment identified prior to MSL, or discovered by MSL.
   1. Determine the nature and inventory of organic carbon compounds
   2. Inventory the chemical building blocks of life (C, H, N, O, P, S)
   3. Identify features that may represent the effects of biological processes

(B) Characterize the geology and geochemistry of the landing region at all appropriate spatial scales.
   1. Investigate the chemical, isotopic, and mineralogical composition of martian surface and near-surface geological materials
   2. Interpret the processes that have formed and modified rocks and regolith

(C) Investigate planetary processes of relevance to past habitability including the role of water
   1. Assess long-timescale (i.e., 4-billion-year) atmospheric evolution processes
   2. Determine present state, distribution, and cycling of water and CO_2

(D) Characterize the broad spectrum of surface radiation, including galactic cosmic radiation, solar proton event, and secondary neutrons.

The objective and investigations were developed by NASA in part from the work of the MSL Project Science Integration Group (PSIG). The final report of the PSIG can be obtained from the URL http://mepag/reports/PSIG_Final_Full_Report4.ppt. This final report provides additional detail down to measurement suggestions for some investigations.

The mission will focus on a roving, long-duration science laboratory that will provide a quantitative improvement in surface measurements and pave the way for future martian surface and sample return missions. The flight system will also demonstrate the technology for accurate landing and may utilize technology for large feature hazard detection and avoidance in order to reach promising but otherwise difficult to access landing sites. This assessment of habitability is to be made through multidisciplinary measurements related to biology, climatology, geology and geochemistry in terrain which may include (depending on the site selected) sedimentary, hydrothermal, ancient and/or ice-bearing deposits.

1.4 APPLICABLE DOCUMENTS

The following list summarizes documents, or specific portions thereof, that are an integral part of the Proposal Information Package and are applicable to the MSL Science Instrument Payloads and Investigations, as applicable specified within the body of this document.

Applicable Document	Doc ID Number	PIP Ref	Web Location
Announcement of Opportunity	[TBS]	1.1	[TBS]
Digital Time Division Command/Response Multiplex Date Bus	MIL-STD-1553B	3.4.3	http://centauri.larc.nasa.gov/msl/pip/MIL-STD-1553B-Base.pdf
Biological Contamination Control for Outbound and Inbound Planetary Spacecraft, February 19, 1999	NPD 8020.7E	3.5	http://nodis3.gsfc.nasa.gov/library/displayDir.cfm?Internal_ID=N_PD_8020_007E_&page_name=main
Planetary Protection Provisions for Robotic Extraterrestrial Missions, Rev. B, April 16, 1999	NPG 8020.12B	3.5	http://nodis3.gsfc.nasa.gov/library/displayDir.cfm?Internal_ID=N_PG_8020_012B_&page_name=main
JPL Institutional Parts Program Requirements, March 2003	JPL-D-20384	8.1.2	http://centauri.larc.nasa.gov/msl/pip/D-20384_JPL-IPPR.doc
Instructions for EEE Parts Selection, Screening, Qualification, and Derating (Supercedes NASA GSFC 311-INST-001)	NASA GSFC EEE-INST-002	8.1.2	http://centauri.larc.nasa.gov/msl/pip/EEE-INST-002.pdf
General Specification for Semiconductor Devices	MIL-PRF-19500	8.1.2	http://centauri.larc.nasa.gov/msl/pip/MIL-PRF-19500.pdf
Qualified Products List of Products Qualified under MIL-PRF-19500, General Specification for Semiconductor Devices	QML-19500	8.1.2	http://centauri.larc.nasa.gov/msl/pip/QML-19500.pdf
General Specification for Hybrid Microcircuits	MIL-PRF-38534	8.1.2	http://centauri.larc.nasa.gov/msl/pip/MIL-PRF-38534.pdf
General Specification for Microcircuits	MIL-PRF-38510	8.1.2	http://centauri.larc.nasa.gov/msl/pip/MIL-M-38510.pdf
General Specification for Integrated Circuit (Microcircuit) Manufacturing	MIL-PRF-38535	8.1.2	http://centauri.larc.nasa.gov/msl/pip/MIL-PRF-38535.pdf
Qualified Manufacturers List of Custom Hybrid Microcircuits Manufactured to the Requirements of MIL-PRF-38534	QML-38534	8.1.2	http://centauri.larc.nasa.gov/msl/pip/QML-38534.pdf
Qualified Manufactures List of Integrated Circuit (Microcircuits) Manufactured to the Requirements of MIL-PRF-38535	QML-38535	8.1.2	http://centauri.larc.nasa.gov/msl/pip/QML-38535.pdf
Plastic Encapsulated Microcircuits (PEM's) Reliability/ Usage Guidelines for Space Applications	JPL D-19426	8.1.2	http://centauri.larc.nasa.gov/msl/pip/JPL_D-19426.pdf
JPL Software Development Requirements	JPL D-23713	8.2.2	[LINK TO BE SUPPLIED]
JPL Design Principles	JPL D-17868	8.2.2	http://standards.jpl.nasa.gov/contractor/d17868-2.html

1.5 REFERENCE DOCUMENTS

The following list summarizes documents, or specific portions there of, that are referenced within this document. Relevance is specified within the body of this document.

Reference Document	Doc ID Number	PIP Ref	Web Location
Reliability Analyses Handbook	JPL D-5703	8.1.1	http://acquisition.jpl.nasa.gov/rfp/OVWM_TWTA/exhibit1/D-5703.pdf
MSL Mission Assurance Plan	JPL D-xxxxx	8.0	INITIAL RELEASE WILL BE AVAILABLE TO SUPPORT AO
MSL Environmental Requirements Document	JPL D-21382	8.1.4	INITIAL RELEASE WILL BE AVAILABLE TO SUPPORT AO
MDS Overview, August 6, 2002		2.3	http://centauri.larc.nasa.gov/msl/pip/MDS_Tour_020806.pdf
Mars Global Reference Atmosphere Model (MarsGRAM) 2002 Version by C.G. Justus and D.L. Johnson (User guide, NASA/TM-210961, April 2001	NASA/TM-210961	3.6.2	http://trs.nis.nasa.gov/archive/00000549/
"Environment of Mars, 1988", October 1988	NASA-TM-100470	3.6.2	http://ntrs.nasa.gov/
"A Revised Thermosphere for the Mars Global Reference Atmospheric Model (MarsGRAM 1996)	NASA-TM-108513	3.6.2	http://ntrs.nasa.gov/
Sand and Dust on Mars, February 1991	NASA-CP-10074	3.6.2	http://ntrs.nasa.gov/
MSL Project Science Integration Group Final Report, May 2003			http://centauri.larc.nasa.gov/msl/pip/PSIG_Final_Full_Report4.pdf
JPL Flight Hardware Logistics Website		7.6	http://fhlp.jpl.nasa.gov
An Introduction to Space Radiation Effects on Micro-electronics - L.D. Edmonds	JPL Pub 00-06 May 2000	3.7.2, 8.1.2	http://centauri.larc.nasa.gov/msl/pip/JPL_00-06.pdf
Organic Contamination Science Steering Group Report		3.6.1	INITIAL RELEASE WILL BE AVAILABLE TO SUPPORT AO
COSPAR Planetary Protection Policy (20 October 2002)			http://centauri.larc.nasa.gov/msl/pip/COSPAR_PPPolicy.pdf

2. GENERAL MISSION DESCRIPTION

This section provides a general overview of the mission and spacecraft, and gives the mission context in which Payload activities will occur.

2.1 MISSION

The phases of the MSL mission are defined in Table 2.1.

Table 2.1: MSL Mission Phases

Mission Phase	Start of Phase	End of Phase
Pre-Launch	Spacecraft delivery to KSC	Terminal Countdown L – 3 hours
Launch / Injection (Oct. - Nov. 2009)	Terminal Countdown	Separation
Cruise - Near Earth - Earth-Mars Transfer	End of Launch/Injection - Separation - TCM_1 plus 1 day	~ 125 km altitude - TCM_1 plus 1 day - EDL minus 45 days
Approach	EDL minus 45 days	~ 125 km altitude
EDL (Entry Descent & Landing) (Aug. - Dec. 2010)	End of Cruise	Landing
Surface Operations / Primary Mission	Landing	Primary Mission: Landing + 670 sols (one Mars year, 687 Earth days) Minimum Mission: Landing + 335 sols (343 days)
Data Analysis, Validation & Archive Closeout Period	End of Surface Operations Primary Mission	End of Surface Operations Primary Mission + 6 months
Surface Operations Extended Mission (not currently funded)	End of Primary Mission	End of Rover Useful Life, or End of Ops Funding (whichever comes first)

2.1.1 Pre-Launch

Pre-launch phase covers all activity at Kennedy Space Center (KSC) prior to terminal countdown, and includes final spacecraft assembly, functional testing and encapsulation in the Payload Fairing, Radioisotope Power System (RPS) and Radioisotope Heater Units (RHU) installation, final removal of "Red Tag" remove-before-flight items, and configuring for launch. Pre-launch phase payload activities will be limited and there is no project requirement for continuous on-site Principle Investigator (PI) support of the pre-launch activities.

2.1.2 Launch / Injection

Launch/Injection phase includes terminal countdown, launch and final stage separation. The MSL rover will launch from the KSC Eastern Test Range, with a 20-day launch period, opening as early October, 2009 and closing in November, 2009. The launch vehicle is expected to be from either the Delta IV or Atlas V families. Payload Science Instruments will be in a power-off state during the Launch / Injection phase.

2.1.3 Cruise

The cruise phase begins when the spacecraft separates from the launch vehicle and ends prior to entry, descent and landing (EDL). The cruise phase lasts approximately 10 to 14 months, depending on the launch date and landing site selection. The rover is enclosed inside the aeroshell during cruise.

The cruise phase is subdivided into three sub-phases as shown in Table 2.1. Major activities performed in the near-Earth subphase include initial acquisition of the spacecraft signal by the Deep Space Network (DSN), initiation of the nominal cruise attitude profile, checkout of the spacecraft engineering functions, and the first trajectory correction maneuver (TCM-1).

The Earth-Mars transfer sub-phase extends from one day following TCM-1 to 30 days prior to arrival at Mars. Routine spacecraft health checks and required TCMs will be performed during the Earth-Mars transfer.

2.1.4 *Approach*

The Mars approach phase begins approximately 45 days prior to landing and includes one or two TCMs for navigational purposes. The approach phase ends when the vehicle has entered the martian atmosphere at an altitude of 125 km.

The cruise stage itself will not have a dedicated flight computer or relay capability, and will utilize the stowed rover's flight computer and relay capability.

Payload Science Instruments will have several opportunities for aliveness/health checks and configuration/ resource constrained calibration activities over the course of the Earth-Mars Transfer sub-phase, as discussed in Section 4.2 and Section 5.4 of this document. Aside from these activities, the Payload Science Instruments will be in a power-off state during the cruise phase.

2.1.5 *Entry, Descent, and Landing (EDL)*

The EDL phase begins at altitude of 125 km, and ends with a soft touchdown of the rover on the surface and sky-crane upper stage flyaway. The landing date at Mars varies with launch date and landing site, and ranges from May 19, 2010 to not later than December 16, 2010. The 'not later than' date is driven by a requirement to complete EDL at least 30 days prior to the loss of communications associated with solar conjunction (1/15/11 - 2/27/11). Figure 2.1.5a shows the Earth-Mars relative positions and Mars L_s at landing.

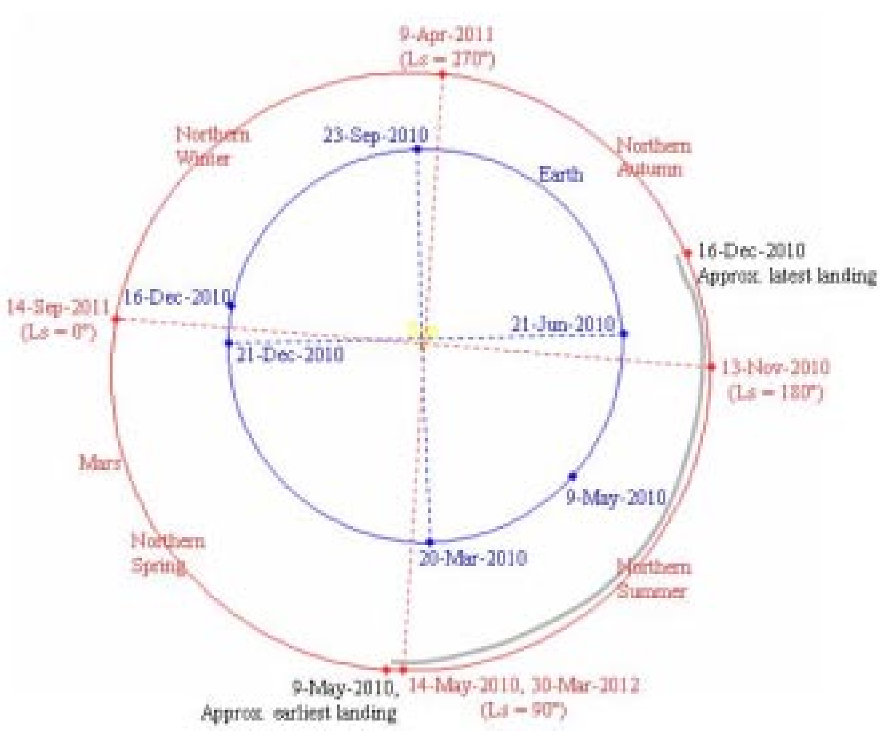


Figure 2.1.5a: MSL Landing Dates - Earth & Mars Orbits/Relative Positions

A final trajectory correction maneuver will be performed prior to atmospheric entry. Separation of the cruise stage from the entry vehicle will occur prior to entry. The landed mission spacecraft will enter the Mars atmosphere directly from its interplanetary trajectory, without first capturing into orbit about Mars. Aeromaneuvering will be performed during the hypersonic portion of atmospheric flight in order to reduce the landing site errors that result from atmospheric variations. Following parachute deployment, heatshield will be released, the mobility system deployed and the landing radar initiated. The descent stage and rover will be released from the backshell about 600 m above the surface and the terminal descent engines will be fired to slow the descending vehicle. At 5 m over the landing site, the vehicle will hover and the rover will be lowered on a tether/umbilical line for a wheels-down soft landing (less than 1 m/s) on the martian surface. The tether connecting the upper stage and the rover will be released, and the upperstage with tether attached will perform a fly-away to a hard landing a safe distance away from the rover. The descent and landing sequence described above is illustrated in figures 2.1.5b and 2.1.5c. Landing accuracy is expected to be within 10 km of targeted site (or, 10 x 5 km 3-sigma ellipse, with major axis in along-track direction).

Payload Science Instruments will be in a power-off state during the Entry, Descent and Landing phase.

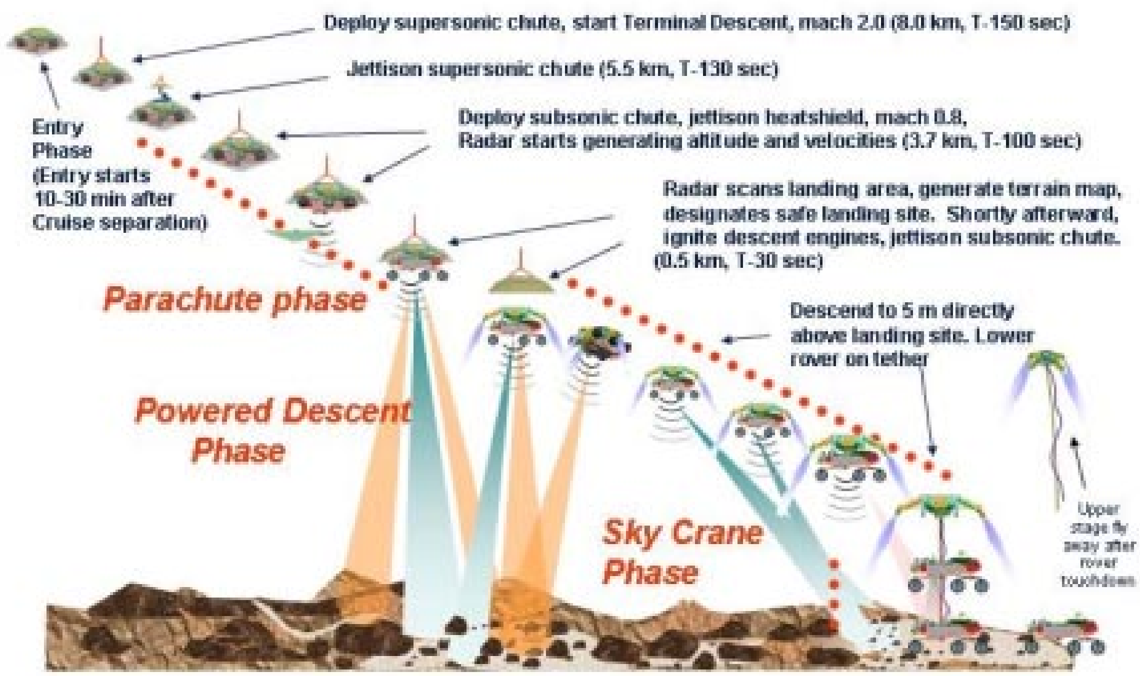


Figure 2.1.5b: Sky Crane Landing and EDL Configurations

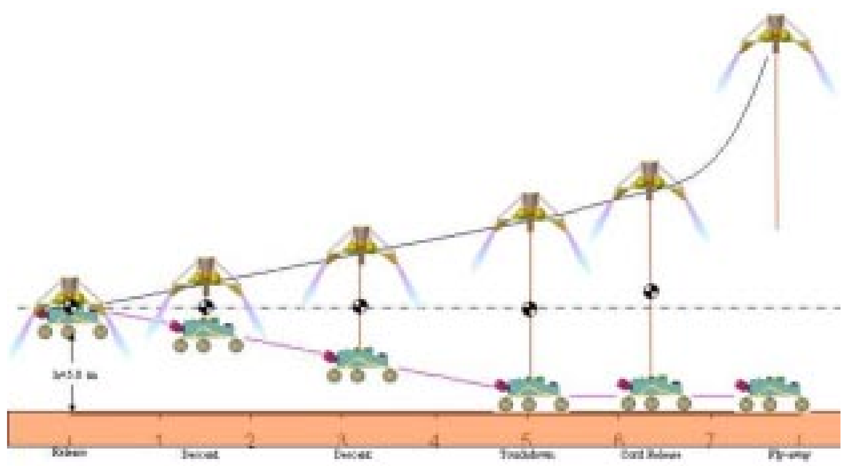


Figure 2.1.5c: Skycrane Hover - Rover Landing & Release - Skycrane Fly-away

2.1.6 Surface Operations/Primary Mission

Primary landed mission operations continue one Mars year, 670 sols (687 days). The landed mission begins after touchdown, with the mobility system already deployed. Initial landed operations include critical rover deployments, rover health checks, and establishment of communication with Earth. Critical deployments include high gain antenna, remote sensing mast (RSM) and release of launch lock constraints on arms. After the remote sensing mast has been deployed, the rover will image the landing site. These data, along with rover health telemetry, will have priority for data return. Science instrument health checks will be included in the early surface ops activities.

Nominal surface operations can be divided into five main types of activities. This division is intended as an aid to understanding the MSL surface activities and scenario-dependent resource allocations, and is not intended to exclude any type of investigation.

Traverse between at least three geologically distinct sites found within a landing-ellipse-sized area is anticipated during the mission. There is no requirement to traverse any specific distance, however in support of the goal to visit geologically distinct sites, the rover is expected to be capable of traversing several kilometers during the course of the mission.

The rover will downlink data to Earth utilizing available resources and assets, via Direct to Earth (DTE) or UHF-relay communication to orbiting satellites. Significant contributing factors to the total daily down link capability include specific location on Mars, Earth-Mars relative positions, and available orbital assets. The MSL mission data volume capability and science payload allocation within that capability is discussed in Section 3.2.5.4.

Five different Sol Templates describe the building blocks of the mission operations plan: Traverse and Approach, Site Reconnaissance (Remote Sensing Science), sample acquisition and sample preparation and handling (SA-SPAH) & Contact Science, Analytical Laboratory & Contact Science, and Recharge/Telecom. The Sol templates listed here define preliminary “types” of actives, and are a simplified version of the expected operation scenarios. They are a useful tool for understanding the interplay between operational scenarios and resource availability/allocations. It is understood that, in practice there is room for individual variation within each Sol Template.

(1) *Traverse and Approach.*

(2) *Site Reconnaissance (Remote Sensing).*

(3) *Sample Acquisition / Sample Processing & Handling and Contact/In situ Instrument Data collect.*

(4) *Analytical Laboratory & Contact Science*

(5) *Recharge / Telecom.*

The five Sol Templates are discussed in detail in Section 4.4.1.

2.1.7 End of Mission / Data Analysis, Validation & Archive Closeout Period

The Primary Mission ends at landing plus 670 sols. An extended mission may continue until the end of the Rover's useful life or end of ops funding, whichever comes first. Analysis, validation and archiving activities will continue for 6 months after the completion of the Primary Mission.

2.2 SPACECRAFT CONFIGURATION

2.2.1 Launch Configuration and Cruise Configuration

The rover configuration during the launch phase is shown in Figure 2.2.1a.

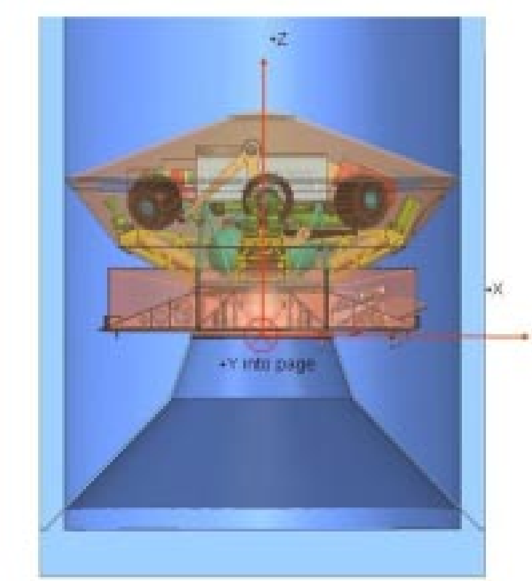


Figure 2.2.1a: MSL Launch Configuration Cruise Configuration

The rover remains in a fully stowed and locked configuration as shown in Figure 2.2.1b for the duration of the cruise phase. The cruise stage utilizes the rover's flight computer and power.

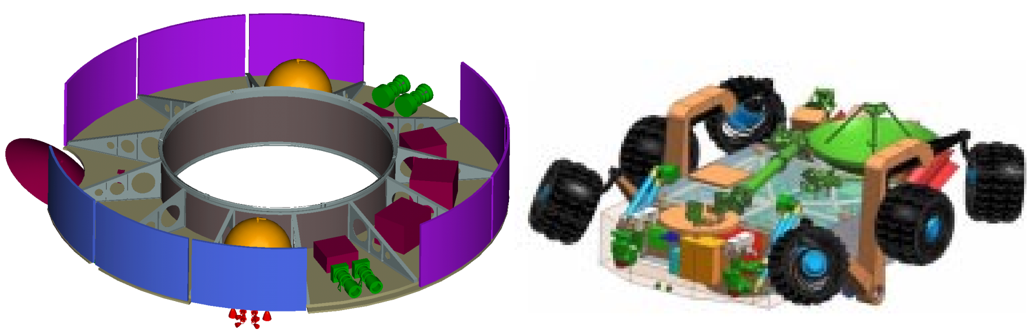


Figure 2.2.1b: MSL Cruise Stage and Stowed Rover Configuration

2.2.2 EDL Configuration

The sequence of spacecraft configurations that occurs during EDL are shown in Figures 2.1.5b and 2.1.5c.

2.2.3 Landed Configuration

General specifications for the MSL Rover are shown in Appendix B.

Figure 2.2.3 show the fully deployed rover and identifies the three main areas that have unique capabilities to accommodate science payload: the Remote Sensing Mast (RSM), the Sample Acquisition Arm, the Instrument Arm, and the Payload Module. Other locations on the rover have limited capability to carry science payload. Accommodation outside the three main areas may require instrument-unique accommodation.

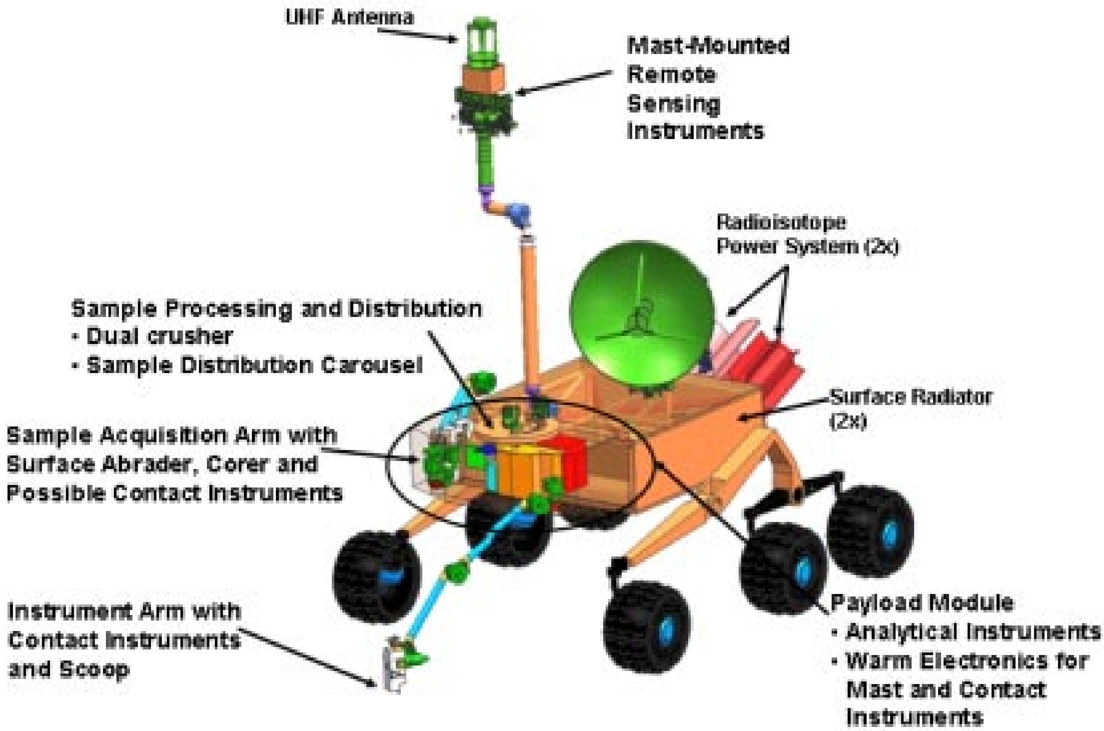


Figure 2.2.3: MSL Landed Configuration - Fully Deployed Rover

2.3 MISSION SOFTWARE OVERVIEW

The MSL Mission System Software refers to all Spacecraft Flight Computer (SFC) Flight Software (FSW) and Ground Data System (GDS) software used to support the science mission. Figure 2.3 provides a context diagram. Flight Software refers to all software running in the SFC, including any software to support instrument operations. Instrument Flight Software refers to software running inside an instrument's dedicated computer. Instrument Flight Software, and unique, PI supplied instrument data analysis software is not considered part of the Mission System Software. Section 3.2.6, Computational Resources describes the basic Rover flight software functions and constraints relevant to instrument proposers. Section 5.0, Mission Operations System (MOS) describes how the flight and ground software is used in context with the flight team processes. Section 6.0, GDS describes the GDS software (SW), and its interfaces to the remaining elements (Data Transport, Planetary Data System (PDS)). Testbed, Simulation, and ground support equipment (GSE) software are also part of the GDS and are used in support of FSW verification, Flight Hardware integration and test in Assembly Test and Launch Operations (ATLO), and during flight in support of Mission Operations.

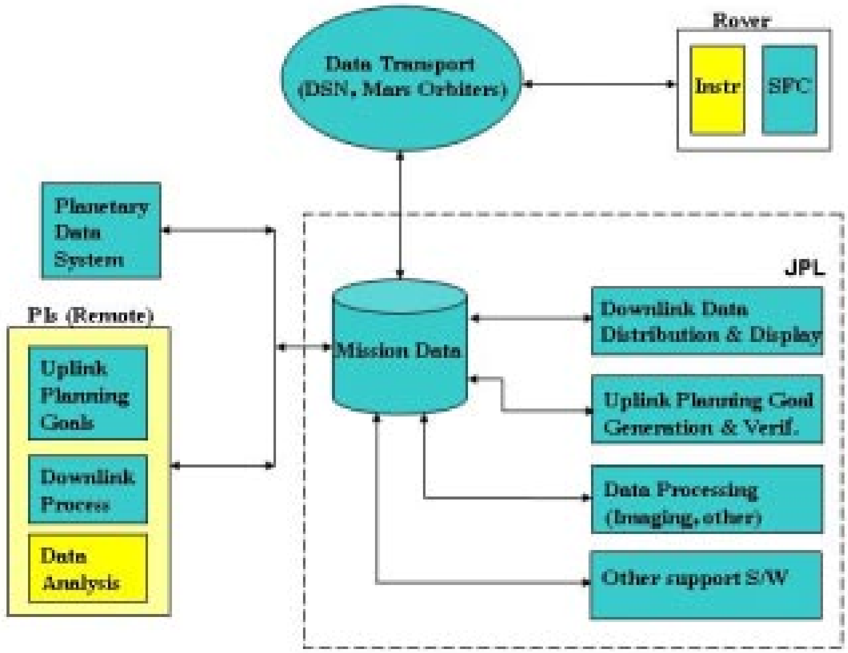


Figure 2.3: MSL Mission System Software Context.

Significant portions of this software (especially, the Rover SFC SW, much GDS Uplink Planning, Goal Generation, and Goal Verification Software, and portions of the Mission Data Handling Software, and Downlink Data Distribution and Display Software will utilize the Jet Propulsion Laboratory (JPL) Mission Data System (MDS) architecture. The MDS architecture provides a structured process and set of frameworks which will result in a very robust and fully validated set of software. It also is designed to facilitate integration between all the flight software and ground software elements. An overview of this architecture is described in the MDS Overview document available in the MSL Library.

The MDS architecture is based on the concepts of State Variables (or States) and Goals. State variables are states of the project system which the software must control or be aware of. States may be simple (such as the on-off state of a power switch), or complex (such as the orientation and translation of various coordinate frames relative to each other). The contents of various project data repositories, including the flight and ground stores is considered a state of the system; this state will include information as to the presence of particular requested data products.

Instrument-internal flight software running in the instrument computer is not required to utilize the MDS architecture. In order to accommodate these cases, joint analysis of interface requirements will by performed, and a “bridge” and/or hardware/software “adapter” will be built at the interface. This will make the non-MDS and the MDS architecture Software compatible with each other. It is up to the PI to decide if the MDS architecture will be used for development of experiment specific ground software. However, all software proposed to execute in the Spacecraft Flight Computer (SFC) must be implemented in the MDS architecture, and will be considered an instrument-unique accommodation (See Appendix F).

3. ACCOMMODATIONS & CONSTRAINTS IMPOSED BY MISSION AND ROVER DESIGN

The rover is expected to be capable of nominal operations at up to 30^{o} rover tilt (Mars gravity), with the exception of the Sample Processing System and Handling (SPAH) system which is expected to be capable of nominal operations at up to a 20^{o} rover tilt (Mars gravity). Instruments in the Analytical Laboratory that accept samples from the SPAH should operate nominally at 20^o rover tilt, all other types of instruments should operate nominally at a 30^o rover tilt.

3.1 LANDING SITE CONSTRAINTS & SELECTION

MSL flight system in being designed with the capability to allow landing the rover between latitudes 60º North to 60º South, with a surface elevation accessibility of up to 2.5 kilometers referenced to the Mars Orbital Laser Altimeter (MOLA) geoid, within a 10 km x 5 km landing ellipse. The 10 km x 5 km landing ellipse estimate does not include the effect of constant direction winds while on the supersonic and subsonic parachutes. Such winds are site, season and time of day dependent and will be considered in the landing site selection process.

The landing site selection process will be open to the Mars science community and will follow the pattern established for the selection of Mars Exploration Rover landing sites. The landing site can be chosen as late as the final year prior to launch, accommodating a selection responsive to discoveries from the Mars Reconnaissance Orbiter (MRO) and all previous Mars missions.

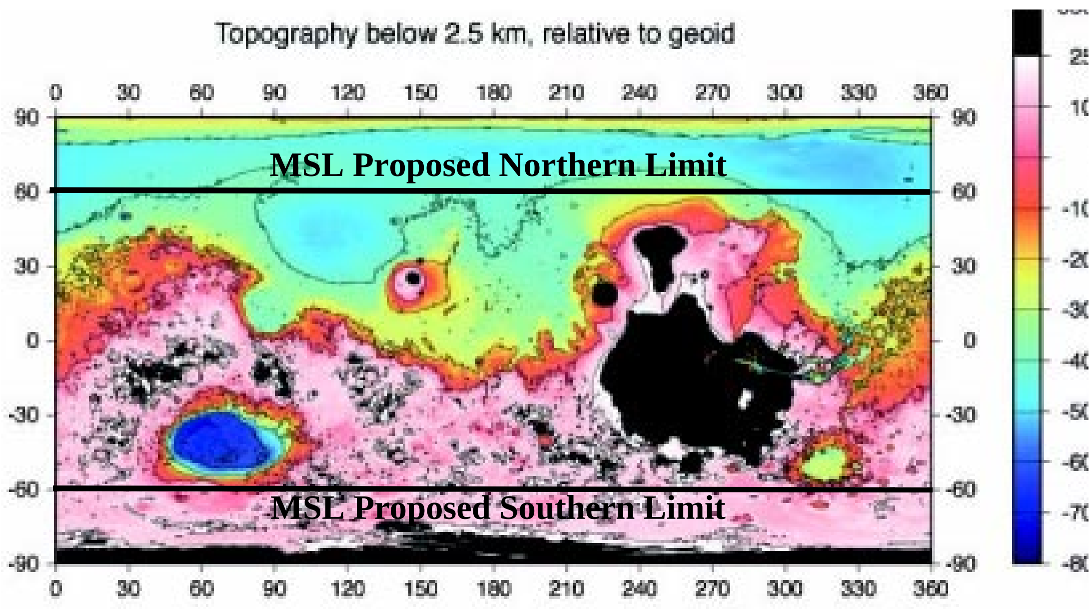


Figure 3.1: Mars Accessibility Map(Topology Relative to MOLA Geoid)

3.2 RESOURCES AND INFRASTRUCTURE AVAILABLE FOR PAYLOAD OPERATIONS

The mechanical infrastructure that provides accommodation and support for the science instrument payload is summarized in Table 3.2. These elements are identified in the rover model shown in Figure 2.2.3. More detailed descriptions of the functionality of each subsystem are provided in the following paragraphs.

3.2.1 Payload Module Assembly

The Payload Module Assembly includes a payload module chassis which houses the analytical laboratory science instrument payload, the Sample Acquisition and Sample Processing and Handling (SA-SPAH) system, the arm-mounted science instruments, and, although not physically connected to the Payload Module Chassis, the Remote Sensing Mast and the mast-mounted science instruments. The modular nature of this assembly is an important feature that is expected to facilitate testbed and integration and test activities by allowing the bulk of the activities to occur on a stand-alone payload module. This is discussed in more detail in Post-Delivery Hardware Support, Section 9 of this document.

Table 3.2: Payload Module Assembly Mechanical Infrastructure Summary

Mechanical Element	Brief Description
Payload Module Chassis	Support structure dedicated to science payload and sample acquisition and processing, attached to the +x side of the rover body
Sample Acquisition / Sample Handling and Processing (SA-SPAH)	
Sample Acquisition Arm	Rover arm whose end effector carries corer and surface abrader, and can accommodate contact/in-situ science instrument(s)
Instrument Arm	Rover arm whose end effector carries contact/in-situ science instrument(s) and scoop
Rock Corer	Primary tool for sample acquisition for the Analytical Lab instruments, carried on Sample Acquisition arm Diameter: 0.5 cm $\leq$ diam $\leq$ 1.5 cm, specific diameter [TBD]), Depth/Length: selectable; [2.0]cm min to 10 cm maximum
Surface Abrader	Rock surface preparation tool carried on Sample Acquisition Arm
Scoop	Secondary sample acquisition tool for the Analytical Lab instruments, carried on Instrument Arm. Primary utility is regolith sampling
Rock Crusher, Primary	Crushes acquired samples into <1 mm diameter pieces
Rock Crusher, Secondary	Exactly same as Primary, provides redundant of rock crusher capability
Sample Distribution System	Portions and Distributes crushed sample to analytical lab instruments.
Spent Sample Ejection System	Provides gravity enabled spent sample ejection from precrush, and predistribution points, depositing ejected sample back onto the martian surface.
Mast	
Remote Sensing Mast (RSM)	One-time deployable mechanical structure for mounting elements that require elevated position and/or pointing
Scan Platform	RSM-mounted Azimuth-Elevation capable platform at 2 to 3.5 meters above ground level. The scan platform will accommodate remote the remote sensing instrument suite. The RSM will also provide accommodations for Navigation stereo cameras and UHF antenna.

3.2.2 *Sample Acquisition and Sample Preparation & Handling (SA-SPAH) Capabilities*

MSL will provide a Sample Acquisition (SA) and Sample Preparation and Handling (SPAH) system as facility capability. The MSL SA-SPAH system is critical to the scientific strategy for the mission in that it provides for the placement of the contact instruments, acquires samples (cores, regolith or rock fragments), provides first order processing of the acquired samples and delivers acquired samples to the instruments of the analytic laboratory. The principal elements of the SA-SPAH, as summarized in Table 3.2, include two arms, a corer, a surface abrader, a scoop, rock crushers, a sample distribution system, and a spent sample ejection system. Details of operational/design characteristics for these systems will be finalized after science payload selection. Proposals should address desired sample characteristics, including volume, crush size, etc.

It is anticipated that most of the samples delivered to the analytic laboratory will come from cores of rocks and outcrops. Over the course of the one Mars year primary mission the SA-SPAH system is expected to be capable of delivering to each analytical laboratory instrument a baseline quantity of 74 samples, and not less than 28 samples. Some of the samples will be regolith and some from rock fragments if any of suitable size are found on the surface.

A concept drawing of the SA-SPAH system is shown in Figure 3.2.2. The ultimate implementation of the capabilities given in this document will be tailored to the specific needs of the selected payload, and may appear quite different from the concept drawing while still supplying the same functionality.

Cross contamination between successive samples delivered to the analytical lab science instrument payload is expected to be less than or equal to 0.5% by mass. Contamination issues are discussed in further detail in Section 3.6.

All elements of the SA-SPAH system will be capable of nominal operation on the martian surface at a rover tilt of up to 20°.

3.2.2.1 Arms

The SA-SPAH will provide arm(s) for sample delivery to the analytical lab, and accommodation for contact/in-situ science instruments. The current implementation plan provides two identical arms, one primarily for science instruments, the other primarily for sample acquisition. Each arm will place tools and instruments against, and normal to, science targets within a defined workspace. The two arms are expected to have a significant overlap between their individual workspaces. The Sample Acquisition Arm (SAA) is expected to carry the surface abrader and the corer and also have capability to carry some science investigation hardware. The Instrument Arm (IA) will carry science instruments, and also carry a scoop for sample acquisition. The vibration and dust environmental requirements for the instruments on the SAA are expected to be driven by abrasion and coring activities.

A concept model showing arms attached to the payload module is shown in Figure 3.2.2. Absolute placement accuracy of each arm at science targets and instrument inlets is expected to be ± 1 cm, with accuracy and repeatability sufficient to allow arm-mounted science instruments and corer access to a surface prepared by the abrasion tool. The rover flight computer will control placement of arm mounted instruments for contact science. Arm-mounted payload science instruments must be capable of accommodating JPL provided contact sensing for arm motor control and instrument placement purposes.

Cable runs between instruments and tools mounted on the arm are integral to the arm design and motion capability, and are considered to be part of the arm mechanical subsystem. This cabling resource is a driver for arm accommodation. Arm cable runs will be suitable for power and balanced digital signal transmission; accommodation can be made for other required cable types with minimum bend radius of less than 1 cm (TBD) and sufficient pliability, as may be required by science payload instruments. Proposals are encouraged to minimize and must identify cabling requirements, including signal type and quality, for arm mounted instruments. PIs will have responsibility for specification input and design approval for cable runs between rover body and arm-mounted instruments. JPL will have responsibility for the final design and fabrication of these cables. Low level analog signals in s/c provided intra-instrument cables should be avoided, and if proposed will require special accommodation. Fiber optic paths or other complex instrument-unique functions in the intra-instrument connections will be treated as special accommodation items.

3.2.2.2 Surface Abrader

The surface abrader is expected to be capable of removing up to approximately 5 mm of the outermost layer of a relatively flat rock surface area. The abraded surface area will be sufficient to accommodate a 3 cm diameter science instrument contact with the abraded surface. The surface abrasion process will create a freshly exposed flat surface suitable for contact science instrument observations and core sample acquisition. There is no planned capability to collect the material removed during the abrasion process.

The surface abrader is expected to be capable of 50 operations; with a goal to achieve up to twice that number.

Induced vibration environment in the region of the surface abrader may be significant, and is discussed in the environments section of this document.

3.2.2.3 Corer

The Corer is the MSL Rover's primary sample acquisition tool. Cores is expected to have a single, specific diameter within the range 0.5 to 1.5 cm, and commandable core length up to 10 cm, with a minimum core length of not greater than 2 cm. The corer will be capable of acquiring samples from consolidated materials of basalt-like hardness and softer. The corer lifetime and capability are expected to be sufficient to allow delivery of an appropriate number of samples to support the quantity of samples delivered to the analytical laboratory instruments described in Section 3.2.2.

The MSL Corer is in a relatively early stage of development, consequently the capabilities described above are focused on the primary functional requirements. The final, implemented design may bring additional capabilities. The ability to re-enter a previously cored hole for further sampling or to enable access to only a subsurface segment is (TBD). A capability to use the Corer to acquire samples from unconsolidated material, such as regolith and crumbled rock is (TBD). A capability to acquire icy core samples is not a baseline requirement but is expected to be possible with their baseline tool suite. Bulk sample temperature increase during acquisition will be minimized, with a goal to not preclude acquisition of icy material. There is no requirement to break consolidated cores, or sort broken or unconsolidated cores, into discrete segments while preserving the associate depth information.

3.2.2.4 Scoop

The scoop offers a second mode of sample acquisition. The scoop is expected to be capable of acquiring mixed regolith and pebbles from the surface, and possibly scraping to acquire sample from exposed icy surfaces. The scoop will have minimal trenching or digging capability. More extensive digging or trenching, if required, is expected to be provided by the mobility system. The mobility system is expected to have the capability of trenching unconsolidated or loosely cemented surface regolith.

In nominal operations, scooped samples are processed through the crusher for crushing and portioning, however scooped samples may be delivered directly to the analytical laboratory instruments, bypassing the rock crusher. In the event of a corer failure, the scoop will become the primary mode of sample acquisition.

3.2.2.5 Rock Crusher & Pre-staging Area

The Rock Crusher is expected to process non-icy consolidated and unconsolidated input material, yielding an output sample with particles sizes less than 1 mm. A pre-crush staging area may be provided to allow the acquired sample to be a target for arm-mounted contact suite instruments and the mast-mounted instruments prior to crushing. If the sample continues to the instruments in the analytical lab, it is fed to the rock crusher and crushed between two plates repeatedly until the particles are small enough to pass through a prescribed opening that controls the particle size to the 1 mm maximum dimension. This successive fracturing comminution process generates a sampling of the input material that is roughly homogeneous over time. Figure 3.2.1.5 shows typical fine particle size distribution for representative materials after crushing by a developmental prototype crusher (max particle size 1.6 mm). Coarsely crushed residual material can be made available for contact suite observations after the required quantity of fully crushed product has been generated.

The pre-crush staging area operates at the Mars ambient temperature. The crushing operation is not temperature controlled but will be designed and operated so as to minimize temperature changes in the sample.

Rock Crusher contribution to previous sample contamination is minimized by design, including use of vertical surfaces, and materials that resist accumulation of static charge.

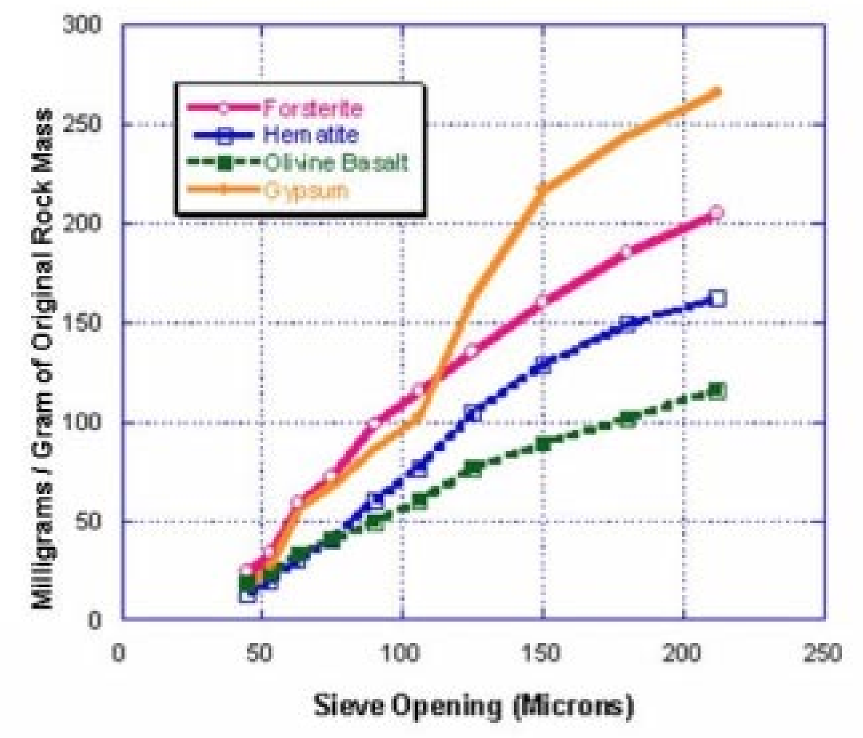


Figure 3.2.1.5: Typical Rock Crusher Output Particle Size Distribution (fines only)

3.2.2.6 Sample Distribution System

The Sample Distribution System will distribute crushed sample portions of approximately, 1 gm representative value each, to the analytical laboratory science instruments. The sample distribution system will be a gravity fed device, that will be capable of nominal operations on Mars at a tilt of up to 20^o. All analytical laboratory instrument sample inlets must, together, fit under the distribution system. Input samples to the crusher can be crushed and appropriately portioned so that at least one portion can be distributed to each instrument in the Analytical Laboratory. Figures in this document show a 'carousel' type distribution system, however the actual implementation, while having the same functionality, may look significantly different. Final design of the portioning and distribution system will be based on the accommodation requirements of the selected science instrument payload.

Sample portions can be stored within the distribution system until passed to analytical laboratory instruments, or discarded; however, samples will be acquired and processed serially. A new sample will be acquired only after the previously acquired sample has been cleared from all rover subsystems, including crusher and distribution systems, and excluding the laboratory instruments.

Capability to introduce blank or index/calibration samples into the sample processing chain can be considered and will be evaluated as instrument-unique accommodation items.

The sample processing elements will be exposed to the martian environment following landing.

3.2.3 Remote Sensing Mast

The rover will carry a one-time deployable Remote Sensing Mast Assembly (RSM). The mast will provide mechanical interface platform(s) and pointing/rastering capabilities to accommodate remote sensing, including panoramic imaging capability. The RSM is expected to provide pointing capability in azimuth (360^{o}) and elevation ($+90^{o}$ skyward, -60^{o} toward deck). Scan platform pointing is expected to provide approximately 1 mrad accuracy and precision in azimuth and elevation, sufficient to raster-scan a point spectrometer. The RSM will provide no optical accommodations beyond mechanically pointing an instrument platform. Space will also be made available for instrument components inside the rover body Warm Electronics Box (WEB), and cabling suitable for power and balanced digital signal transmission between the WEB and the mast-mounted science instruments will be supplied by the spacecraft. Proposals must describe cable general requirements and functions. In addition to the PI instrument(s), the mast will carry a stereo pair of navigation cameras and a UHF antenna.

3.2.4 Mobility Capability

The mobility system is responsible for long-range traverse, short-range target approach, and appropriately positioning the rover at a selected target for purposes of sample acquisition and science activities. In addition, the mobility system is expected to have the capability to expose subsurface regolith by excavating a trench up to a depth of approximately 0.25 meter.

During periods of traverse, the rover will provide nominal mobility rates of 50 m/sol at a driving speed of 5-10 cm/sec when the vehicle is moving. The total mission traverse capability is expected to be at least 6 km. Target approach algorithms are expected to allow the vehicle, from up to a 20 m distance, to place a contact instrument or tool on a targeted surface feature within 3 sols after identification of the target.

3.2.5 Payload Resources Allocation

The following sections describe the Mass, Envelope, Power/Energy, Data Volume allocated to the payload science investigations. Proposals must specify the proposed investigation's utilization of each of these resources, including profiles and timelines for power and data volume. The blank resource matrix in Appendix D may be used as a template to aid in providing the required information.

3.2.5.1 Mass Allocation

Total Science Instrument Payload mass available for Investigations proposed in response to this AO is 49 kg, including proposed mass reserves. One kilogram of the 49 kg is reserved for the potential Class 4 surface radiation environment sensor described in Section 1.3. Figure 3.2.5.1 illustrates the payload mass allocation for the MSL rover.

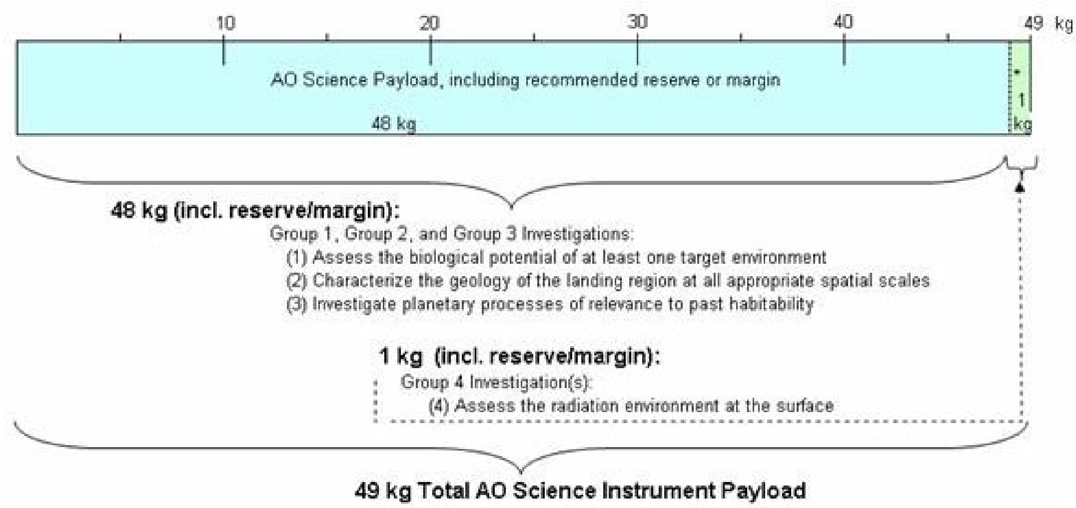


Figure 3.2.5.1: MSL Payload Mass Allocation

The maximum mass that can be safely carried at each rover location is shown in Table 3.2.5.1. This is the mass than can be mechanically accommodated, and the fact that the sum of the maximum carrying capabilities is greater than the total payload mass is intended to allow flexibility in the selection process. Obviously, the total payload mass is constrained by the 49 kg limit stated above. Within the constraints shown below and the science payload total mass allocated to arm and mast capabilities will mature based on the selected payload.

Table 3.2.5.1: Maximum Mass Carrying Capability

Locations	Maximum Mass Carrying Capability (kg)
Payload Module	49.0
End-effector of Sample Acquisition Arm	0.3
End-effector of Instrument Arm	3.0
Remote Sensing Mast **Az/El Raster-Scan Capable Platform**	15.0

Investigators must propose current best estimate masses *with recommended margins* consistent with the instrument design maturity. When developing instrument proposals, mass estimates should include all science instrument payload equipment, e.g., electronics, thermal insulation to meet instrument-unique requirements, caging mechanisms, and radiation shields. JPL will provide and the flight system will carry the mass for any thermal blankets and/or surface insulation required for system-level thermal maintenance. Intra-instrument cabling between non-collocated instrument elements (e.g., arm mounted sensor and payload module mounted electronic boxes) will be provided by the spacecraft. Proposals must provide assumptions for this cabling including; number of conductors, cable type, connector type, and any special shielding requirements to a level of detail that will support the accommodation assessment. The spacecraft will provide, and hold the mass for, the above described intra-instrument cables, mounting brackets and fasteners, alignment cubes, and engineering temperature sensors.

Reserve/contingencies for mass uncertainty/growth will be held based on recommended values to be included in the investigation proposals. Some percentage of negotiated mass reserve will be held and managed by the individual investigators, and the remainder will be held in a pooled reserve earmarked for Payload Science Instruments to be managed jointly by the MSL Science Office and Payload Office.

3.2.5.2 Volume (Mechanical Envelope) Allocation

The volumes shown below are the total volume available in each specified location. These are preliminary volumes and may vary by 10-20% in various dimensions. There is some (TBD) space available inside the rover body to accommodate payload as well as space available on the rover deck to accommodate calibration targets for mast and arm mounted instruments.

Total Instrument volume allocation in the Analytical Laboratory is shown in Figure 3.2.5.2a. This figure also shows conceptually the sample distribution carousel and, by association, the analytical laboratory instrument inlet location constraints. Instrument proposals must specify required areas and locations of sample ejection ports at the bottom of their instrument volume. A clear path to the ground will be provided for these ports.

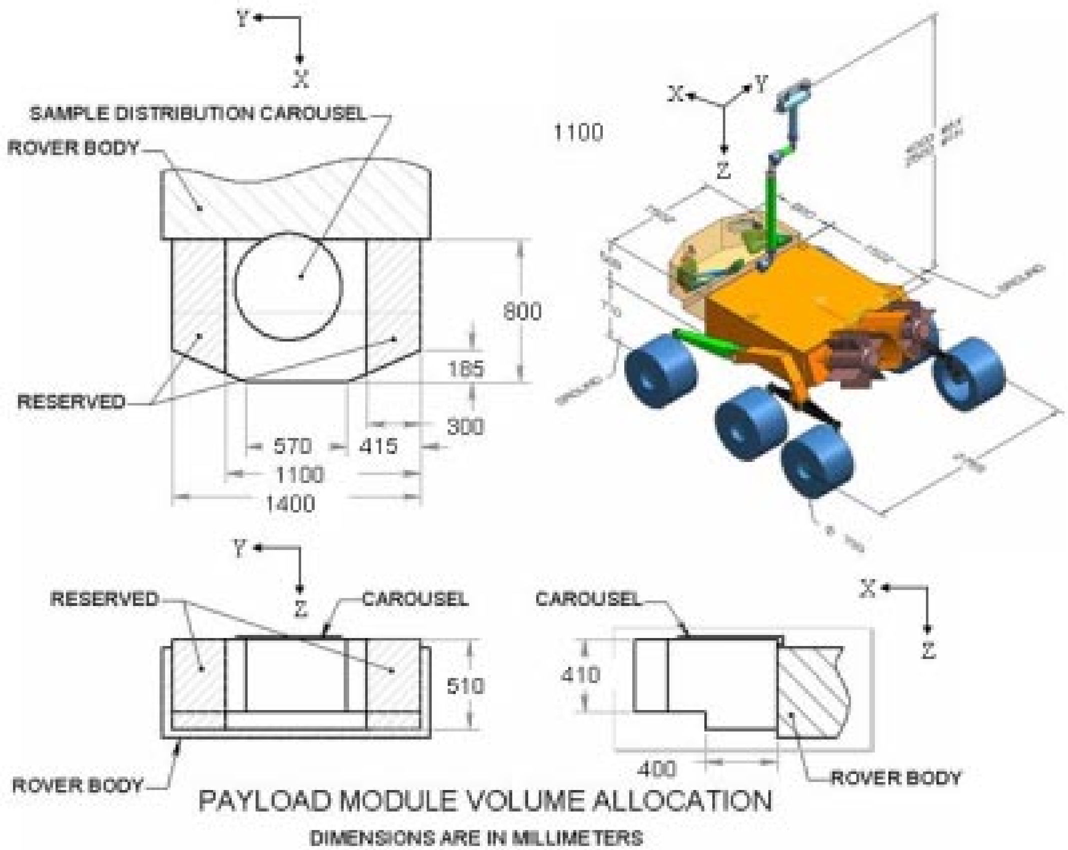


Figure 3.2.5.2a: Payload Module / Analytical Laboratory Instrument Envelope

Contact science instrument volume allocation on end-effector of arm(s) is shown in Figure 3.2.5.2b. This volume may be shared by several instruments, thus in implementation, a significant portion of the volume shown may be required as 'free space' between instruments. Additionally, a Remote Warm Electronic Box (R-WEB) volume, nominally at 15x15x5 cm, is expected to be available on each arm. The R-WEB volume is not included in the volume shown in Figure 3.2.5.2b. Instruments are constrained to 3 cm maximum diameter at the instrument/abraded-target contact face.

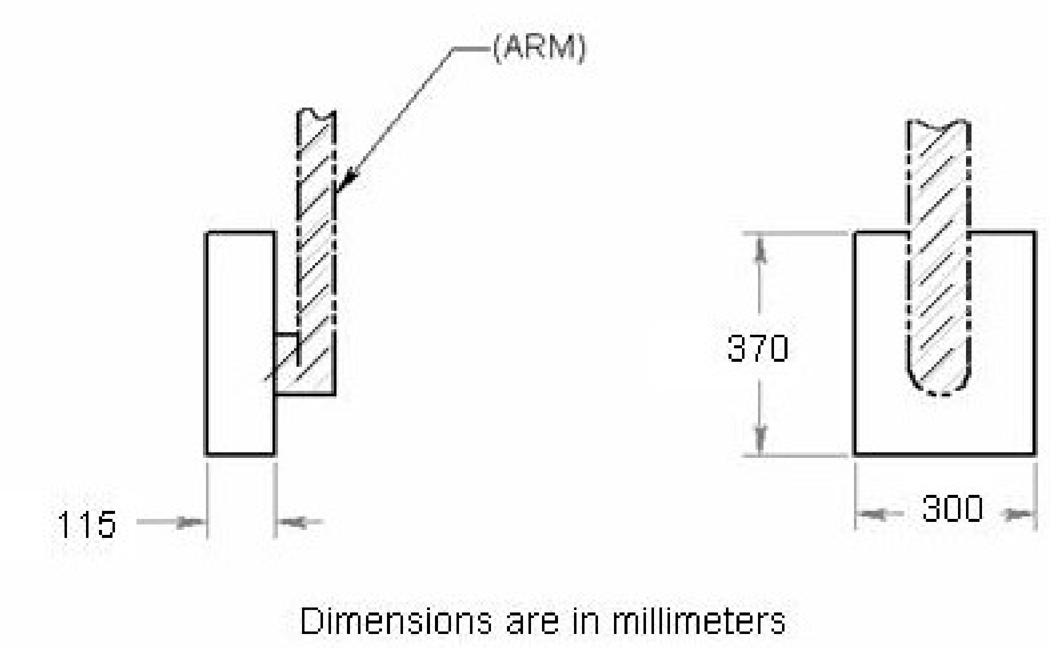


Figure 3.2.5.2b: Arm(s) mounted Instruments Envelope

Total Instrument volume allocation on the Remote Sensing Mast (RSM) is shown in Figure 3.2.5.2c. The RSM Remote Warm Electronics Box (R-WEB) , nominally sized at 20 cm x20 cm x10 cm, is fully contained inside the 17x29x42 cm volume. The RSM scan platform height is expected to be between 2.0 and 3.5 meters above ground level, and 1.0 to 2.5 meters above the rover top deck.

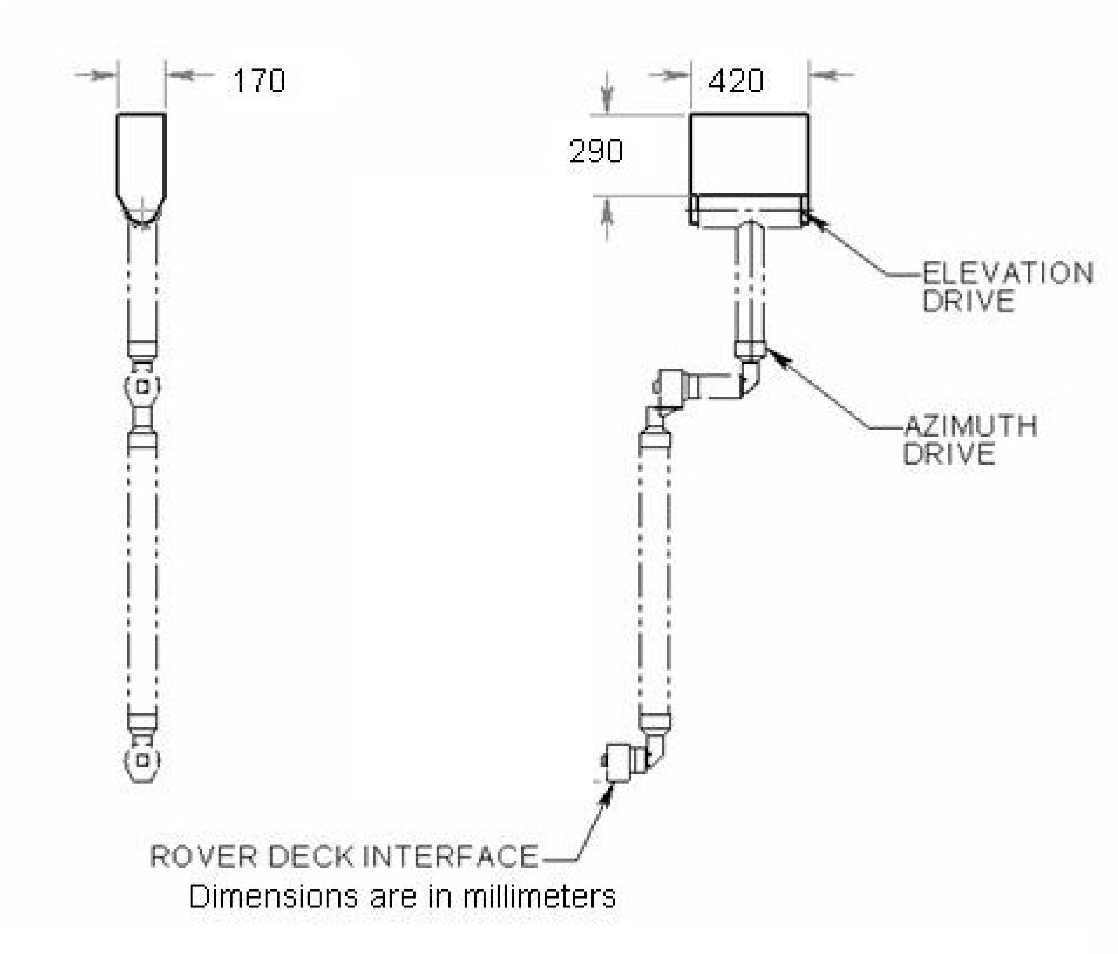


Figure 3.2.5.2c: Mast-mounted instruments envelope

3.2.5.3 Power / Energy Allocation

The rover provides 200 to 250 Whr per sol energy allocation for science instrument operation, as shown in Table 3.2.5. The power available is scenario dependant. The science instrument payloads must not consume more than 84 (TBR) W peak power, limited by power switching capabilityInstruments must specify peak, average, standby and ops timeline. Energy usage is critical. MSL will be driven by energy requirements more than peak or average power.

3.2.5.4 Data Volume Allocation

The MSL nominal rover data downlink capability is expected to be at least 100 Mbit/sol at maximum Earth/Mars range, with a potential downlink capability on the order of 500 to 1000 Mbit/sol, utilizing a combination of relay and direct-to-Earth communications links. Regardless of the daily downlink data volume, approximately 50 Mbits/sol will be reserved for low latency downlink of science and engineering data required for critical daily operations planning. The remaining science data may be subject to higher latency . The Spacecraft Flight Computer (SFC) and Flight Software (FSW) will provide buffers for data to be downlinked as well as for data to be stored for later processing. The combination of these two buffer types (On-board data storage and downlink data buffering allocation for science) is 1.0 to 1.3 GBytes. The allocation of this space, between storage for downlink and storage for later processing, may be made sol-to-sol by the operations team.

The instruments must be capable of meeting minimum MSL science objectives using the minimum data volume defined in this document. The project intends to provide an option for guarenteed error free data return for selected data types as requested by proposers. This option is based on retention and retransmission until data receipt is confirmed at JPL.

Instrument data generation and packaging, including data compression algorithms shall be consistent with the data delivery model. Two data delivery modes will be available, selectable per data product. First, unreliable delivery (send once, no ack) has 2% data loss. The data loss in unreliable mode includes large outages (due to ground equipment failures, late acquisitions, weather, etc.) and small outages (1-2 frames spread throughout the data stream at a rate of ~8 gaps per 10,000 frames). Second, reliable delivery (retransmit to fill gaps) can be virtually 100% complete, at a cost of increased storage and latency.

Total data return capability will be constrained by the following downlink opportunities:

(1) Approx. three UHF passes per sol depending on latitude, and

(2) Two X-Band passes per sol, seasonally reduced to zero.

Figure 5.5.1 in the Mission Operations section gives an overview of the unconstrained data return potential from which these project capability will be built.

Decisions as to how to allocate the limited daily downlink capacity and manage the science data storage capacity will be made by the operations teams, including science and instrument teams. Proposals must include a typical data volume by obervation type or mode consistant with sol templates described in Section 4.4.1. Table 3.2.5 shows scenario dependent data storage, buffering and transmission resources available to science instruments.

Typical scenarios for the 100 Mbit/sol and the 500 to 1000 Mbit/sol cases are shown in Figure 4.4.1.

Table 3.2.5: Scenario-Dependent Resources Allocated to Science: Power, Data Downlink, Data Storage

Sol Template (see Section 4.4.1 for Sol Template Descriptions)	**Operational Power Allocation (Watt•hr/Sol)**	**Low Latency Data Transmission (Mbits/Sol)**	**High Latency Data Transmission Bandwidth Link (Mbits/Sol) - - bandwidth - -**		**Data Storage and Downlink Data Buffering (Gbytes)**
			Low	**High**	
Site Reconnaissance	250	40	40	750	1.0 to 1.3
Traverse	100	0	40	750	1.0 to 1.3
Contact & SA-SPAH	200	40	40	750	1.0 to 1.3
Analytical Laboratory & Contact Science	200	40	40	750	1.0 to 1.3
Rest / Telecom	0	0	40	750	1.0 to 1.3

3.2.6 Computational Resources

The Rover's primary computational resources are supplied by a compute node containing a Power PC 750 or equivalent processor. This processor, referred to as the Spacecraft Flight Computer (SFC), will be capable of executing at a minimum of 133 MHz. All general purpose data processing, both engineering and science, except that contained in instrument internal computers, will be performed using the SFC. Allocation of computational resources on this computer will be based on priorities. First priority is given to processes required for Spacecraft survival, health, and safety, including Fault Protection. Second priority is given to the engineering infrastructure processes necessary to operate the spacecraft. These include communication with Earth for uplink and downlink data, and control of the telecom equipment, Rover mobility and driving processes, surface navigation, thermal control management, power management, acquisition of engineering data, and data from the Science Instruments, etc. A major portion of the infrastructure is the goal/command execution process. This allows time and event based delayed execution of the science and engineering activities. These activities are planned and uplinked as Goal Networks (this provides the equivalent of sequencing capability). It is estimated that these background and engineering activities will require about 50% (TBD) of the SFC resources. Third priority is given to executing Rover engineering and science scenarios. Portions of these scenarios (and some of the engineering infrastructure processes, also) will require all the processing resources available for discrete (usually short) periods of time. It is expected that in operations, the SFC processor activities will be managed to allow its usage to be optimized to allow 100% utilization. Unused processor time during idle periods may be allocated for deferred processing of previously-collected instrument data. It is part of the uplink development process within the MOS to constrain, schedule and/or time-slice these activities within the capabilities of the SFC. Most of the remaining portion of this section will outline the expected/baseline instrument support processes implemented in software on the SFC. This baseline support, which is available to instruments in general, is summarized as follows:

- the ability to turn on and off power to instrument;

- ability to send commands to instruments;

- ability to retrieve engineering/housekeeping data, minimal monitoring of instrument health and operational state, and ability to safe and unpower an instrument on detection of failures;

Baseline accommodation includes of a single common data processing algorithm to all instrument data. This algorithm will be selected by the science team, but is expected to be a lossless compression algorithm.

Proposers must identify any additional instrument- or investigation-unique computational processes which they propose to be executed within the SFC. Processing within the SFC involves design analysis, interface definition, algorithm definition and/or inheritance, and implementation within the constraints of the MDS Architecture. If desired, the PI will be given an option to contract (after selection) with the project FSW team to do the final implementation, verification, and validation. Cost of such instrument specific software efforts will be book kept as instrument-unique accommodations. Please refer to Appendix F for more information on proposing instrument-unique processing accommodations.

3.2.6.1 Requirements on the Instrument Data Systems

Instruments are expected to provide sufficient buffering so that they do not require servicing by the SFC any more than 10 times per second. Instruments should also accommodate input/output transactions at any time during a 0.1 second period; the SFC will not accept tighter timing requirements. These requirements have the following implications:

- Instrument provides sufficient buffering to limit data return interactions (instrument-to-SFC) to no more than 10 per second.

- Sufficient buffering to limit command interactions (SFC-to-instrument) to no more than 1/second.

- Instrument microprocessor or controller, if necessary, to meet the 10 per second and timing requirements, particularly for process control, data acquisition, or any other computation or control processes not feasible across the SFC interfaces.

- Ability to handle accurately-timed spacecraft time synchronization messages from the SFC, and to provide internally, any tighter timing for instrument control, data acquisition or time-tagging.

Figure 3.2.6.1a shows a schematic of a generic instrument interface with the System Flight Computer. See Section 3.4.5, Science Payload Data Interface for details.

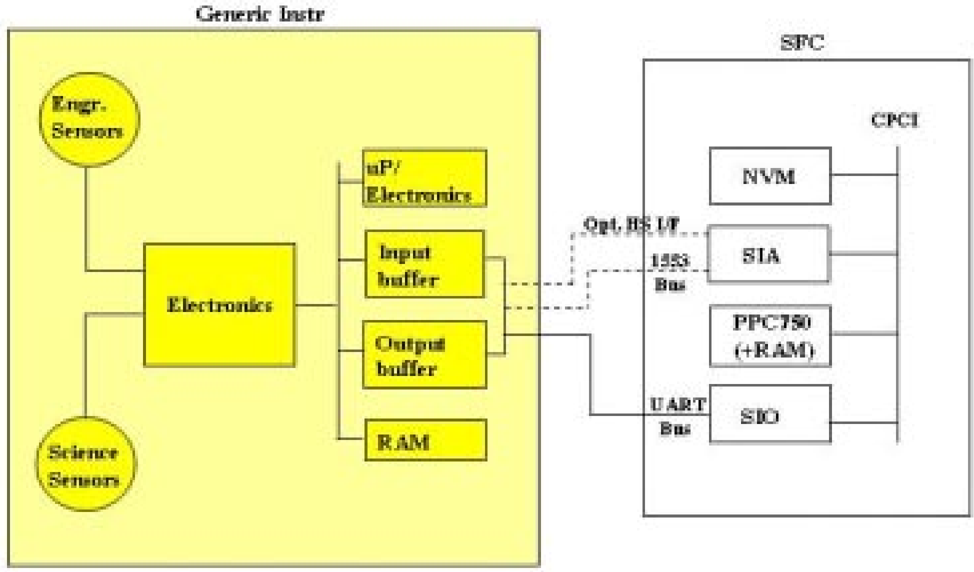


Figure 3.2.6.1a: Generic Instrument Interfacing with the Spacecraft Flight Computer (SFC)

Figure 3.2.6.1b gives an overview of the baseline instrument/FSW processing accommodation approach. These processes provide for a basic channeling of data between the PI and the instrument, while providing mechanisms for coordinating instrument commanding and data acquisition with other ongoing Rover activities.

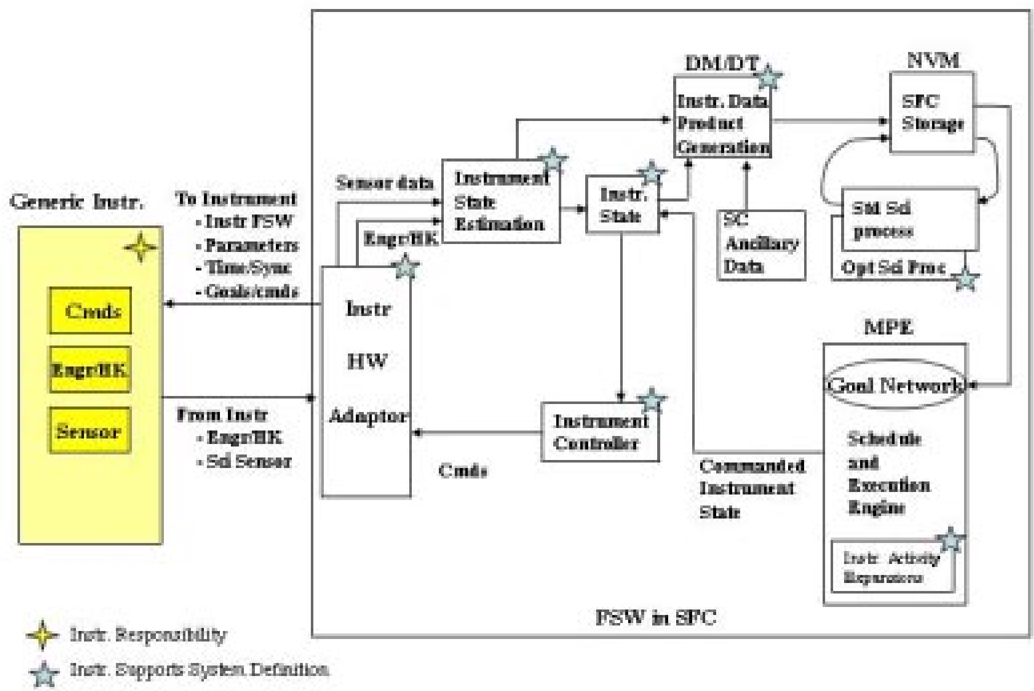


Figure 3.2.6.1b: Baseline instrument/FSW processing accommodation approach

The baseline flight software will provide the following capabilities to be applied to instrument control and data acquisition:

- All Instrument input and output data will be handled in a software component called the Instrument HW Adapter
- Instrument Engineering/Housekeeping data will be examined by an Instrument State Estimation component which extracts and stores the portion of the Instrument State that is needed for on-board coordination. Additional estimation processes will also provide the instrument data and metadata (for both Engr/HK, and Sensor data) needed by the Data Management/Data Transport services to produce the Instrument Data Products.
- The Instrument Data Products (including any S/C Ancillary Data needed) will be stored in S/C mass memory for further processing and/or delayed transmission to Earth.
- The Mission Planning and Execution (MPE) component will issue ground flight team defined instrument goals/commands (either raw, as sent from the ground; or with on-board expansions from within MPE) which cause the Instrument Controller component to send low level commands to the instrument via the Instrument HW Adapter at the appropriate time/event coordinated conditions.

Additional details can be found in Appendix H, Additional Details on FSW Design.

In order to support development of the baseline flight software capabilities providing Instrument control and data handling, each Instrument team will be required to provide:

(1) Full definition of the instrument interfaces including data buffering, protocols, and transactions (input and output) on the instrument side of the interface.

(2) System Engineering support to define the baseline capabilities implemented in SFC Flight Software. This includes: instrument HW interface, instrument state determination (including instrument health monitoring), instrument control (including sending of commands processed by the instrument processor), instrument Data Product generation (including ancillary data), expansion of instrument activities, instrument operational constraints and interactions with other spacecraft activities, etc. The instrument team should identify this support in the system engineering role statements. Typically, this requires approximately 0.5 FTE from instrument selection to ATLO delivery.

(3) Instrument internal processing of any instrument-specific fast, closed-loop control, including analysis of instrument data and formulation of low level commands. The system FSW resident in the SFC cannot provide very low latency, high rate data acquisition or commanding. SFC data pickup is limited to no more often than 10 Hz, $\pm$ 1 Hz (TBR). Commanding is constrained similarly, with an objective of commanding no more than once per second.

3.3 ENGINEERING USE OF SCIENCE IMAGING CAPABILITY

In the event of a mast-mounted Navigation Camera system failure Remote Sensing Science instruments may be required to take on the Navigation Cameras' mission critical engineering functions. The requirements on the Navigation cameras are listed in Appendix C as a reference. Specific duplication of the Navigation Camera capability is not required, but rather, such backup functions would be used as available. There will be no additional mission assurance requirement levied on the instrument. It is recognized that operational interactions with flight system will require more extensive work, and this additional scope will be borne by the Flight System.

3.4 PAYLOAD INTERFACE DEFINITIONS

Thermal, Power, Grounding, Data, and Instrument-Unique interfaces are discussed in the following sections.

3.4.1 Thermal Control & Thermal Interfaces

There are three classes of thermal support expected to be available for proposed instruments. First, instruments located in the payload WEB and attached to the thermal control plate, can expect thermal control plate temperatures to be maintained at ± 20° C diurnal thermal cycle amplitude. Second, instruments located within any of the remote WEBs listed below can expect a bulk enclosure temperature diurnal cycle amplitude of ±25° C. Third, instruments choosing to locate outside of a WEB are completely responsible for their own thermal management and must allocate power resources accordingly, within the overall payload power allcation identified in Table 3.2.5.

A pumped fluid loop system, plus additional heaters in selected locations, provides robust thermal control throughout the rover main body, payload module and specific areas on the rover's extremities, notably the three Remote Warm Electronics Boxes (R-WEB) located on the Instrument Arm, the Sample Acquisition Arm, and the Remote Sensing Mast. This system will reduce rover system-level thermal cycling, and also meet thermal needs for extreme latitude winter operation. The expected thermal interface temperatures are shown in Table 3.4.1. The values in Table 3.4.1 describe the thermal interfaces not the bulk temperature of the elements within the WEBs and R-WEBs.

Table 3.4.1: Warm Electronic Box Thermal Interface for Surface Operations

Location	Expected Diurnal Temperature Cycle at Thermal Interface	Minimum/Maximum Temperature at Thermal Interface	Comments
Main WEB	± 20 deg C	-40 / +50 deg C	Serviced by Fluid Loop
Payload WEB	± 20 deg C	-40 / +50 deg C	Serviced by Fluid Loop
Remote WEBs			
R-WEB - Arms	± 25 deg C	-40 / +50 deg C	
R-WEB - Mast	± 25 deg C	-40 / +50 deg C	

Figure 3.4.1 shows representative diurnal temperature cycling superimposed over a sinusoid whose amplitude is the sum of the seasonal and latitudinal set point variation over possible MSL landing sites.

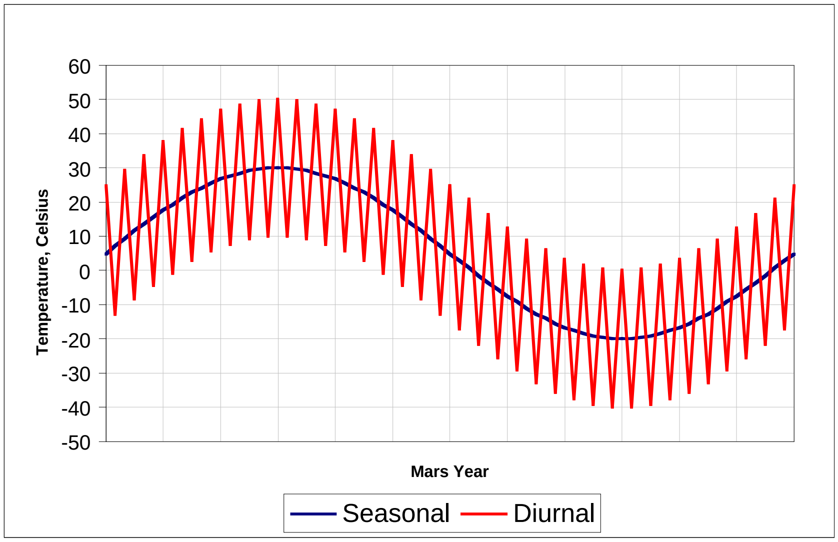


Figure 3.4.1: Diurnal and Seasonal Temperatures at Payload Interfaces

The wall between the payload module and the rover body is expected to be thermally maintained by the fluid loop. RPS heat will thus be made available via a conductive/radiative interface to the instruments in the payload module for the prevention of deep thermal cycling of sensitive elements, such as electronics assemblies. Because the thermal wall is maintained by the fluid loop, it will act as both heat sink and heat source. The specific mechanical configuration of the thermal interface will be developed after instrument payload selection.

Thermal control of R-WEBs is expected to be achieved by replacement heaters and limiting allowable power dissipation. The design is based on power dissipation limits for the Arm R-WEBs of 1.5 W and mast R-WEB 5.0.

For instruments located within the payload module, if an instrument requires a portion of its volume to operate at temperatures colder than those provided by the payload WEB, the bottom surface of the instrument volume can be used as a radiator viewing the martian surface. Other radiator views may be considered on an instrument-unique accommodation basis. Responsibility for insulating any cold sections, and for thermal control within these cold sections will reside with the instrument.

The power necessary to provide bulk thermal accommodation within the WEBs and R-WEBs is book-kept by the flight system. Proposals should include an estimate of these loads in their proposal description of their thermal design.

The preferred approach is to maximize use of conductively heated web and minimize use of survival heaters interior to science instruments as this allows system level optimization of power resources. Any requirement for control heaters internal to the science instrument to provide tighter control than specified for survival heaters will be the responsibility of the PI and required power will be accounted for in the instrument operational power timeline.

During cruise phase, the spacecraft is expected to provide a thermal environment that is consistent with the surface phase requirements.

3.4.2 Science Payload Power Interfaces

MSL is expected to provide in-rush current limited, switched 22 to 36 volt nominal power, with current sensing and over current trip protection provided through a single master switch on the host power subsystem. It is probable that a host master switch will be shared among multiple instruments via an unprotected slave switches. Because of this, instruments will be required to provide local in-rush current limitation and over current trip protection. The in rush and current trip limitations will be lower than general power bus protection. The general power bus will be current limited in the 3-5 amp range. Science instruments will provide their own power conditioning. Instrument chassis is to be isolated from electrical ground by 1 Mohm. The instrument shall not present a load to any of the electrical interfaces when powered off.

3.4.3 Power on/Reset and Power Interruption

Instruments shall be designed to establish a known safe configuration when power is applied. Instruments shall be designed to safely tolerate an interruption of power at any time. Loss of measurement or loss of data is not a constraint.

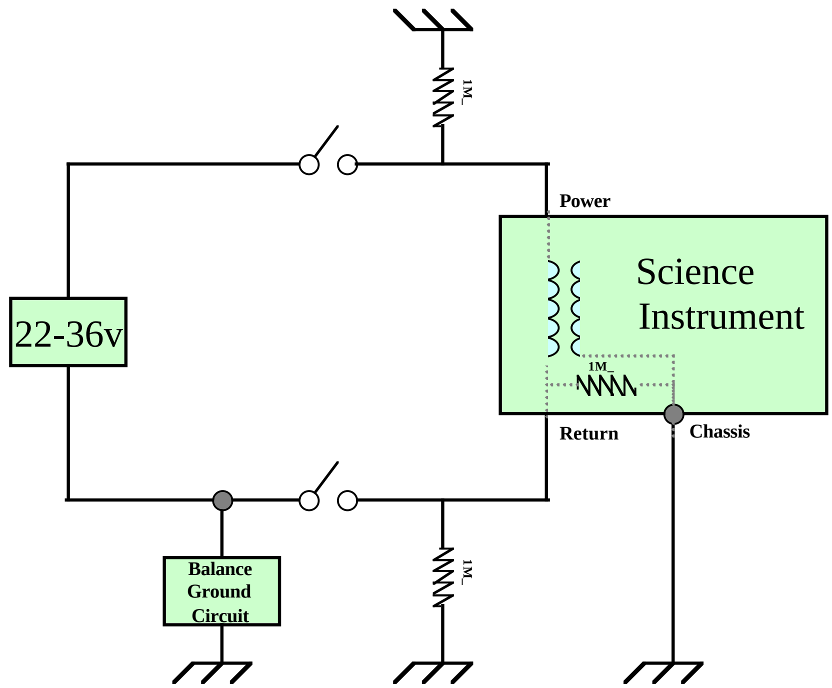


Figure 3.4.4: Grounding and Shielding Diagram

3.4.4 Science Payload Grounding and Shielding Interfaces

The nominal Grounding and Shielding interfaces to instrument hardware is shown in Figure 3.4.4.

The instrument shall be designed with 1 Mohm resistor attached from power return to instrument chassis, and the design shall be compatible with a 1 Mohm resistor from the power return wire to spacecraft chassis and from positive supply to spacecraft chassis.

The instrument will be designed for nominal input power that ranges from +22 to + 36 V. In the case the spacecraft suffers a short between the positive power terminal of the battery and chassis, the power input to all instruments will then be -22 to -36 V.

The instrument will be able to accommodate power line fault conditions changing rapidly back and forth between the normal and the full fault condition as described above.

The payload will be designed so that no dc current flows in the spacecraft chassis external to the payload for any of its functions, under all input power line normal or fault conditions.

3.4.5 Science Payload Data Interfaces

The system is expected to make available three different bus interface types for instrument communication to the host. These interfaces are redundant Mil Std 1553B buses, a redundant Low Power/Bandwidth UART Bus (100 KBS), and High Speed Point-to-Point (RS422) Communication interfaces. These interfaces are illustrated in Figure 3.4.5. The Mil Std 1553B bus is the default means of communication between the host and the instruments. For instruments where the power constraints of the Mil Std 1553B bus are not acceptable and can work within the constraints of the 100 KBS bandwidth, a Low Power/Bandwidth UART Bus is provided. For instruments that require high-speed communication and/or high data volume with the host, a limited number of point-to-point high-speed serial interfaces may be provided to the instruments based on availability, data rate needs and system-level optimization of overall cost.

The redundant Mil-Spec 1553B Instrument Interface bus is the default means of communicating with the instruments and Guidance, Navigation and Control sensors within the MSL Avionics architecture. This bus conforms to the military standard, is transformer coupled and redundant.

A low power/bandwidth (100 KBS) redundant differential communication bus may be used for instrument communication to the host. This low power bus uses the industry standard 16550 UART for basic communication across separate command and data busses. MSL has defined a custom protocol for this interface, which consists of the following: unique start sequence, address field, data field and ending with a 16-bit checksum.

A limited number of point-to-point high-speed serial interfaces may be provided to the instruments. These high-speed bidirectional interfaces will use a custom protocol sent over a three-wire RS422 hardware interface (clock, data, frame) with separate command and telemetry wiring. Instruments requesting use of high-speed interfaces will be required to provide dual interface wiring and circuitry to communicate with the redundant strings of the Command and Data Handling system. Commands to an instrument are sent at a rate of 1 Mbps. Serial telemetry from an instrument can be collected at rates of up to 6 Mbps.

MSL will provide end-circuit designs for these busses. These interfaces shall be designed to preclude a single fault in the instrument propagating into all data busses.

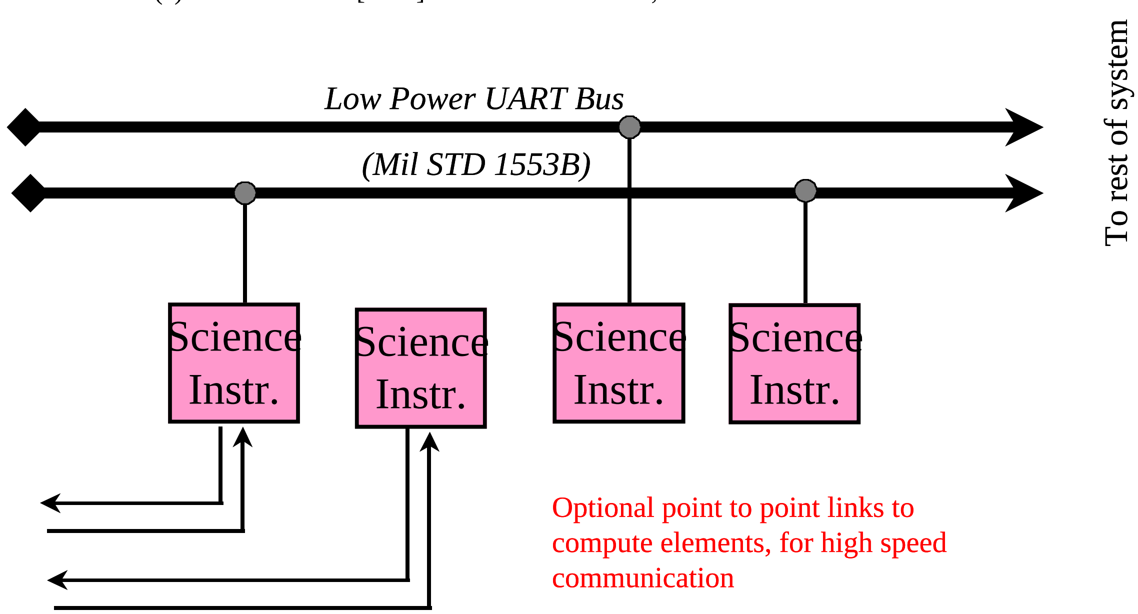
MSL will provide end-circuit designs for theses busses. Interfaces shall be designed to preclude a single fault in the instrument propagating into both redundant low power busses and/or both redundant pairs of 1553 busses.

Instrument shall provide:

(1) Local Instrument interpretation of host commands for data preparation, data buffering and local instrument control.

(2) Buffering to accommodate data return with following parameters:

(a) 100 msec [TBR] between transactions;



(b) [TBD] bytes/transaction (parameters different for each interface type)

Figure 3.4.5: Baseline Architecture Distributed I/O

In addition to the required science payload data interface, each instrument is encouraged to provide a direct access connector that allows the Instrument Ground Support Equipment (GSE) to operate in a listen-only mode after the instrument has been mechanically and electrically integrated into to the Flight System or to the Payload Checkout Bench testbed. When the direct access connector is in use, commanding, power, etc. will come from the system testbed and data will go to the spacecraft command & data handling via the main connector. In parallel with that, the Science Instrument GSE will listen through the Direct Access connector. When not in use, including in flight, the Direct Access connector must be covered and signal lines terminated appropriately, with a PI supplied termination cover.

For safety considerations, all pins on the Direct Access port must be isolated/protected via a current limit resistor. Opto-Isolation on the GSE end interface is optional. For certain analog measurements on the Direct Access port, where a current limit resistor is precluded, opto-isolation on instrument end will be required.

3.4.6 Instrument-Unique Interface Accommodation Items

Any proposed interface other than what is identified in this document as the nominal science instrument interface is referred to as an instrument-unique MSL payload interface. Proposed instrument-unique MSL payload interfaces will require assessment for system design and performance impacts. Implementations of instrument-unique MSL payload interfaces will be reviewed during accommodation assessment for cost impacts. Cost for providing instrument-unique accommodation will be added to the proposed costs as part of the overall investigation cost analysis. This includes the need for additional hardware, performance requirements, and operational complexity.

3.5 PLANETARY PROTECTION

All elements of the MSL mission will comply with planetary protection requirements, policies, and procedures. The following documents, of the latest approved versions, are applicable:

> NPD 8020.7E Biological Contamination control for Outbound and Inbound Planetary Spacecraft, February 19, 1999 (Directive to use NPG 8020.12B)
> NPG 8020.12B, Planetary Protection Provisions for Robotic Extraterrestrial Mission, Rev., B, April 16, 1999 (Guideline on Planetary Protection categorizations)
> COSPAR Planetary Protection Policy, 20 October 2002 (Describes new category of IVc)

The planetary protection (PP) requirements established by NASA policy NPD 8020.7E and detailed in NPG 8020.12B, set forth the policy, procedures and approach, relative to PP, that the Mars Science Laboratory Project will implement. NPG 8020.12B also includes the PP parameter specifications for Mars landed missions as an appendix. COSPAR Planetary Protection Policy (20 October 2002) defines a new category (IVc) , addressing special regions and off-nominal landings, which is pertinent to MSL. The preliminary interpretation of these requirements and parameter specifications, as they apply to the Mars Science Laboratory Project, including proposed extensions of the parameter specifications, and proposed deviations, if any, are provided below.

The MSL project is going forward under the assumption that, per COSPAR 2002 Policy Statement, MSL is a IVc mission.

This working assumption is based on:

(1) MSL will not carry instruments for the investigation of extant life

(2) MSL will not target a "special region" as defined by the COSPAR Planetary Protection Policy (20 October 2002).

(3) MSL project expects to meet science objectives by providing a biologically sterile sample handling and analysis chain (TBS)

(4) Water ice containing samples may be acquired.

Proposers will be required to meet PP requirements, and for proposal purposes should assume the approach appropriate to their investigation, as summarized in Table 3.5.

Table 3.5: Planetary Protection Requirement Assumptions:

Approach	Applicability	Requirement	Typical Method
I	Instruments that will not make direct contact with a surface to be sampled and are not packaged with instruments or tools that are part of the sampling chain.	Cleanable to an average bioburden on the exposed surfaces prior to launch of less than 300 viable spores/m^2	Wipe with a mixture of isopropyl alcohol and water, plus assay verification
II	Instruments that will contact martian material, are part of the sample handling chain and/or ae packaged with instruments that contact the surface	Average bioburden on the exposed surfaces prior to launch of less than 300 viable spores/m^2, and hardware must be steralizable by DHMR. Hardware must be clean of organic compounds to a level of 1 nanogram/cm^2 (TBR)	Dry heat microbial reduction (DHMR) at a specified humidity, duration and temperature profile, 50 hour at 110^o C, or 5 hours at 125 ^{o} C

Investigation hardware that may be placed on the surface and have no interaction with sample or sampling chain should assume the use Approach 1.

Based on the final PP requirements, each instrument may be required to undergo the appropriate level of cleaning prior to delivery. In addition, each instrument must be designed to be tolerant of dry heat microbial reduction (DHMR) performed at the rover system level. Where a unique science capability drives usage of materials not tolerant of the DHMR environment specified in Table 3.5, instrument-unique accommodation via a heat rejection interface to a cold sink (TBD) will be provided. Proposers must identify any potential requirement for heat rejection during a rover system level dry heat microbial reduction.

3.6 CONTAMINATION CONTROL

3.6.1 Organic Contamination Control

Given likely measurement sensitivity levels, control of forward organic contamination from Earth materials is an issue. Approaches which minimize sensitivity to, or reduce control requirements on, contamination should be considered and described. Spacecraft will take the following measures as a baseline:

- Contamination from Earth. Solid sample material delivered to the analytical lab may have up to [TBD] (ppm) of terrestrial organics. The source of this contamination is the sum of both as-cleaned conditions and the accumulation of any outgassing products during previous mission phases.

The report of the Organic Contamination Science Steering Group, available from the Acquisition Library, offers additional guidance on this topic. [NOTE: This document is planned to be released and posted to the acquisition library in the December 2003 timeframe]

Typical spacecraft materials contamination control requirements are summarized in Section 8.1.5.

3.6.2 Analytical Laboratory - Contamination from Previous Samples.

Each sample collected, processed, and distributed by the SA-SPAH system may be contaminated by the previously processed sample. The cross contamination between successive samples delivered to the Analytical Laboratory is expected to be no greater than 0.5% by mass. Contamination will be minimized in the sample processing and distribution system by use of vertical surfaces and use of materials and techniques to minimize accumulation of static charge. Further reduction in residual contamination may be achieved by dilution, through the acquisition and processing of multiple identical samples and other operational and procedural means.

3.7 ROVER ENVIRONMENTS

The MSL rover will be exposed to approximately the environments described in this section. Higher fidelity environment definitions will become available as the spacecraft architecture and the mission plan progress. The instruments must be designed to survive specified Qualification/Protoflight levels.

3.7.1 Dynamic Environments

The following sections give an overview of the expected dynamic environments that will be levied on the science payloads.

3.7.1.1 Random Vibration

The random vibration design and test levels are shown in Table 3.7.1.1a and Table 3.7.1.1b. Test inputs can be "notched" to achieve a more flight-like environment and, if necessary, to prevent exceeding the low to mid-frequency limit loads. In cases where vibration test requirements have significant design impacts, force limiting (NASA-HDBK-7004B) can be used to incorporate impedance mismatch compensation. Other types of tests or tailoring may be used such as transient pulse or response limiting.

Table 3.7.1.1a: Assembly Random Vibration Test Acceleration Inputs

Assembly Location	Frequency, Hz	Flight Acceptance Level	Qualification/ Protoflight Level
Applicable to all MSL Rover Science Instruments	20 - 80 80 - 450 450 - 2000 Overall	+ 6 dB/octave 0.04 g^2/Hz - 6 dB/oct 5.5 g_{rms}	+ 6 dB/octave 0.08 g^2/Hz - 6 dB/oct 7.7 g_{rms}

Table 3.7.1b: Assembly Random Vibration Force Limit Specifications

Frequency, (Hz)	***Force Spectral Density Level (N^2/Hz)***
20 - f_0	$S_{FF} = 96\ C^2 M_0^2 S_{AA}$
f_0 - 2000	$S_{FF} = 96\ C^2 M_0^2 S_{AA}(f_0/f)^2$

Where

S_{FF} is the force spectral density

S_{AA} is the acceleration spectral density

C^2 is a constant ranging from usually 2 to 5 depending on the weight and the attachment stiffness of the test article

M_0 is the weight of the test article in kg

f_0 is the fundamental frequency of the test article in the axis of test

3.7.1.2 Pyroshock Simulation Testing

Preliminary shock environments are specified below. Pyroshock specifications, as defined in Table 3.7.1.2a for the corresponding zone shown in Table 3.7.1.2b, are intended to represent the structurally transmitted transients from pyrotechnic devices used to achieve various separations.

Table 3.7.1.2a: MSL Spacecraft Assembly Locations and Respective Pyroshock Zones

Assembly Location	***Pyroshock Zone (see Table 3.7.1.1-b)***	***Shock Sources***
Rover Electronics Chassis mounted	**3**	Rover Release & High Gain Antenna (HGA) and Remote Sensing Mast (RSM) Releases
<u>Rover Outside Mounted Assemblies</u> - Payload Module & Analytical Lab Instruments	**3/4 (TBR)**	Rover Release & Instrument Arm & Sampling Arm Releases HGA and RSM Releases
<u>Remote Sensing Mast</u> - Science Instruments	**3**	Remote Sensing Mast Release
<u>Instrument & Sampling Arms</u> - Turret Mounted Instruments	**3**	Arms Release and Deployment

Table 3.7.1.2b: Assembly Pyrotechnic Shock Requirements by Spacecraft Zones

ZONE	***Frequency, Hz***	***QUAL, PF Peak SRS Response (Q=10)***
1	100 100 - 1,600 1,600 - 10,000	5 g + 10.0 dB / Oct. 500 g
2	100 100 - 1,600 1,600 - 10,000	10 g + 10.0 dB / Oct. 1000 g
3	100 100 - 1,600 1,600 - 10,000	20 g + 10.0 dB / Oct. 2,000 g
4	100 100 - 1,600 1,600 - 10,000	40 g + 10.0 dB / Oct. 4,000 g
5	100 100 – 1,600 1,600 – 10,000	60 g +10.0 dB / Oct. 6,000 g

1 g = standard acceleration due to gravity = 9.81 m/s^2

3.7.1.3 Sinusoidal Loads - Sample Acquisition Arm

Table 3.7.1.3 provides swept-sine vibration test levels required to qualify equipment mounted on the Sample Acquisition Arm for the excitation generated during coring and abrading. A sinusoidal sweep from the lowest frequency to the highest will be required. These test levels shall be applied at the assembly mounting interface in each of three orthogonal axes.

Table 3.7.1.3: Assembly Swept-Sine Vibration Test Acceleration Inputs for Sample Acquisition Arm Mounted Instruments (TBR)

Frequency	Flight Acceptance Test Levels	Qual and Protoflight Test Levels
20 - 100 Hz	8.8 G (zero-to-peak)	12.5 g (zero-to-peak)
100 - 1000 Hz	- 3 dB / octave	-3 dB / octave
1000 - 2000 Hz	2.8 g (zero-to-peak)	4 g (zero-to-peak)
Sweep rate: 1 octave/minute for QUAL 2 octaves/minute for PF and FA		

3.7.2 Charged Particle/Radiation/Neutron Environment

The Total Ionizing Dose (TID) and Displacement Damage Dose (DDD) for the MSL instruments are summarized in Figure 3.7.2a and 3.7.2b, respectively. This preliminary assessment of the MSL instrument payload environment includes surface charged particle radiation environment from both the Mars ambient environment and two RPSs, and the Total Ionizing Dose the instruments will be exposed to over the time period from launch through one Mars year of surface operation. Values specified in these figures include a Radiation Design Factor (RDF) of 2. Instruments must be designed to withstand the TIDs and operate nominally under the fluence conditions shown in Figure 3.7.2-a.

Instrument Location	Cruise (300 days)		Surface (670 sols, 687 Earth days)		TOTAL (krad)
	RPS (rad)	Natural (rad)	RPS (rad)	Natural (rad)	
Payload Module					
Analytical Laboratory	33	2900	76	28	3.0
Contact / Arm-mounted**					
Stowed	36	2900	N/A	N/A	3.0
Deployed	N/A	N/A	76	28	
Mast Mounted*					
Stowed	108	2900	N/A	N/A	3.0
Deployed	N/A	N/A	231	28	
Rover Body					
Bottom Rear	792	2900	1814	28	5.5
Mid-body	115	2900	264	28	3.3
Bottom Forward	130	2900	297	28	3.4

RDF = 2 1 rad = 1 cGy = 10^{-2} Gy

* Mast-Mounted instruments:
TID is based on 10 month cruise in a mast stowed position, plus 1 Mars year of ops in a deployed position
** Contact /Arm-Mounted instruments:
TID is based on 10 month cruise in an arm stowed position, plus one Mars year ops in stowed position..
Major Assumptions:
1) No attenuation of radiation through spacecraft/rover structural materials
2) No scattering off the martian surface
3) TID values scaled from Cassini 18-module RTG
4) RPS assumed to be parallel to the martian surface
5) For natural radiation for the cruise phase, used 1-year solar proton fluence and assumed 100-mil of spherical aluminum shielding

Figure 3.7.2a: Surface System Radiation Environment – Total Ionizing Dose, rad(Si)

Instrument Location	Cruise (300 days)		Surface (670 sols, 687 days)		TOTAL (Equiv 1 MeV neutron fluence, cm^2)
	RPS (Equiv 1 MeV neutron fluence, cm^2)	Natural (Equiv 1 MeV neutron fluence, cm^2)	RPS (Equiv 1 MeV neutron fluence, cm^2)	Natural (Equiv 1 MeV neutron fluence, cm^2)	
Payload Module					
Analytical Laboratory	1.8E+09	2.6E+10	4.0E+09	6.0E+08	3.2E10
Contact / Arm-mounted**					
Stowed	1.6E+09	2.6E+10	N/A	6.0E+08	3.1E+10
Deployed	N/A	N/A	2.7E+09	6.0E+08	
Mast Mounted*					
Stowed	4.4E+09	2.6E+10	N/A	6.0E+08	4.1E+10
Deployed	N/A	N/A	9.8E+09	6.0E+08	
Rover Body					
Bottom Rear	2.1E+10	2.6E+10	1.7E+10	6.0E+08	9.5E+10
Mid-body	5.0E+09	2.6E+10	1.1E+10	6.0E+08	4.3E+10
Bottom Forward	5.8E+09	2.6E+10	1.3E+10	6.0E+08	4.6E+10

- Mast-Mounted instruments:
- DDD is based on 10 month cruise in a mast stowed position, plus one Mars year of ops in a deployed position.
- Contact/Arm-mounted instruments:
- DDD is based on 10 month cruise in an arm stowed position, plus one Mars year ops in stowed position.
- Major Assumptions
  1) No attenuation of radiation through spacecraft/rover structural materials
  2) No scattering off the martian surface
  3) RPSs assumed to be parallel to the martian surface
  4) For natural radiation for the cruise phase, used 1-year solar proton fluence and assumed 100-mil of spherical aluminum shielding

Figure 3.7.2b: Surface System Radiation Environment - Displacement Damage Dose in terms of Equivalent 1 MeV neutron fluence, cm^2

For reference, further information can be found in *An Introduction to Space Radiation Effects on Micro-electronics* - L.D. Edmonds (JPL Pub 00-06, May 2000)

3.7.3 Mars Surface Operations - Additional Environmental Information

Note: This section includes some historical and preliminary data. An MSL specific Environmental Requirements Document is being assembled and will be available with the final release of the PIP.

The environment of Mars will be only briefly described in this document. An extensive description of the Mars atmosphere, including pressure, temperature, density, winds, and dust storm effects as a function of longitude, latitude, altitude, time-of-season and time-of-day exist in the published literature. The Mars' 6 to 10 mBar atmosphere must be taken into account in instrument design to mitigate potential corona discharge. A fully referenced description of Mars surface properties, including chemical and physical properties, thermal inertia, dielectric constants, regolith temperature, charge particle radiation and solar flux, can be found in NASA technical Memorandum TM 100470, "Environment of Mars, 1988", October 1988 and TM 108513, "A Revised Thermosphere for the Mars Global Reference Atmospheric Model (MarsGRAM). Further information can be found about MarsGRAM through the NASA technical information center at http://ntrs.nasa.gov/. A collection of information specific to sand and dust on Mars is contained in NASA Conference Publication 10074, "Sand and Dust on Mars", February 1991. Other payload design considerations regarding the atmosphere include convective heat transfer and wind loading.

- Thermal Radiation. The thermal radiation environment at Mars is shown in the table below. A dust optical depth factor (extinction factor) of 0.2 applies for a nominal day. On a clear day the optical depth approaches 0. In a dust storm, the optical depth may be much greater than than 0.2, worst case dust optical depth is greater than 3.

Thermal Radiation	**Perihelion**	**Aphelion**
Direct Solar (optical depth 0.0)	710.0 W/m^2	490 W/m^2
Albedo (optical depth 0.0)	0.33 W/m^2	0.25 W/m^2
Direct Solar (optical depth 0.2)	587.0 W/m^2	405.0 W/m^2

- Thermal. Atmospheric and surface temperatures on Mars may range from -123°C to +30°C (or wider depending on landing site selected). Thermal control and thermal interfaces to the payload are described in Section 3.4.1.
- Descent Pressurization Rate. During descent, the ambient external pressure will increase from interplanetary hard vacuum (<10^{-11} N/m^2 or 10^{-14} torr) to the Mars surface pressure of less than 1300 N/m^2 (10 torr). Maximum repressurization rate is <130 N/m^2 /sec (1 torr/sec) during this profile. [TBR]
- Contamination by Monopropellant Engines. The MSL Skycrane system will employ a hydrazine monopropellant propulsion system to effect a soft landing. The descent engines are canted away from the rover, so any plume products (mostly nitrogen and ammonia) deposited on the rover will likely be due to atmospheric re-circulation of the plume. The amount of plume product contamination is still unknown, but it is expected to be small.
- Cruise Heat Rejection System (HRS). The pumped fluid loop cruise heat rejection system is expected to contain approximately 2 liters of liquid water. Cruise HRS fluid loop water is vented from cruise stage just prior to entry. Initial analysis indicates that liquid in the piping around the RPSs will completely vent prior to touchdown.

4. MISSION SCENARIOS

This section discusses the activities that the flight system (with emphasis on the payload) will undergo from Pre-Launch phase through Surface Operations Primary Mission. It includes discussion of those activities taking place just prior to launch (such as removal of red-tag items and encapsulation, and special consideration for integration of the RPS with the flight system as part of the launch processing flow), as well as opportunities for cruise operations (calibrations, etc.) for the payload, within described constraints. The entry, descent, and landing scenario is described, including the scenario for rover deployment from the descent stage. Initial commissioning activities for the rover after arriving on the surface are described, as well as examples of typical surface activity scenarios that the rover will execute during the mission. The ground activities to plan, design, command and analyze these activities will be discussed further in Section 5 below.

4.1 PRE-LAUNCH THROUGH LAUNCH FLIGHT SYSTEM FLOW

Proposals must identify any instrument related activities that must be accommodated during the pre-launch phase; for example, required purge operations, removal of 'red tag' remove-before-flight items, or installation of radioactive sources.

All science instruments will be launched in a powered off state and no science instrument activities are planned during the launch phase.

4.2 CRUISE AND EDL ACTIVITIES

After launch the flight system will transition to the cruise phase of the mission which lasts approximately 300 [TBR] days for the MSL 2009 opportunity. During cruise, the rover payload is totally enclosed in the aeroshell. The rover is designed to provide sufficient downlink during the cruise phase of the mission to monitor overall spacecraft health and status. There will be several opportunities for science payload aliveness/health checks and calibration checkouts during cruise. Science instrument calibration activity may also be accommodated, however no motors or actuators external to instruments will be operated.

All science payloads will be powered off during the Entry, Descent and Landing phase. A general description of EDL activities can be found in Section 2.1.5 of this document.

4.3 SURFACE OPERATIONS PHASE INITIALIZATION SCENARIOS AND ACTIVITIES

The first five sols after landing (TBR) will be devoted to surface mission initialization. The landed mission begins with critical rover deployments (High Gain Antenna (HGA) and Remote Sensing Mast (RSM)), initial rover health checks, and establishment of communication with Earth and/or an orbiting asset. After the RSM has been deployed, the rover will image the landing site. These data, along with rover health telemetry, will have priority for data return. The first communication opportunity will depend on the landing site, date, and time of landing.

Under nominial initialization procedures, initial rover health checks will include calibration/check out of the HGA gimbal, the RSM Azimuth/Elevation Driver, and the various SA-SPAH elements. The rover will check status of all major subsystems. Initial landed engineering camera and science instrument payload health checks will also occur during Surface Mission Initialization.

4.4 SURFACE OPERATIONS PHASE PRIME MISSION SCENARIOS AND ACTIVITIES

The following is a summary of the assumptions and pattern of rover activity over the 670-sol primary surface mission. Conditions affecting the possibilities for operation of science payloads are emphasized in the discussion. Figure 4.4 shows the seasons during the landed mission, and the long-term sun visibility at latitudes within the site-selection constraints of 60^{o} South to 60^{o} North.

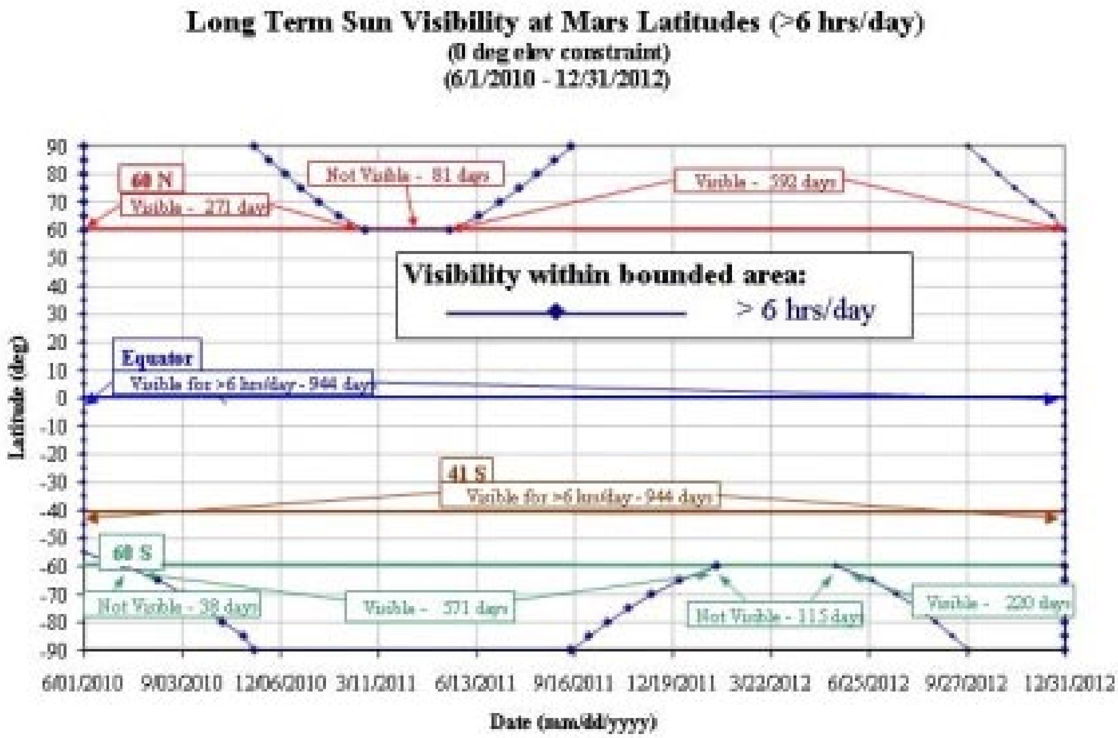


Figure 4.4: Sun Visibility During Surface Operations

4.4.1 Sol Templates

Five different Sol Templates describe the building blocks of the mission operations plan: Traverse and Approach, Site Reconnaissance (Remote Sensing Science), SA-SPAH & Contact Science, Analytical Laboratory & Contact Science, and Recharge/Telecom. The Sol templates described here define preliminary “types” of activities, and are a simplified version of the expected operation scenarios. They are a useful tool for understanding the interplay between operational scenarios and resource availability/ allocations summarized in Table 3.2.5. Resource availability by sol template type, including downlink capabilities are shown in Table 3.2.5.

The Sol Templates defined here are not meant to be complete or exhaustive but are representative of operations building blocks. It is understood that, in practice different sols of the same Sol Template type are not expected to be identical. It is further understood that the sol templates defined here lack sufficient detail to be operationally viable, however it is believed that the level of detail is sufficient for the stated purpose of understanding the interplay between operation scenarios and resource availability/ allocations. An example scenario composed of Sol Templates is shown in Figure 4.4.1.

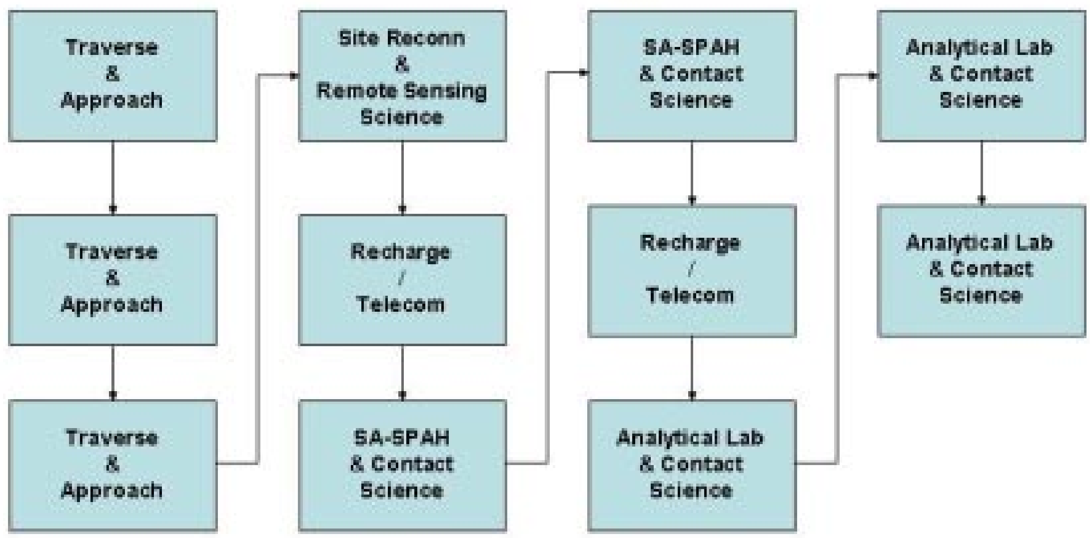


Figure 4.4.1: Example Sample Sol-Template-Based Science Scenario

4.4.1.1 Traverse & Approach

The Traverse & Approach Sol Template exemplifies sols where the primary activity is driving and engineering in support of driving, including navigation and hazard imaging. This sol template applies both to long traverses between sites and to the final approach prior to making contact with a specific target of interest within a site.

Traverses will be paused approximately once per rover-length to acquire hazard camera images for use by on-board hazard avoidance algorithms. Approaches may require more frequent pauses and could require 3 sols from 10 meters out until actual contact. Some portion of the hazcam image data will be transmitted back to earth for engineering and science evaluation as low-latency downlink data. Figure 4.4.1.1 shows fields of view of the MSL hazard cameras. High Latency Downlink is also accommodated during this template.

Science instruments may operate during traverse on a non-interference basis or in support of the driving activity, however to facilitate understanding of resource utilization, the Traverse Sol Template does not include science instrument activity. Limiting factors for instrument operation during traverse may include vibration environment, power management, and memory management.

Figure 4.4.1.1: Hazcam image area for mobility, sample acquisition, and in-situ work.

4.4.1.2 Site Reconnaissance (Remote Sensing Science)

The Site Reconnaissance (Remote Sensing Science) Sol Template is exemplary of sols where the primary activity is mast-mounted instrument science. This Sol Template type will nominally be the first science activity at each new location. The rover may acquire, for example, at least one full-color and at least one stereo 360-degree panoramic image of each visited location. These data will be used by the surface operations team to select rock and regolith targets for further analysis.

4.4.1.3 SA-SPaH & Contact Science

The SA-SPAH & Contact Science Sol Template is exemplary of sols where the primary activities are sample acquisition, triage, science decision making, and analysis. These activities include sample collection by corer or scoop, rock abrasion, sample crushing, and science activities by arm mounted instruments. Opportunity will be provided for arm-mounted contact science instruments to acquire data on samples for purposes of evaluation and triage pre- and post-crushing. There will be capability to view samples with arm-mounted instrument(s) pre-collect in-situ , post-collect on top of crusher prior to falling into crusher mechanism, and after partial or full crushing. Sample processing termination opportunities exist at each stage of sample acquisition and preparation. Termination capability within PI instruments is not required, and is left to the discretion of each instrument provider. Only one collected sample will be processed through the Rover's systems at a time, acquisition of a new sample will start only after the previous sample has been entirely processed out of all subsystems.

4.4.1.4 Analytical Lab & Contact Science

The Analytical Lab and Contact Science Sol Template is exemplary of sols where the primary activity is Sample Analysis by the instruments in the analytical lab and by arm mounted instruments targeting samples prior to their ingestion into the analytical lab instruments.

4.4.1.5 Recharge / Telecom

The Recharge/Telecom sol template is exemplary of sols where battery recharge and high latency telecom are, together, given priority. There is no science instrument activity during this sol type. The goal is to achieve full battery charge over the course of a single sol, while maximizing the data downlink volume. This can be achieved by foregoing all non-essential activities except high-latency telecom.

5. MISSION OPERATIONS SYSTEMS

This section discusses the expected operations concept for the MSL mission, including team structures, uplink and downlink planning scenarios, daily operations timeline, and potential evolution of the operations approach over the course of the mission (early operations and commissioning, routine operations, and potential operations "campaigns" throughout the mission). This concept is in a very preliminary stage at this point, and is derived from the current plans for MER flight operations, making expected adjustments for the considerable difference in mission duration. The concept is expected to evolve considerably over the course of Phase A, in response both to more detailed studies within the project as well as lessons learned from the actual conduct of the MER mission. Following investigation selection, these operational assumptions will be revisited to fully incorporate the needs of the investigations selected, and the operational needs of these investigations. This section focuses on the people and processes used to operate the mission, while the tools used to execute these processes are discussed in more detail in Section 6 below.

5.1 OPERATIONS CONCEPT AND EXPECTED PI SUPPORT OF OPERATIONS

During the surface science phase of mission operations, the project anticipates two modes of ground team operations. The first would involve a centralized co-located operations core at JPL including all science personnel required for rapid turn-around (e.g. daily or more frequently) science mission decision making and instrument operations. This mode would be expected to be used in the early surface mission, just after landing while the vehicle and its interactions with the environment are still being characterized. The second mode, expected to be employed throughout the majority of the mission, is a distributed mode wherein the principal investigators would participate in the science mission making process several times per week, but would be able to delegate the more tactical (i.e., daily) science and instrument operations processes to other members of their team who could participate either remotely or on site at JPL as deemed appropriate by the experiment team. If mission considerations warrant, the project would hold open the option to revert to the co-located, daily, operational paradigm for special mission events, such as science campaigns at unique seasonal or geologic opportunities.

Operations presence for the science teams at JPL pre-launch would be limited to 1-2 surface Operational Readiness Tests (ORT) of duration less than one week to be conducted during the last year before launch, to simulate operations during the early portions of the surface mission, when science operations may be centralized. An additional 1-2 ORTs of similar duration would be conducted pre-launch in the distributed operations mode, which would not require members of the science operations teams to be physically present at JPL. Several additional ORTs will be conducted during the cruise period.

In addition to formal Operations Readiness Testing to be used to validate the flight-configured ground data system and formal operations procedures, the project anticipates several periodic field tests in the time period of 2-3 years before launch, using representative rover models in simulated terrain. Although flight-like instruments may not be available in this time frame, science team members will be expected to participate in these field test (travel to locations at or near JPL for 1-2 week duration) as a form of "development testing" to be used to inform the detailed design of the surface operations procedures.

The MSL ground system is expected to incorporate several novel features. The project intends to implement a distributed, standards based ground data system that will leverage existing infrastructure and commercially available hardware available in the time-frame of pre-launch testing and mission operations. Software required to interact with the central data system at JPL, compatible with one of a small set of specified standard Unix/Linux platforms, would be provided to each experiment team, as well as system administration support to install and maintain this software. The need for specialized dedicated hardware to be used only for these functions is not foreseen, and the project would not intend to provide such unique specialized hardware to the experiment teams. As such, any hardware required for the conduct of mission operations should be proposed as part of the experiment costs.

Additionally, costs of instrument-unique command and telemetry software, for instrument operations, as well as science data analysis software, and operations team process and procedure definitions (to be captured in the Experiment Operations Plan) must be contained in the proposal. As part of lead-up to the Mission System Critical Design Review, the project will conduct a series of detailed peer reviews of both the central common ground systems as well as the distributed science operations design. The science teams should plan to support cross membership in these reviews, participating both in reviewing capabilities provided to them, as well as having capabilities that they provide being reviewed.

Prior to the start of ATLO, the project will conduct training of the science team in the basic ground system functionality (command/telemetry access and data flow) to allow the instrument teams to utilize the flight ground system to control and monitor their instruments during system test both locally at JPL and remotely from the home location of the instrument providers.

Finally, during the distributed operations portion of the surface mission, it is anticipated that video conferencing capabilities at each distributed site will be used to accomplish the level of interaction both between the experiment teams themselves as well as between the experiment teams and the engineering operations teams. If experiment teams do not feel that they will have an appropriate level of dedicated access to such existing facilities at their home locations, the cost of implementing MSL-dedicated facilities should be included as part of the experiment proposal.

5.2 OPERATIONS TEAMS AND FACILITIES PLANS

5.2.1 Flight Team

Figure 5.2.1 identifies the organization of the MSL Flight Operations Team. This section provides on overview of the functions assigned to each element, with emphasis on science team interactions.

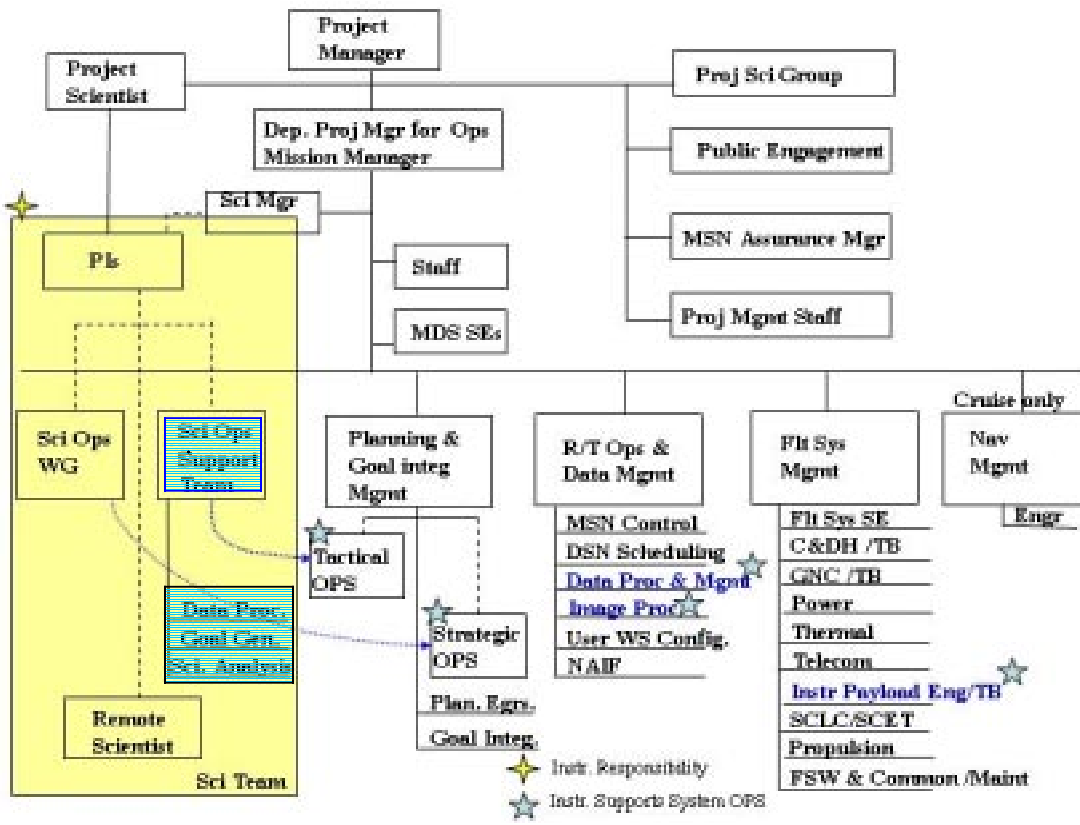


Figure 5.2.1: MSL Flight Team Organization Chart

5.2.1.1 Project Management

The Project Manager is supported during mission operations by the Project Scientist, the Project Science Group, the Science and Payload Manager, the Public Engagement Office, the Mission Assurance Manager and Staff, System Engineering, and Configuration Management Staff, the Deputy Project Manager for Operations, the Mission Manager, and the PIs.

5.2.1.2 Navigation Team

The Navigation Team is responsible for delivering the Cruise Spacecraft to the proper Mars Entry-Descent-Landing conditions. These conditions are influenced by the launch and landing site selected, and other engineering considerations.

5.2.1.3 Spacecraft Flight Systems Engineering Team

The Spacecraft (S/C) Flight Systems Engineering Team is responsible for the overall health and safety of the S/C Engineering Subsystems. They provide S/C level and engineering subsystem performance analysis, operate the S/C testbed, define S/C model maintenance, support Sequence input and review, provide Flight software maintenance, and lead S/C anomaly analysis and recovery. Rover mobility operations are defined within this team. During the Daily Plan Execution Evaluation, they will confirm execution was “as expected, given the circumstances”, and request domain expert support for selected “unexpected events”. This team is also responsible for real time monitoring instrument health and safety from JPL on a daily basis. Should instrument behavior indicate a health problem, the PIs instrument expert will be consulted, and/or instrument safing contingency plans executed at the earliest opportunity. The fundamental responsibility for instrument health rests with the PI.

5.2.1.4 Real Time Operations and Data Management

The Real Time Operations and Data Management Team provides real time DSN coordination and anomaly resolution, verifies real time GDS operations, coordinates Data Return, monitors S/C for Health, Safety, and Selected Events in real-time, radiates and verifies command receipt by S/C, and maintain activity logs involve sub-system, flight/ground activity, and product flow activity. This team utilizes Deep Space Management Systems (DSMS) services, and selected Mission Management Office (MMO) operations to provide for tracking, telemetry, command, and data system operations.

5.2.1.5 Planning and Goal Integration

The Planning and Goal Integration Team provides leadership for both the weekly Strategic and the daily Tactical uplink processes. They respond to the Project Mission Plan to provide detailed mission event planning, contingency planning, DSN scheduling, sequence/goal net planning and integration, sequence/ goal net assembly, translation, and validation, and sequence/ goal net predictions. Each instrument should expect to provide one Science Ops Support Team member to participate in the Tactical processes lead by the Goal Integration Team.

5.2.1.6 Science Operations Team

Each PI provides personnel for the Science Operations Team, specific to his experiment. This is a virtual team whose members need not be collocated. Members can be at JPL or at remote PI sites, as specified by the PI. Within the Science Operations Team, two groups must be supported, the Science Operations Working Group and the Science Operations Support Group.

The Science Operations Working Group is responsible for responding to the Project and Science Acquisition Plans by making inputs to the Mission Plan, and to the Strategic Planning Process. The weekly Strategic Planning Process establishes the data return and spacecraft resource allocation for the next two to four weeks. This provides guidance and constraints for the daily Tactical Planning Process. It is anticipated that Strategic processes will be worked on a 5-day per week, Earth-time (Pacific) first shift basis. Each instrument should provide at least one (full or part-time) Science Ops Support Team member to participate in the Strategic planning and goal integration processes. Costing should take into account the required frequency and complexity of instrument support to this team.

The Science Operations Support Group is responsible for generating Science Command Requests (activities, commands/ goals) for integration into the daily Tactical Uplink Process, for daily science data processing, and for supporting science data analysis. For costing purposes, assume this team will operate one shift per day, 7 days per week, on Mars sol time. Whenever an instrument's data is involved in the tactical decision making, or whenever an instrument is requesting interactive commands, instrument team participation is required. For very interactive instruments commanding every sol, this would require two people to cover all shifts. Costing should take into account the required frequency and complexity of instrument support to this team. However, other work schedules may be chosen for long periods of the mission (5 days, sol time; 5 days, Earth pacific time), based on overall cost constraints and human factors. The design of instruments and experiments should be compatible with any of these shift strategies.

All the decision making science and engineering data required for decision making needs to be available at the beginning of the 8 hr session, with all the appropriate parties involved. Science results that need to be addressed in a way other than according to the weekly strategic plan need to be folded into the Science Operations Team.

5.3 OPERATIONAL FACILITIES PLANS

The primary MSL Mission Support Area (MSA) will be provided at JPL. This area accommodates all elements of the flight team required to assure spacecraft health and safety, and most of the JPL – supplied engineering systems and subsystems team members. These facilities will be established prior to the start of spacecraft integration and test, and most of the test operations will be supported from this Mission Support Area (MSA).

The JPL MSA will be sized to accommodate Key Science Flight Team elements for selected periods, including the early surface operations for characterization of the spacecraft and instruments in the Mars Surface Environment. PIs should specify their needs for this MSA space.

However, it is anticipated that due to the long mission duration, many PIs will chose to operate their instruments remotely, from a self-supplied, physically secure MSA at their home facility. MSL will support this option by allowing secure remote access to the JPL-resident ground data system and tools, and/or providing software and data connectivity for running the "standard" MSL GDS SW in local PI-provided (JPL-specified Unix/Linux) computers.

5.4 OPERATIONAL TIMELINES FOR CRUISE PHASE

Most of the Earth to Mars Cruise is quiescent (no science activities). During this period, there is one U/L sequence every 2 to 4 weeks, downlink data is planned three passes per week for health and safety monitoring, and trajectory tracking. Except for Instrument Checkout Periods described below, there is no science instrument activity. All instruments are in cruise/safe mode (typically, OFF). Two or more Instrument Checkout Periods are planned. These should be performed using a single instrument checkout plan, with one sequence/goal net developed, and that one sequence/goal net used the required number times in cruise. Downlink data will be continuous during the checkout active periods. The only planned real time response will be to place an instrument in a single safe condition.. Also, about half way through cruise, two or more Surface System Operational Readiness Tests (ORT) will be performed. Staffing and schedule timelines will be based on surface operations for this last readiness activity.

5.5 OPERATIONAL TIMELINES FOR SURFACE PHASE

This section covers current understanding of how telemetry will be analyzed and commands generated on a daily basis, so proposers can see what intervals of time (and on what shifts) might be needed. The number of people required to support each investigation, of course, will be up to the proposers to provide.

5.5.1 Spacecraft Data Flow Context

Figure 5.5.1 shows the data flow context for the MSL surface mission. The MSL Rover has capability to send and/or receive data from any selected combination of Mars Orbiters (Odyssey (ODY), Mars Reconnaissance Orbiter (MRO), and Mars Telecom Orbiter (MTO)) and any DSN 34 or 70 Meter Station. MSL expects to use only 34 M DSN Stations. The diagram identifies potential data return paths on each leg of the links. The total expected daily data return volume is defined in Section 3.2.5.4, and is contingent on many constraints including aperture fees, orbiter availability and geometry, landing site, Rover and Orbiter mass storage capability. The MSL/MTO X-band, and the MTO/DSN Ka-band legs are first time applications, and performance is less certain than on the other links.

During the uplink development process, unique experiment/activity names and target names will be defined and associated with the new goals. These names will also be associated with the data products generated by the goals. The names and goal/data associations help to bind the data with the original experiment intent and provide meaningful labels for data tracking and retrieval.

As part of the Strategic U/L Process, The Mission Planning and Goal Integration Team (with its support from Science and Engineering Team members) is responsible for defining the specific configuration for a planning horizon of two to four weeks.

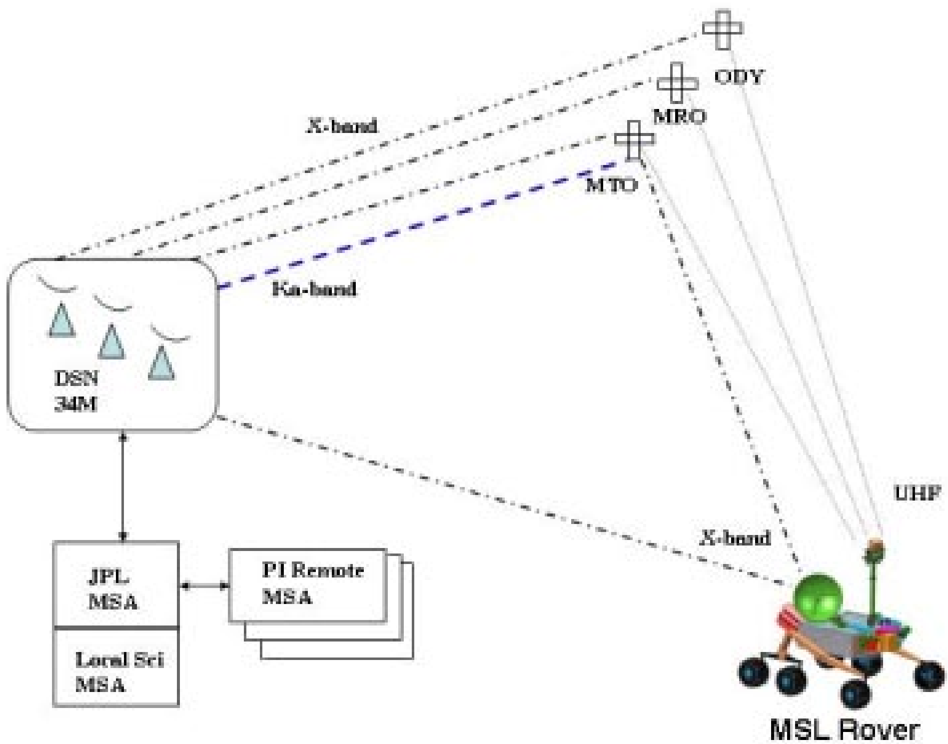


Figure 5.5.1: Data flow context for the MSL surface mission.

5.5.2 Surface Phase Overview

Surface Operations is characterized by a long primary mission duration driven by an inherently interactive geological exploration and surveying process. The Rover has limited resources (power, mass storage, bandwidth, CPU, etc.) which require both flight and ground based management. The operations are driven by a small set of repeating Science Scenarios. These Scenarios are built of Sol Templates (as described in Section 4.4.1). The mission operations system efficiency depends on Ground Data Software and Flight Software that makes it easier and faster for a relatively small (compared to Mars Exploration Rover) flight team to analyze and control Rover operations. The operations design is organized around decisions to be made within each science scenario.

5.5.3 Operations Planning Hierarchy and Timeline

Three levels of planning hierarchy are supported. The first is the Mission Plan (and Science Plan/Objectives), which covers the entire primary mission. Since the Mission Planning phase is completed pre-launch, and only used to guide the operations, it is not further discussed in this section. The second is the Strategic Planning Process, which covers the Next TBD (2 to 8) Weeks - 5 days per week, on prime shift. The third is the Tactical Planning process, which covers TBD (1, 2, or 3 Sols, depending on activity type) – baseline 7 days per week, on Mars Sol time.

5.5.3.1 Strategic Planning/Uplink Process and Timeline

Strategic Planning/Uplink Process activities will run five days per week, Monday - Friday prime shift (earth time), planning for two to eight weeks into the future.
The Strategic Planning/Uplink Process tasks include:

- Plan DSN, Relay Orbiter usage, Engineering Calibration/Maintenance, etc.
- Map Major Science Objectives to Tactical activity types, Shift scheduling, detailed resource planning for Power, Storage, Bandwidth, etc.
- Define & maintain models & parameters for Planning Tools
- Uplink “background” goals
- Relay Orbiters (primary downlink path) used symmetrically with Direct-to-Earth for Uplink and downlink for both science and engineering data
- Lay out the Scheduling and Uplink Verification Environment for Tactical Planning

Typically, one or more meetings per day will be held (combined JPL local, and science remote participation) leading to the approval and partial (background activities, data link schedules) uplink of a new plan covering TBD (2 to 4 weeks) each week.

5.5.3.2 Tactical Planning/Uplink Process and Timeline

Tactical Planning/Uplink Process activities will run seven days per week, Mars SOL time, planning for one to three sols into the future.
The Tactical Planning/Uplink Process tasks include:

- Receiving the decision making data, processing it for decision making review, distributing it
- Receiving and routing the rest of the science and engineering data for further processing and distribution
- Analyzing decision data, creating recommendations, and reviewing proposed actions
- Preparing individual user inputs to the two-phase U/L Planning Process
- Reviewing, correcting, finalizing user inputs for 2nd pass in the U/L Process
- Reviewing, correcting, approving the proposed U/L product Goal Networks
- Routing, Uplinking the products from the DSN to the Rover (direct, or through Orbiter)

Science team members are key participants on the Planning and Goal Integration Team responsible for executing the weekly strategic and daily tactical processes. These members may either be resident at JPL, or operate from the remote PI facilities. See Figure 5.5.3.2 for a typical one-day template overview.

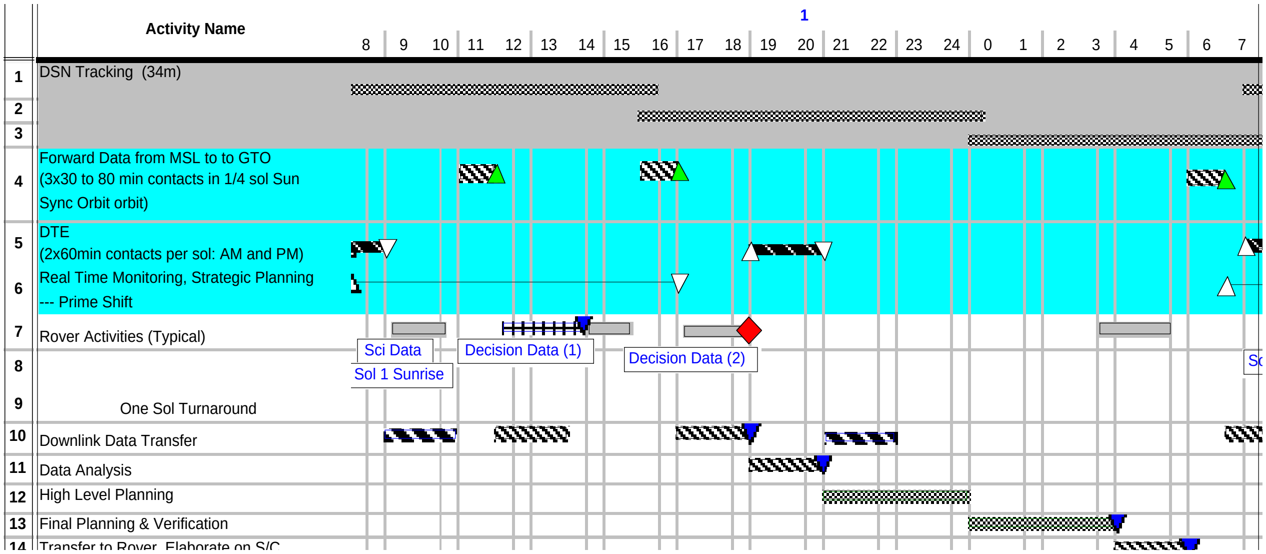


Figure 5.5.3.2: Typical one-day template overview

6. GROUND DATA SYSTEM (GDS)

This section discusses the configuration of ground data systems to be used in the planning, simulation, uplink, downlink, analysis, and product generation tasks described above in Section 5 above. Assumptions about interfaces between the central project ground data system and the parts to be developed by each experiment will be described as will the level of common infrastructure services and interfaces that the project intends to employ. Additionally, the project's expectations on the instrument functional models (software-based) to be used in operations are described in this section.

6.1 GDS CONFIGURATION OVERVIEW

A functional representation of the ground data system software is given in Figure 6.1 below. These software tools are used to support the MOS Team functions defined in Section 5 above.

The GDS software includes:

- A set of uplink development software supporting planning, goal expansion/ elaboration, goal analysis/ visualization, and goal net (sequence) propagation and verification.
- A set of simulation hardware and software supporting SFC and instrument flight software development and operational maintenance, and for high fidelity verification of new mission activities.
- A set telemetry analysis and display software supporting query access to downlinked data (state variables, measurement, and data products).
- A set of PI defined instrument data processing software. Typically, some of the processing functions are implemented in conjunction with the JPL MIPL processing facility, and some are separately implemented by the instrument team. Eventually, science data will be archived in the Planetary Data System (PDS).
- Sets of adapted DSMS-supplied software, providing multi-mission navigation capabilities, Mars orbiter relay planning and operations, data management & archiving capabilities, and access to the DSN command & telemetry delivery capabilities.

Additional details can be found in Appendix G, Additional Details on GSW Design.

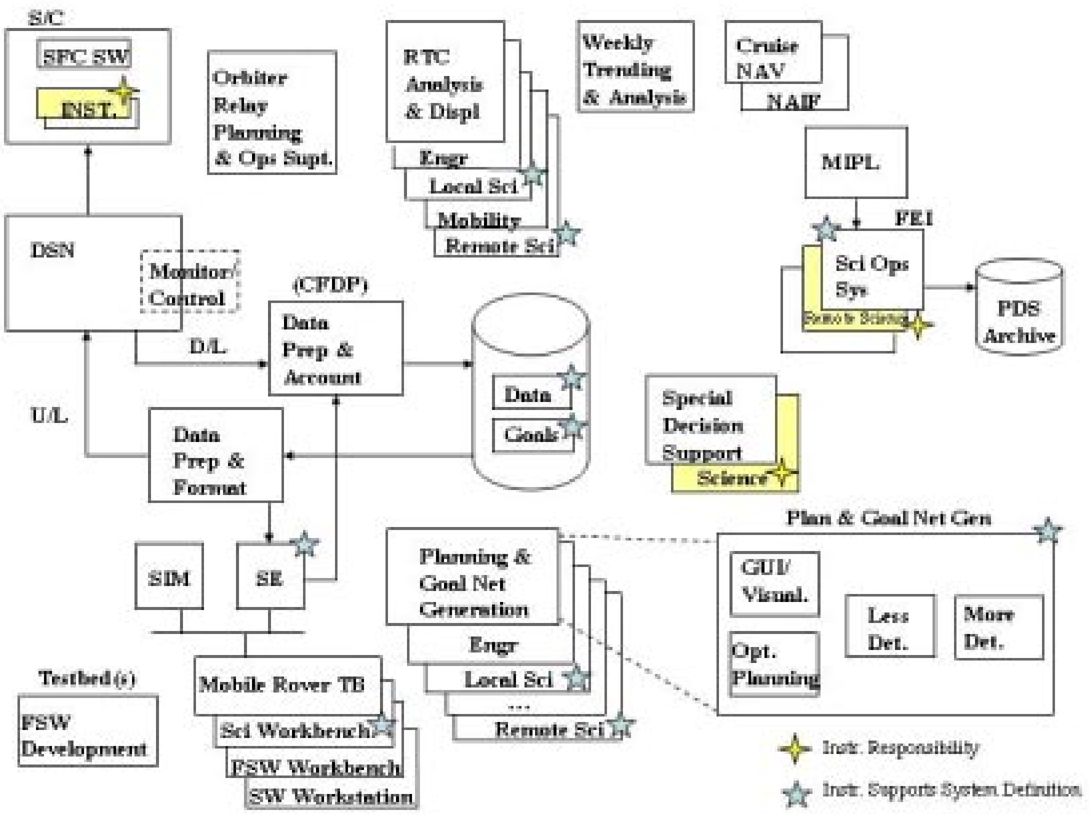


Figure 6.1: Functional representation of the ground data system software

6.1.1 Proposer/PI responsibilities

This section provides a detailed overview of the instrument PI responsibilities for GDS/MOS Requirement inputs cited in Section 7.4.4.6 in support of GDS development and operation. Subsequent sections will address responsibilities for particular software within the GDS.

(1) Instrument behavior and data are needed for common areas of the GDS (those areas dealing with all instruments and subsystems). Portions of this support are also common to that described under the Flight System Computational Resources and Flight Software, Section 3.2.6. This support includes:

(a) Definition of Instrument SW Interface protocols

(b) Definition of Instrument Telemetry and Data Products

(c) Definition of Instrument Commands, Goals, Goal Elaborations (expansions)

(d) Definition of Instrument models (behavior/modes/flight rules) for uplink planning and goal integration

(e) Definition of Instrument resource utilization (Power, Data, Bandwidth, CPU, etc.)

(2) Instrument data processing requirements (Engineering/Housekeeping, and Sensor Data). These include:

(a) Data compression/decompression

(b) Extraction of Health and Safety data for review

(c) Extraction of Sensor Data needed for Tactical Decision Making

(d) Data preparation for archiving

(e) Extraction and/or analysis of other data needed for Mission Operations

(3) Required Instrument Simulation SW and data

(a) Software only behavioral models to support testbed simulations when the instrument hardware is not present

(b) Definition of Bit-level (interface) models

(c) Instrument SE, capable of providing sensor stimulus and/or data insertion

(d) Typical instrument sensor data consistent with various instrument modes and data products

(4) Instrument definition of Telemetry Display and Analysis SW

(a) Definition of any unique display requirements

(b) Definition of instrument data viewers for the instrument

(c) Definition of instrument data analysis routines to be linked to the display data

(5) Instrument Data Processing Software

(a) Data compression/decompression requirements and/or algorithms

(b) Extraction of Health and Safety data for review

(c) Extraction of Sensor Data needed for Tactical Decision Making

(d) Data preparation for archiving

(e) Extraction and/or analysis of other data needed for Mission Operations

(6) Instrument Decision Support Software

(a) For fast, tactical decision making, some proposers may require specialized analysis software over and above the Instrument Data Processing Software.

(7) Instrument DSMS Software

(a) Full definition of Data Products for Data Catalog and Data Management handling

7. SCIENCE / PAYLOAD MANAGEMENT

This section describes the roles and responsibilities of key personnel in the successful development and conduct of science investigations for the MSL mission. Only those roles and responsibilities addressing payload management issues are addressed here. While each investigation provider is encouraged to utilize techniques that have proven successful on previous space missions, the following principles apply:

(1) Consistent with applicable NASA Management Instructions, the Principal Investigators (PIs) bear the primary responsibility for ensuring that their instruments are designed and developed in a manner which will meet the objectives of the selected science investigations. The PIs must demonstrate to the Project that this responsibility has been fulfilled, as the Project will not attempt an independent verification that the performance requirements are met.

(2) Project design control will focus on the interfaces of the instrument with the Surface System, and Mission Operations System including system-level test, and mission design.

(3) The Project shares with the PI the responsibility for ensuring that the Mission Assurance (MA) aspects of the instrument development effort are consistent with both the mission duration and the expected environments. Consequently, the Project will assess the

development effort to verify that the MA aspects of the PI's Project-approved Experiment Implementation Plan (EIP) are being implemented.

(4) Each PI is fully responsible for ensuring that the selected investigations are implemented within the resource allocation existing at the time of MSL science confirmation, except as modified by written Project approval.

7.1 ROLES AND RESPONSIBILITIES

Briefly, the MSL Project Manager is responsible for the overall MSL mission success, the Project Scientist for the scientific integrity of the MSL mission, the Payload Manager for payload development and delivery for integration with the spacecraft, the Mission Manager for flight operations, and the Principal Investigator for the success of her/his experiment.

7.1.1 Payload Manager Responsibilities

The JPL Payload Manager provides payload contract management and is responsible for payload development, interface conformance of the instrument to the approved Interface Control Documents (ICD), and delivery of the payload for integration. Key functions of the JPL Payload Manager include, but are not limited to, the following:

(1) Establish and approve the interface agreements between the payload elements and other systems, as part of the functional requirements and the design specification of the payload system.

(2) Plan, direct, and control resources, schedule, risk, and performance commitments in fulfilling the payload system objectives.

(3) Provide support for integration of the payload system with the flight system, as appropriate.

(4) Assure the quality, accuracy, and integrity of the technical documentation, including reports and other correspondence.

7.1.2 Project Scientist Responsibilities

The Project Scientist is responsible for the scientific integrity of the mission. The Project Scientist represents the Scientific Investigators of the mission to the Project and to NASA. He also represents the Project, its Science Teams, and the Mission Science to the broader science community and to the general public. Key functions of the MSL Project Scientist include, but are not limited to, the following:

(1) Make recommendations, as appropriate, to the MSL Project, the JPL Mars Exploration Directorate, and NASA Headquarters regarding changes in the MSL science objectives, including those of individual investigations.

(2) Chair the Project Science Group (PSG). Through the PSG the Project Scientist:

(a) Adjudicates conflicts amongst the science investigations

(b) Evaluates and makes recommendations to the MSL Project regarding proposed modifications to mission design or instrument operations

(c) Ensures preparation and approval of the Science Requirements Document

(d) Approves the Science Data Analysis, Management & Archiving Plan prior to data acquisition

(3) Assure public dissemination of scientific results by the MSL Project and its science investigations through professional meetings, publications, and releases by the public affairs office, including active support of outreach activities.

7.1.3 Principal Investigator Responsibilities

The Principal Investigator (PI) is responsible for all aspects of the selected science investigation. These include the instrument design and development, fabrication, test and calibration, and delivery and post delivery support of flight hardware, software, and associated support equipment within project schedule and negotiated resources. The PI is also responsible for planning and support of the instrument operation, data analysis, and overall conduct of the investigation including leadership of Participating Scientists selected as team members later in the project life cycle. Key functions of the Principal Investigator include, but are not limited to, the following:

(1) Be the investigation's primary point of contact with other Project elements regarding investigation requirements, schedules, and funds, and where applicable, earned value reports. Represent the investigation in relevant Project reviews and meetings.

(2) Generate and maintain documentation regarding the Investigation:

- (a) Functional Requirements Document (FRD)
- (b) Experiment Implementation Plan (EIP)
- (c) Experiment Operations Plan (EOP)
- (d) Inputs to the Interface Control Documents (ICDs)
- (e) Investigation contribution to Science Requirements and Science Data Management Plan (SDMP)
- (f) Calibration Plan
- (g) Test/Verification Plan
- (h) Functional Description Document
- (i) Other documents listed in Section 7.4.4

(3) Generate and maintain a risk list, and support the project's process for early identification and management of risk-items, both technical and programmatic.

(4) Ensure delivery and operation of an instrument able to achieve the investigation science objectives within mission resources, assuming nominal spacecraft operation:

- (a) Meet approved schedules and cost plans
- (b) Design, build, test, and calibrate the instrument appropriately including applicable reliability and quality assurance requirements.
- (c) Design, build, test, and verify software and unique ground support equipment
- (d) Support integration and test of the instrument at the surface system integration facility and at the launch site

(5) Participate in the Project Science Group (PSG) meetings and associated working groups.

(6) Participate in Landing Site Selection Workshop Process.

(7) Support mission operations planning and execution, including:

- (a) Definition of mission database contents, including but not limited to, flight rules sequences, calibration data, telemetry, and commands
- (b) Integrated mission data/sequence development and flight software integration, using the surface system test bed and Payload Checkout Bench (PCB)
- (c) Operations test and training, including GDS and end-to-end tests

(8) Conduct the instrument's operation consistent with the Mission Plan and the MSL Project resources, including:

- (a) Generation and validation of instrument commands, sub-sequences, and flight software modifications
- (b) Evaluation of the instrument's heath, safety, and performance in test and in flight

(9) Ensure that the reduction, analysis, reporting, and archival of the results of the investigation meet with the highest scientific standards and completeness, consistent with budgetary and other recognized constraints.

7.2 SCIENCE / PAYLOAD DEVELOPMENT SCHEDULE

Figure 7.2 illustrates the MSL master payload schedule, including payload deliverables and reviews.

7.2.1 Flight Hardware Delivery Schedule Margin

Proposals will be required to show 10 weeks of funded schedule margin on Flight Model delivery dates shown in Figure 7.2

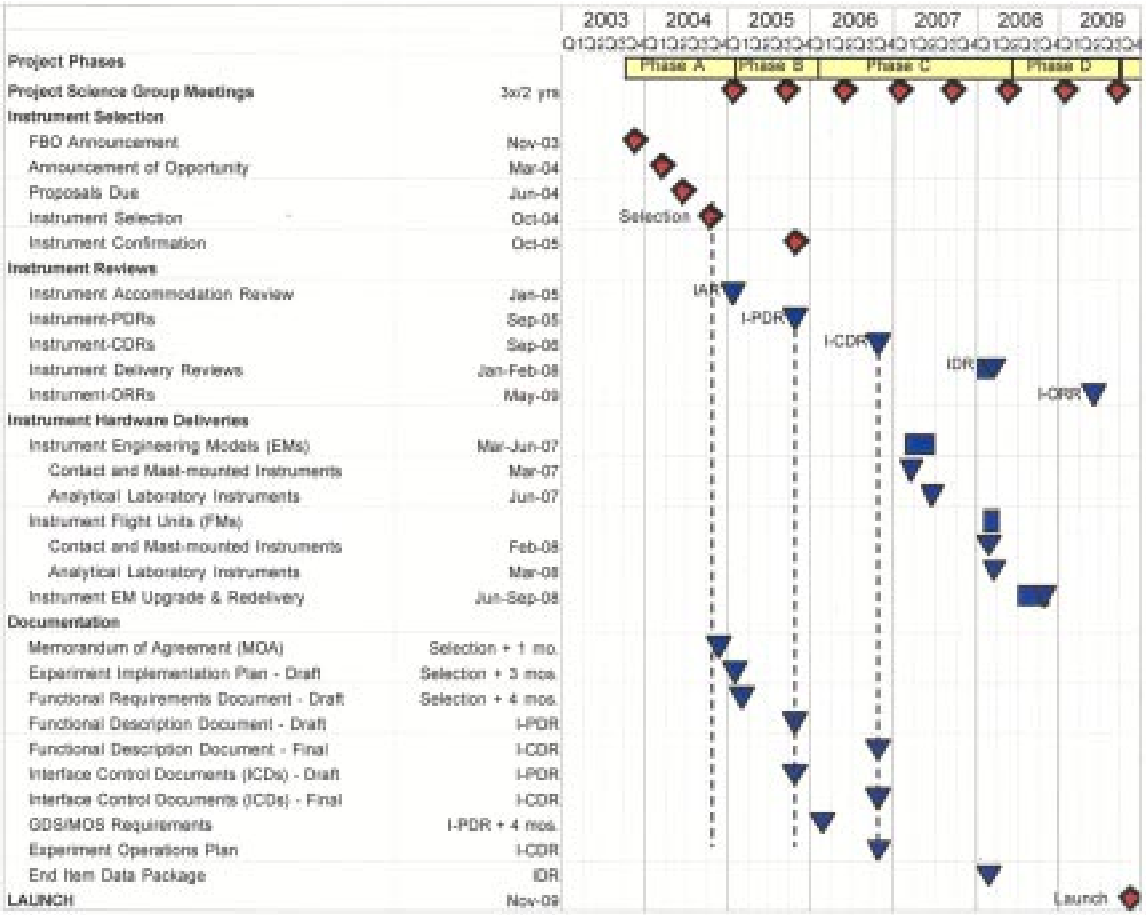


Figure 7.2: MSL Science Instrument Payload Delivery and Review Schedule

7.3 REVIEWS

The payload PIs or their designates will be expected to attend and support, as needed, project design and management reviews, ground system reviews, and occasional informal reviews scheduled by the project with instrument issues to be discussed and/or presentations to be made by the PI or representative. In addition, payload specific reviews will be held for all investigations. Table 7.3 is a summary of the scheduled science instrument reviews.

Table 7.3: Science Instrument Review Summary

REVIEW/EVENT	HOST	DATE
Payload Initial Selection	--	October 04
Monthly Management Reviews (MMRs)	PI	Monthly
Kickoff	JPL	Selection + 1 mo
Instrument Accommodation Review (IAR) (support)	JPL	Selection + 3 mo
Instrument Preliminary Design Review (I-PDR)	PI	Selection + 10 mo
Payload Selection Confirmation	--	Selection + 12 mo
Instrument Critical Design Review (I-CDR)	PI	PDR + 12 mo
Instrument Delivery Review (IDR)	PI	FM Delivery – 1 mo
Hardware Readiness Certification Review (HRCR)	JPL	FM Delivery + 1 wk
Instrument Operations Readiness Review (I-ORR)	PI	Launch – 6 mo

7.3.1 Programmatic Reviews

In general, the instrument design reviews precede the project design reviews and, except as noted, will be held at the PI's or provider's location.

The Payload Manager, with input from PI, will select and convene a standing review board for the payload milestone reviews (IAR, I-PDR, I-CDR, I-ORR). This board will participate throughout the investigation lifecycle to provide continuity of review. Board membership will include Project Science and Technical Management representatives, as well as members from the PI and major subcontractor organizations. As appropriate, the standing review board may be augmented by technical and discipline experts for any given review.

PI should plan for and mount appropriate technical peer reviews prior to milestone reviews to validate approach and design decisions. These peer reviews will be summarized at the milestone reviews.

7.3.1.1 Monthly Management Reviews (MMRs)

Monthly management reviews of programmatic, financial, and technical status will be held at the instrument provider's site. Major topics to be addressed are:

(1) Progress during past reporting period vs. plan

(2) Discussion of activities accomplished and not accomplished

(3) Discussion of problems, concerns and recovery plans

(4) Schedule status and variance from baseline discussion

(5) Cost discussion, including comparison of actual and planned cost and an explanation of any variances

(6) Technical/design status, major technical issues and risks, waivers, and problem/failure report status

(7) Implementation progress, including procurement and subcontract status

7.3.1.2 Instrument Accommodation Review (IAR) [Simmonds]

Approximately 3 months after the initial science payload selection and the start of preliminary design activities, each investigation will conduct an Instrument Accommodation Review (IAR) at JPL. The purpose of the IAR is to establish the instrument's compatibility with the surface system and to facilitate early establishment of a firm commitment with the instrument provider for the Project-supplied resources and interfaces (including, but not limited to, mass, power, volume, sample requirements and fields of view, etc.) to conduct their investigation. The final negotiated commitment documented in the ICDs will be used by the Project to assess the overall payload needs and as the basis for recommending the confirmed payload to NASA at the Confirmation Reviews (CRs) held by NASA.

7.3.1.3 Instrument Preliminary Design Review/Confirmation Review (I-PDR/CR)

The instrument provider will hold an instrument preliminary design review (I-PDR) at the hardware developer's location. This review is intended to allow the Project insight into the progress being made in the instrument design and comparison to the planned performance and estimated margins. The findings will be reported at the project system preliminary design review (PDR).

The completed functional requirements document (FRD) and the interface control documents (ICDs) presented at the I-PDR are summarized at the system PDR, with the instrument provider in a supporting role. Topics at the I-PDR include discussion of the FRD, description of flight interfaces, and interactions between other instruments competing for shared surface system resources, as well as status of any long-lead procurements. The FRD goes under formal change control prior to I-PDR. The ICDs goes under formal change control less than thirty (30) days after this review is completed and support a formal freeze of interfaces with the payload module and surface system approximately 3 months prior to the system PDR.

The Confirmation Review is the final step in the selection process by NASA and, although PIs do not attend or participate directly in this review, the Experiment Implementation Plan and the Instrument Preliminary Design Review results will be key inputs.

7.3.1.4 Instrument Critical Design Review (I-CDR)

The last design review prior to initiating flight hardware fabrication is the instrument critical design review (I-CDR). The I-CDR precedes the flight system critical design review (CDR) at the completion of the payload detail design. Topics include status of hardware design, fabrication, test, and calibration, software design and test plans, plans for integration, description of support equipment, finalization of interfaces, command and telemetry requirements, and discussion of environmental and system tests. The I-CDR includes reports from technical Peer Reviews held in preparation for this review. The findings of the I-CDR will be reported at the project CDR, with the PI in a supporting role.

7.3.1.5 Instrument Delivery Review (IDR)

The instrument provider will conduct an Instrument Delivery Review (IDR) just prior to instrument delivery to the flight system. Topics include results of verification of the instrument compliance with the FRD and the ICD, the results of environmental testing, and the completeness of the end item data package (EIDP). Closure and risk-rating of pre-delivery problem/failure reports will also be reviewed.

7.3.1.6 Hardware Readiness Certification Review (HRCR)

HRCR is a final review of documentation and open item closeout process accompanying delivery of flight hardware for integration. The HRCR is conducted by JPL Payload System Engineering with support from the PI team.

7.3.1.7 Instrument Operations Readiness Review (I-ORR)

An instrument operations readiness review (I-ORR) will be conducted for each investigation team to assure interface compatibility between the mission operations system and the investigating team and to assess the operations readiness of the science team. This review is scheduled to occur about six months before launch and will focus on the operations environment, including hardware and facility readiness, a walk-through of the uplink planning and downlink analysis process and capability, and a review of the status of data analysis software.

7.3.2 Instrument Interface Meetings (IIMs)

A series of meetings will be scheduled to work out interface issues and document the design in the interface control documents (ICD). The MSL Project will host the initial “Kick-Off” meeting at JPL. It is likely that the instrument interface meetings (IIM) that follow will become “virtual” meetings, with the instrument provider supporting by a combination of conference calls, video conferences and e-mails.

These are not formal reviews, but rather working meetings between the instrument provider engineers, the spacecraft engineers, and the JPL instrument interface engineers. The initial focus will be on hardware and software interface issues, but will transition into scenario-based resource sub-allocation and operational strategies as the launch date approaches.

7.3.3 Use of Teleconferencing and Video Conferencing

Wherever possible, the project will utilize collaborative online meeting (e.g., Sametime), screen sharing, teleconferencing and videoconference facilities to minimize travel expenses for routine meetings; e.g., IIMs, MMRs, etc. PIs will be required to support a project standard for video and teleconferencing.

7.4 DELIVERABLES

In the following sections, Tables 7.4.2, 7.4.3, and 7.4.4 identify preliminary payload delivery dates. As described in the following sections, the instrument providers must, while meeting schedule and cost, do the following:

(1) Shortly after selection, sign a memorandum of agreement (MOA) or contract, as applicable, with the project documenting resource allocations.

(2) Provide and maintain required documentation (see Section 7.4.4)

(3) Support the development and maintenance of ICDs.

(4) Provide monthly technical progress reports (TPR) and monthly financial management reports (FMR).

(5) Deliver a CAD model of top assembly,an analytical thermal model, and a payload interface simulator to the project.

(6) Deliver an engineering model that represents the form, fit, and function of the flight unit; negotiate any deviations with the MSL Project.

(7) Deliver flight hardware (including thermal blankets if required by the ICDs) with suitable shipping containers and any protective covers required.

(8) Deliver a refurbished EM which incorporates any configuration, or operational changes made to the flight unit since initial EM delivery.

(9) Provide necessary instrument-unique payload Ground Support Equipment (GSE) for stand-alone integration, and launch operations.

(10) Provide an instrument end item data package (EIDP) for each flight model hardware deliverable, as described in Section 7.4.4.9.

(11) Provide timely information (see Table 7.4.3) to establish and maintain controlled baselines for software interfaces, shared computational resources, mission data and mission operations timelines and sequences.

7.4.1 Earned Value Reporting

The PI will be required to initiate cost accounts according to an agreed upon Work Breakdown Structure and Dictionary. An integrated schedule and baselined budget will be required three months before the implementation phase to support project-level earned value reporting and analysis. Earned Value reporting and statusing will begin after the Preliminary Design Review. The project office will establish reporting metrics and dollar thresholds and related guidance for future variance analysis before PDR. The PI will also be required to periodically provide an estimate-at-completion (EAC) as part of the regular management review process. Any individual investigation whose contract value exceeds $25 M will be required to independently implement an acceptable earned value reporting system.

7.4.2 Hardware

The instruments must be accompanied by all ground support equipment (GSE) needed to support system test including optical and/or thermal targets. It is assumed that GSE delivered with the EM will also support the FM delivery. An end item data package (EIDP) must accompany the flight hardware. The Flight-like Payload Bus Interface simulator, engineering model, and flight unit delivery schedule is shown in Table 7.4.2.

Table 7.4.2: MSL Payload Hardware Delivery Schedule

HARDWARE DELIVERABLES	DESCRIPTION	DUE DATE
Flight-like Payload Bus Interface (short-term loan)	Payload interface h/w that is functionally identical to the flight unit; e.g. a plug compatible breadboard	PDR to CDR timeframe
Engineering Model (EM) & GSE must conform to the ICD	Supports Payload Checkout Bench Integration, including mechanical interface verification	March - August 2007
Flight Spare Parts, Subassemblies & Long Lead Items		February/March 2008
Flight Unit	Supports Flight Integration	February/March 2008
Return EM to PI		June 2008
Refurbished Engineering Model (EM) & GSE	Supports PCB/Mission System Model Integration	September 2008

7.4.2.1 Flight-like Payload Bus Interface

A short-term loan of hardware to support early Electrical and Protocol Tests and a preliminary electrical interface checkout test against a representative system-level interface will be required; for example a plug-compatible breadboard, prior to EM delivery. The duration of the loan is expected to be on the order of several days. This unit may be used with the Payload Checkout Bench (PCB) or developmental surface system hardware. The interface must be functionally identical to the flight unit.

7.4.2.2 Engineering Model (EM)

The Engineering Model (EM) is non-flight hardware that must be form, fit, and interface equivalent to the Flight Model (FM) hardware. The EM is planned to be integrated into the Payload Checkout Bench (PCB) to support testbed activities. Specific details will be negotiated with the MSL Project and documented in the ICD. The PCB is used to verify the instrument mechanical interfaces with the surface system. The EM must also be capable of interface pathfinder testing with the flight system during ATLO. Any GSE needed to maintain the health of the EM prior to integration into the PCB (e.g., cooling, purge) must be provided by the PI; the responsibility for any special handling equipment required post-integration and documented in ICDs will transfer to the JPL Flight System team. Any requirements for post-integration special handling equipment such as purge and cooling must be specified in the proposal. The EM system must provide mechanical, electrical, timing, and protocol interfaces that are identical to the flight instrument, be capable of being stimulated to provide operational data, and be compatible with a clean room environment. The EM must also be capable of providing data sets that can be used to exercise the Mission Operations System/Ground Data System (MOS/GDS) Software. It is not required for this unit to be capable of surviving environmental tests unless it is expected to replace the FM for system-level testing. Following initial integration and test operations; and delivery of flight models, the EMs will be returned to the PI for refurbishment to match any configuration changes made on the flight model instrument since the initial EM delivery. Redelivery of the EMs would then support integration of the Mission System Testbed to support operations. This unit will remain with the Payload Checkout Bench/Mission System Testbed during mission operations and will be returned only after the science mission is complete.

7.4.2.3 Flight Unit

The flight unit, or Flight Model (FM) hardware must meet all the requirements contained in the Functional Requirements Document and Interface Control Documents (ICDs), as well as reliability and mission assurance requirements. The FM will be integrated with the flight system. The accompanying Ground Support Equipment must contain all hardware and software required for maintaining the health of the flight unit and providing for stimulation and testing. Requirements for purges, etc., included in the ICD will be provided by the Flight System subsequent to integration. Pre-integration instrument level purge carts, etc., will be the responsibility of the PI. Prior to the FM payload science instrument integration, all instrument level ground support equipment, (e.g., cooling, continuous purge) will be the responsibility of the PI. Any anticipated instrument-unique accommodation elements should be described in the proposal

7.4.2.4 Flight Spares Strategy

Selected flight-level parts, subassemblies and long lead items must be deliverable as spares to be used in the event of a post delivery failure of a flight instrument. PIs must propose a sparing strategy; a final sparing plan will be negotiated with each instrument after selection.

7.4.3 Software and Data

Instrument software and data delivery dates are shown in Table 7.4.3.

Table 7.4.3: MSL Payload Software and Data Delivery Schedule

SOFTWARE DELIVERABLE	DESCRIPTION	DUE DATE
Telemetry Calibration Data • Preliminary • Final	Definition of Instrument Telemetry Calibration Curves, Algorithms, and Tolerances	 I-CDR IDR
Flight Sequences • Preliminary • Final	Definition of Instrument Sequences for Use in System Test to Include All Instrument Operations Modes	 I-CDR IDR
Analytic Thermal Model • Preliminary • Final	Used to develop the system-level thermal design and support the thermal vacuum test	 I-CDR IDR
Analytic Structural Model • Preliminary • Final	Used to develop the system-level dynamic loads and support the system level dynamics tests	 I-CDR IDR
Initial Flight S/W and supporting documentation	Provide the initial FSW load to support EM instrument /Payload Checkout Bench I&T	IDR
Initial Ground Software and supporting documentation	Provide the initial ground software to support system tests	IDR
Final S/W Baseline and supporting documentation	Provide the final FSW load to support flight ATLO	I-ORR
Final Ground Software and supporting documentation	Provide the final ground operations and data analysis software to support launch	ORR-1 Month

7.4.3.1 Software Documentation

Planning, requirements, design, build, test, and verification information that provides insight into the software implementation should be provided as it becomes available, in accordance with the PI's normal development plan, included in the Experiment Implementation Plan.

7.4.4 Documentation

Instrument documentation delivery dates are shown in Table 7.4.4.

Table 7.4.4: MSL Payload Documentation Delivery Schedule

DOCUMENT	**DESCRIPTION**	**EVENT DATE OR DUE DATE**
MOA/Contract	Memorandum of Agreement	Selection + 1 mo
EIP/Safety Plan	Experiment Implementation Plan	Selection + 3 mo
FRD	Functional Requirements Document	Selection + 4 mo
FDD • Preliminary • Final	Functional Description Document Definition of Instrument Operation Constraints and Requirements	 I-PDR I-CDR
Command Telemetry Data • Preliminary • Final	Dictionary of Instrument Commands and Operations Modes; Definition of Instrument Telemetry Parameters	 I-CDR IDR
ICDs • Preliminary • Final	Inputs to Interface Control Documents	 IAR/PDR CDR
Instrument Calibratin Plan		I-CDR
Instrument Test & Verification Plan		I-CDR
GDS/MOS Requirements	Inputs to Ground Data System and Mission Operations System Requirement Documents	I-PDR+ 4 mos.
Experiment Operations Plan	Phase E Technical and Implementation Plans	I-CDR
P/L Handling Requirements • Preliminary • Final	Payload Handling Requirements Document	 I-CDR IDR – 1 month
Operations / Test Procedures		Prior to use
Unit History Log Books		Instrument Delivery Review
End Item Data Package (EIDP)		Instrument Delivery Review

7.4.4.1 Memorandum of Agreement (MOA) / Contract

Shortly after payload selection, the project will enter into an agreement with each instrument provider for the implementation of the selected proposal. The vehicle for this agreement will be a contract for non-government entities, and a memorandum of agreement (MOA) for government entities

The final version of this PIP document (to be released with the AO) will contain an Appendix including a specimen contract, and links to various other contractual references, provisions, etc. Proposers will be requested to review and document any anticipated exceptions to these general contractual provisions in a Proposal appendix as well as to provide certain information that will facilitate the rapid establishment of initial contractual relationships between the JPL MSL Project Office and the Investigator. Though this material and requested response is not formally part of the AO solicitation or the resulting proposals, compliance with the request will facilitate a more rapid contracting process with JPL following the completion of the NASA Solicitation and Selection Process.

7.4.4.2 Experiment Implementation Plan (EIP)

An experiment implementation plan (EIP) is required from all payload providers, and is deliverable prior to the Instrument Accommodation Review. An outline of the EIP follows:

(1) Personnel

(2) Project Interface

(3) Instrument Design, Fabrication, Test, Calibration, Verification and Validation (V&V), and Operations Development Plans

- (a) Schedule and Schedule Management
- (b) Cost Control / Earned Value Reporting (if contract is above $25 M)
- (c) Subcontracts
- (d) Hardware and Software Development
- (e) Operations and Data Analysis Development
- (f) Facility and Interface Development
- (g) Hardware & Software Requirements Verification & Compliance Matrix
- (h) Environmental Testing
- (i) Mission Assurance
- (j) Configuration Management and Control
- (k) Calibration

(4) Requirements for JPL Support and JPL-Supplied Hardware

(5) Requirements for Science Team Support and Data Analysis

(6) Safety Plan

(7) Phase C/D Cost Plan

Investigation proposals should address preliminary planning for each EIP section identified above. As part of the preliminary planning for the Safety Plan, investigations that plan to fly small quantities of radioactive material for heating, calibration, or other reasons must make such intentions clearly defined.

7.4.4.3 Safety Plan

The Investigation Safety Plan is to be incorporated into the EIP, and must supply the necessary payload safety information to the MSL Project Safety Engineer for incorporation into the Missile System Pre-Launch Safety Package (MSPSP) and payload safety reviews at the launch site. All documentation regarding payload safety information, including detailed information on hazardous elements such as radioactive sources, lasers, hazardous mechanical elements, pyrotechnic devices, etc., must be submitted by the MSL project to support launch safety and National Environmental Policy Act (NEPA) reviews.

Software safety/hazard analyses and audits will be conducted by the Project to ensure compliance with NASA / JPL software safety policies, to verify that output values and/or timing do not place the system in a hazardous state, and to ensure that the software responds appropriately under hardware failure scenarios.

7.4.4.4 Functional Requirements Document (FRD)

The PI is responsible for writing the instrument functional requirements document (FRD) subject to project approval.

7.4.4.5 Interface Control Documents (ICDs)

Interface control documents (ICDs) are negotiated directly between the PI and the MSL Project. The MSL Project is responsible for developing and maintaining configuration control of the ICDs, using input from the instrument providers.

ICDs identify all payload interfaces, including the instrument envelope, mounting, mass, center of mass, electrical and mechanical connections, end circuits, consumption and dissipation power, pyrotechnic devices, features requiring access or clearance, sample acquisition and processing requirements, purge requirements, environmental requirements, software requirements, testing, facility support, view angles and clearances, thermal control, red and green tag lists, and GSE interfaces/requirements.

7.4.4.6 GDS/MOS Requirements Documents

In support of Ground Data System/Mission Operations System, PIs will be required to generate an Instrument Operations Processes and Procedures document, and to provide instrument specific inputs to the following project documents:

(1) Operations Concept document

(2) MOS/GDS Requirements document

(3) Preliminary Operations Processes and Procedures document

(4) Preliminary Software Interface Specifications

(5) Preliminary Operations Interface Agreements

7.4.4.7 Experiment Operations Plan

Based on Ground Data System/Mission Operations System Requirements, the PI will be required to generate an Experiment Operations Plan that includes the following:

(1) Overall Approach, Organization and Roles for the Operations Phase

(2) Total investigation costs for ground system development, mission operations, and data processing support in Phase E (not applicable for non US-funded portion of contributed PI Investigations)

(3) A budget for the PI and for each Co-I or TM and for specialized data processing support, as appropriate (not applicable for non US-funded portion of contributed PI Investigations).

(4) Post-launch plans for ground data system development and for operations personnel training and test to achieve orbital operations readiness

(5) Ground system development, mission operations and data analysis schedules for Phase E

(6) An investigation data management plan for science data processing, distribution, analysis, and archiving

(7) Updates to reflect final design in response to GDS/MOS requirements provided previously in this document

7.4.4.8 Payload Handling Requirements and Unit History Logbook

The Payload Handling Requirements document describes the appropriate handling procedures and constraints necessary to ensure the safety of the flight and EM hardware (after delivery) to the JPL. Where appropriate, handling requirements documentation may also be required for Ground Support Equipment.

The unit history logbook accompanies the delivery of the flight hardware. The logbook documents all instrument power cycling and operations entries including initial notation of any anomalous behaviors.

7.4.4.9 End Item Data Package (EIDP)

The EIDP includes, but is not limited to, PFR status and closure information, final drawings, CAD 'solid model' (including dimensions) of top assembly in an agreed electronic format, mass properties, qualification data, reliability analyses including failure modes, effects and criticality analysis (FMECA), parts stress analysis (PSA) and single event effects (SEE), thermal and structural analysis results, footprint drawings, as-built power measurements, final part and materials as built lists (including government-industry data exchange program (GIDEP) traceability), completed instrument requirements verification and compliance matrix, report, planetary protection measures, and high resolution color photographs of the assembled instrument (with scale inserted). An EIDP must be provided for all flight model hardware.

7.5 RECEIVABLES

The MSL project will supply to the instrument providers all instrument-mounted flight connectors, with connector savers, for the interfaces between PI hardware and spacecraft. MSL project will supply all flight temperature sensors and heaters, as may be required, for purposes of temperature monitoring and survival heating. MSL project will provide Science Operations and Planning software that can run a project specified, PI provided Science Operations and Planning Computer (SOPC). These items are summarized in Table 7.5.

Table 7.5: MSL Science Investigation Receivables Schedule

RECEIVABLE ITEM	DESCRIPTION	EVENT DATE OR DUE DATE
SOPC Software	Application Software for Science Operations and Planning	IDR -1 Month
S/W Updates	SOPC software updates	Annually
Electrical Connectors • EM • Flight	Flight System-provided hardware	 Dec 06 June 07
Temperature Sensors • EM • Flight	Flight system-provided hardware	 Dec 06 June 07
Arm/Mast Intra-instrument Cable(s)	Flight system-provided hardware	[TBD]

7.6 FLIGHT HARDWARE LOGISTICS PROGRAM (FHLP) RESOURCES

To support potential cost savings, JPL's Flight Hardware Logistics Program (FHLP) maintains inventory information about residual hardware from other projects that might be considered for use by the instrument provider. This includes flight, flight spare, proto-flight, engineering model, breadboard, and ground support hardware. The hardware inventory includes piece parts, partially completed assemblies, completed assemblies. Final hardware integrity and mission conformance is the responsibility of the receiving customer, although FHLP maintains the hardware and associated documentation in the state it was received with appropriate storage conditions.

Most of this inventory can be found on the AO website under the "Potential Government Furnished Equipment" link

http://[TBS]

Address all hardware requests and questions to Kevin Clark and copy all requests and questions to Jeff Simmonds:

Kevin Clark, FHLP Manager	Jeff Simmonds, MSL Payload Manager
Kevin.P.Clark@jpl.nasa.gov	John.J.Simmonds@jpl.nasa.gov

Hardware requests will be documented as reservations in a Memorandum of Understanding (MOU) once FHLP, the instrument provider and other potential stakeholders have agreed that the hardware can be made available to the instrument provider.

8. MISSION ASSURANCE

This section specifies Mission Assurance (MA) requirements for the MSL science instruments payloads and associated components, with the purpose of ensuring reliable, high quality hardware. Instrument providers are encouraged to meet these requirements through the use of their own existing plans and processes wherever possible.

Qualification, screening and reporting requirements are specified in Section 8.1, Quality Assurance requirements for both hardware and software are described in Section 8.2, while personnel and hardware safety requirements are given in Section 8.3. Other generally applicable requirements are contained in JPL D-17868, "JPL Design Principles" and D-[TBS] "MLS Mission Assurance Plan". PIs are responsible for producing and maintaining records, including test and analysis reports and other controlled records, sufficient to demonstrate compliance with MSL Mission Assurance requirements. This data must be made available for review by MSL Mission Assurance. Applicable portions of this documentation will also be included in the End Item Data Package, as specified in Section 7.4.4.9.

8.1 QUALIFICATION, SCREENING AND REPORTING REQUIREMENTS

Instrument providers must fully space-qualify hardware prior to JPL delivery, in accordance with the requirements specified here. In particular, vendors will be required to conduct reliability analyses as specified in Section 8.1.1, conduct electronic parts screening and upgrades as specified in Section 8.1.2, screen flight hardware materials and submit materials identification and usage lists (MIUL) as specified in Section 8.1.3, and conduct environmental qualification analysis and testing as delineated in Section 8.1.4. Vendors must also meet contamination control, problem/failure reporting and operating hours requirements as discussed in Sections 8.1.5 through 8.1.7, respectively.

8.1.1 Reliability Analyses

Reliability Engineering analyses of science instrument payload hardware are to be conducted in accordance with standard, established industry methods, and include the following:

Required for FM:

- Failure Modes, Effects and Criticality Analysis (FMECA)
- Electronic Parts Stress Analysis (PSA)
- Thermal Stress Analysis
- Structural Stress Analysis
- Single Event Effects Analysis (SEE)

Requirement for GSE:

- An interface FMECA is required for ground support equipment, and must be conducted prior to mating such equipment to flight or EM hardware.

Requirement for EM:

- An interface FMECA is required for EM hardware, prior to mating with flight hardware or flight hardware ground support equipment. The analysis must show that failures do not propagate beyond the instrument interface.

Schematics for flight and GSE hardware must be submitted to JPL as backup documentation to the instrument level FMECA. The flight h/w schematics will be used to support the spacecraft system level FMECA activity. If a design is shown to have a failure mode that could propagate beyond the instrument interface, JPL may require implementation of corrective design changes prior to acceptance of the hardware.

8.1.2 Electrical, Electronic and Electromechanical Parts

Screening of all electrical, electronic and electromechanical (EEE) parts will be conducted in accordance with the JPL Institutional Parts Program Requirements (D-20384). All parts must meet or exceed any of the following reliability standards:

(1) NASA GSFC EEE-INST-002, Level 2

(2) MIL-PRF-19500 JANTXV, QML-19500

(3) MIL-PRF-38534, Class H, QML-38534 (MIL-PRF-38510, Class B) with PIND, DPA and radiographics upscreening

(4) MIL-PRF-38535 Class Q, QML-38535

(5) Military Established Reliability (ER) passive devices, Failure Rate Level R

Parts not meeting minimum standards (883B parts, unique parts, custom parts such as TBD (ASIC) and custom hybrids, and commercial parts) shall be upscreened per above requirement. It is recognized that certain specialty devices may not be capable of compliance with these requirements. Any known or anticipated non-compliance should be identified as part of the proposal.

Plastic parts shall be screened and qualified in accordance with JPL D-19426, Plastic Encapsulated Microcircuits (PEMs) Reliability/ Usage Guidelines for Space Applications, or contractor equivalent.

Expected radiation levels are discussed in the environments section of this document, Section 3.7.2. Payload element and instrument providers may wish to review the effects of this radiation environment on space electronics, as discussed in JPL Publication 00-06.

The Single Event Upset (SEU) rate and occurence of Single Event Latchup (SEL) of electronics in the MSL radiation environment shall be controlled and characterized as follows:

(1) SEU and SEL events which occur during testing to a Linear Energy Transfer (LET) of 75 MeV-cm^2/mg shall be reported. SEL is explicitly not allowed,

(2) Device bit error rate shall not exceed 10^{-10} per day in the galactic cosmic ray environment.

Specifications and references associated with the EEE parts requirements are listed below:

(1) JPL-D-20384, JPL Institutional Parts Program Requirements

(2) NASA GSFC EEE-INST-002, Instructions for EEE Parts Selection, Screening, Qualification, and Derating

(3) MIL-PRF-19500, General Specification for Semiconductor Devices

(4) QML-19500, Qualified Products List of Products Qualified under MIL-PRF-19500, General Specification for Semiconductor Devices

(5) MIL-PRF-38534, General Specification for Hybrid Microcircuits

(6) MIL-PRF-38510 General Specification for Microcircuits

(7) MIL-PRF-38535, General Specification for Integrated Circuit (Microcircuit) Manufacturing

(8) QML-38534, Qualified Manufacturers List of Custom Hybrid Microcircuits Manufactured to the Requirements of MIL-PRF-38534

(9) QML-38535, Qualified Manufactures List of Integrated Circuit (Microcircuits) Manufactured to the Requirements of MIL-PRF-38535

(10) JPL D-19426, Plastic Encapsulated Microcircuits (PEMs) Reliability/ Usage Guidelines for Space Applications

(11) JPL Publication 00-06, “An Introduction to Space Radiation Effects on Microelectronics.”

8.1.3 Materials and Processes

Submittal of Material Identification and Usage Lists (MIUL) will be required for all materials and processes, one month prior to PDR and CDR.

Materials and processes will be reviewed by the project for compliance with requirements (TBS) in the following areas:

Thermal vacuum stability and outgassing	Shelf life limitations
Flammability	Radiation resistance
Galvanic corrosion	Electrical arc-tracking resistance
Stress corrosion cracking	Hazardous materials
Weld process qualification	Static charge sensitivity
Non-destructive inspection requirements	Fungus resistance
Structural design allowables	Fastener material and traceability
Contribution to organic contamination	

In the event materials or processes do not meet JPL screening requirements, Material Usage Agreement (MUA) forms (or contractor equivalent) must be submitted for approval. In addition to "traditional" materials concerns, usage of materials containing organic materials similar to those that are pertinent to the MSL science investigations will also be monitored and/or limited. See Section 3.6.1 for further discussion of this topic.

8.1.4 Environmental Requirements

Analysis Requirements

Analyses must be conducted in a manner sufficient to demonstrate compatibility of deliverable hardware with radiation, venting, re-pressurization environments,and dust as indicated below:

Radiation analysis - ability of instrument and payload electronics to operate adequately in the MSL radiation environment, as defined by specifications for Total Ionizing Dose (TID), Displacement Damage and single event effect, must be shown by analysis. Submission of a JPL Radiation Analysis Completion Statement or contractor equivalent form is required.

Venting, Re-pressurization and dust - ability of instrument and payload hardware to survive the pressure decay environment associated with Earth launch, as well as the re-pressurization environment associated with Mars atmosphere entry and landing, and dust environment over the lifetime of surface operations must be shown by analysis. Submission of JPL Environmental Analysis Completion Statements, or contractor equivalent forms, are required.

Test Requirements

Testing of all fully assembled deliverable hardware, to the appropriate Flight Acceptance, Protoflight or Qualification levels shown in Table 8.1.4 (See JPL Document D-21382, MSL ERD), must be successfully completed prior to instrument delivery. The Instrument provider must submit test plans and a completed JPL Environmental Test Authorization and Summary (ETAS) form, or contractor equivalent form, to JPL for approval prior to the start of testing. A JPL representative may choose to witness any required environmental test. Test data must be submitted to JPL for review and closure of the ETAS.

Required environmental tests include:

(1) Random vibration (force limiting recommended)

(2) Sine vibration for instruments mounted to the Sample Acquisition Arm

(3) Thermal vacuum (Mars ambient, 6 to 10 torr)

(4) EMC: radiated and conducted emissions and susceptibility, plus ground and isolation

(5) Thermal cycling life test (to be evaluated on a case by case basis)

Instruments shall be designed to withstand the pyrotechnic shock environment defined in Section 3.7.1.2. Testing is required for EM hardware if following approach 2 as defined in Table 8.1.4 below. Flight hardware will be tested for the pyroshock environment at the integrated flight system level only.
Two approaches to qualification are presented in Table 8.1.4; either approach may be chosen by the PI team.

Table 8.1.4: Environmental Testing Approaches

	TEST LEVEL		
Science Instrument Hardware	**Qualification**	**Proto-Flight**	**Flight Acceptance**
Approach 1			
• EM	- - - - - No Environmental Test Required - - - - -		
• FM		X	
Approach 2			
• EM	X		
• FM			X

8.1.5 Contamination Control

Contamination Control requirements are established to maintain cleanliness and prevent contamination of engineering hardware and instruments, and to satisfy Planetary Protection strategies. Requirements will exist for the following (see Section 3.6):

(1) Materials usage

(2) Cleaning Processes

(3) Surface Cleanliness

(4) Outgassing and vacuum bakeout

(5) Hardware protection and storage

(6) Facility cleanliness

8.1.6 Problem/Failure Anomaly Reporting

Closed loop problem/failure anomaly reporting (PFR) is required for FM and GSE hardware and software, for EM if following Environmental Test Approach 2 (see Table 8.1.4), or for other critical hardware. Critical hardwrae is defined as flight, flight spare, EM hardware which could be used as flight or spare, and GSE that interfaces with flight hardware. All problem/failure and anomaly reports shall be risk rated for failure effect and cause. Reporting shall occur through an approved contractor reporting system or the JPL PFR system and must begin as shown below:

(1) Flight electronics - 1st application of power at board level

(2) EM electronics - Start of subsystem qualification, or 1st board-level power-on if EM is to used as flight spare

(3) Instruments - 1st application of power at instrument level

(4) GSE - 1st functional test at delivery level of assembly

(5) S/W - 1st interaction with flight or EM hardware

(6) Mechanical h/w - Start of qualification testing

(7) EEE parts - Immediately, following problem or failure.

Closure review of pre-delivery Problem Failure Reports will be included in the Instrument Delivery Review (IDR).

8.1.7 Hardware Operating Hours

Science instruments and payload elements shall have accumulated 300 hours of operation prior to delivery to spacecraft integration. The final 100 hours of pre-delivery operation must be accumulated without hardware modification, and must be free of problems, failures or anomalies.

8.2 QUALITY ASSURANCE REQUIREMENTS

8.2.1 Hardware Quality Assurance

All hardware providers and contractors must be certified to or compliant with ISO 9001.

Hardware providers must demonstrate capabilities in these critical processes (when applicable):

- Plating	- Welding	- Die attachment	- Radiographic inspection
- Anodizing	- Soldering	- Wire bonding	- Ultrasonic inspection
- Heat treating	- Cleaning	- Magnetic particle inspection	- Liquid penetrant inspection

Quality records including manufacturing planning records, detailed steps performed, inspection points, test logs, non-conformance documents, parts lists, engineering changes, etc. must be retained for all hardware and furnished to the MSL project. Full traceability must be maintained on all hardware designated as flight, flight spare, engineering model or ground support equipment that interfaces with flight h/w. Controlled documents including test plans and procedures, drawings and specifications must be maintained and stored. Hardware non-conformances must be identified and corrected through a closed-loop system. Test and assembly operations must be conducted in accordance with a written test plan, which includes step-by-step Assembly Instruction Data Sheets (AIDS), or contractor equivalent, for all critical hardware (as defined in Section 8.1.6). All tests (environmental, acceptance and functional) involving critical hardware must include Quality Assurance survey and approval of test setup and QA witness of test operations.

8.2.2 Software Quality Assurance

Development processes associated with science instrument and payload item software must be compliant with JPL Software Development Requirements, JPL D-23713. Software requirements must be documented and traceable to s/w design/implementation, system and subsystem interface requirements and s/w validation tests. Software developers/providers must maintain objective evidence (verification matrices, test records, reports, memos, meeting minutes, etc.) of requirement compliance.

Science software running on the Spacecraft Flight Computer is subject to additional review, analysis and verification requirements beyond those required for instrument software that is internal to a science instrument. These requirements are discussed in Appendix F.

All software/firmware destined for Payload Science Instrument Qualification (Protoflight), Flight or Flight Spares is subject to the following verification requirements:

(1) Accuracy of as-built product identification

(2) Proper test Plan/Procedures/Reports released

(3) Existence and adequacy of an installation Manual

(4) List of software deliverables including all required documents (under configuration management (CM) control)

(5) Software System requirements test traceability Matrix

(6) List of open/closed PFRs, liens against the current release of software.

Software safety/hazard analyses and audits will be conducted by JPL to verify that output values and/or timing do not place the system in a hazardous state, and to ensure that the software responds appropriately under hardware failure scenarios.

8.3 SYSTEMS SAFETY

Formal safety inspections and audits of facilities, including facility safety, and pre-test hazard assessments will be conducted by the JPL Systems Safety Office, or by an approved Safety Office at the PI/Contractor facility. Any action items resulting from audits will be addressed prior to testing or assembly operations involving critical hardware.

9. POST-DELIVERY HARDWARE SUPPORT

This section covers activities at JPL directly involving Science Instrument hardware (EMs, flight spares (FS), FMs, GSE) that may require PI support. Pre-Launch phase activity at Kennedy Space Center is discussed in Section 9.5.

9.1 INTEGRATION AND USES OF THE ENGINEERING MODEL INSTRUMENTS WITH TESTBEDS

Engineering Model (EM) instruments will be integrated into the Payload Checkout Bench (PCB), a flight-like payload module testbed that includes mast and arms, for mechanical fit checks, electrical interface checks, functional testing with JPL-provided Ground Support Equipment (GSE), and finally flight software checkout. It will have high fidelity, flight-like interfaces and be capable of commanding science payload instruments with the flight and ground software while using the system data bus; it can also collect telemetry. Functional and system-level tests can be performed in this configuration. The EM payload module is expected to also be integrable with the EM rover for field and system tests. Figure 9.1 shows the post-delivery flow of the EM Science Instrument hardware. A block diagram of the payload checkout bench is shown in Figure 9.2.

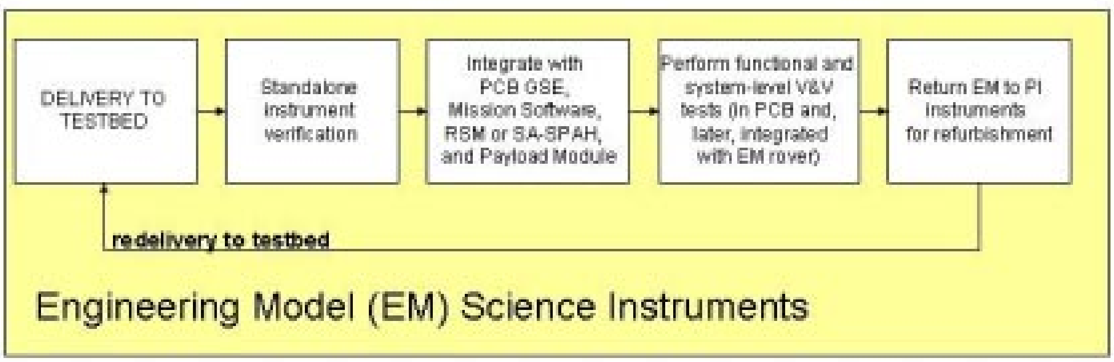


Figure 9.1: Engineering Model Instrument Flow

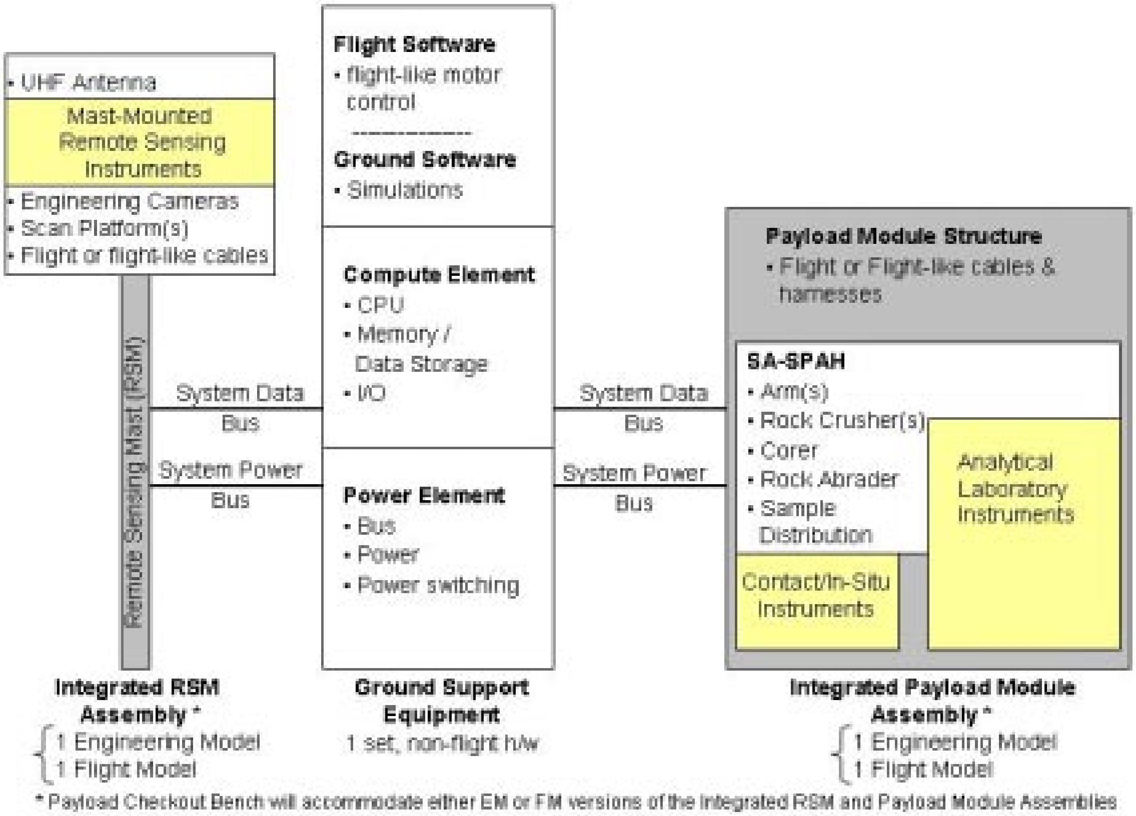


Figure 9.2: Payload Checkout Bench

All Sample Acquisition/Sample Processing and Handling (SA/SPAH) services and interfaces will be available in the Payload Checkout Bench (PCB).

PI support will be required for development of the procedures for integration and testing on the Payload Checkout Bench. PI support will be required during the actual integration of the science instrument into the PCB, and Verification and Validation (V&V) involving that instrument within the PCB. Integration activities will start shortly after delivery and continue for approximately two months. During this period, the integration of each instrument will require approximately 10 days total time of intermittent PI on-site support at JPL. This is an estimated time based on a 'typical' integration, actual times required by specific individual instruments will vary.

System tests using the EM instruments will be conducted throughout the months following PCB integration and continue until the EM instruments are released for refurbishment. PI support for these tests will be scheduled and instrument teams will be alerted as to their frequency, duration, and nature. These tests will require some level of support either remotely or on-site. PIs will be notified in advance of these tests. Proposers should anticipate 10 days of intermittent PI on-site support and four months of remote support during this period.

Once the EM instruments have been refurbished and returned to JPL, they will again be integrated into the PCB and remain there until the end of mission as a part of the MSL Mission Operations Testbed.

9.1.1 Verification and Validation with PCB and EM Instruments

System verification and validation (V&V) within the PCB will consist of scripted tests conducted by trained test conductors and systems engineers along with PI support. All system-level, instrument functionality will be proven within this environment, except where it can only be proven on the flight equipment. Flight software will be used to interact with the instrument. PI support will be required for development of test objectives and the instrument V&V procedures. Proposals must specify if the complexity of the proposed instrument can be expected to require additional integration or V&V time beyond what is called out in this document.

9.2 INTEGRATION AND TEST OF THE FLIGHT MODEL INSTRUMENTS THROUGH ATLO

Integration of the flight model (FM) instruments with the rover occurs in the project phase labeled ATLO (Assembly, Test, and Launch Operations). (See Figure 9.3.) An ATLO Readiness Review (ARR) is held at JPL to verify that the project is ready to begin and conduct assembly, test and launch operations of the flight and ground systems. A successful ARR will enable an ATLO start in [April 2008 - TBR].

9.2.1 Integration of the Flight Payload Module

For the rover science instrument payload, ATLO will start with integration of flight instruments into the Flight Payload Module (PM) using the Ground Support Equipment from the PCB. Mechanical, electrical, functional, and software tests may be performed as was done with the EM instruments. These tests will require PI support and procedures, and following this period of initial FM integration, the EM instruments will be returned to the provider for refurbishment to match any configuration changes occurring since EM initial delivery.

Payload deliveries will be phased to begin with arm- and mast-mounted instruments so as to allow sub-assembly integration to proceed. Analytical Laboratory Instruments arrive later and are integrated directly into the payload module. If special delivery phasing needs to be accommodated due to cleanliness and/or late component/consumable installation, this issue must be addressed in the proposal.

Once integration and these tests are completed, the Payload Module will be ready for integration with the flight rover.

The entire Payload Module with the SA/SPAH and instruments will be integrated with the main rover body and mobility system. This fully built-up rover will be available for Functional Testing at this stage.

Integration of an instrument into the Payload Module and Verification and Validation (V&V) involving that instrument within the PCB will require PI support. The duration of this integration will be two months. During this period, the integration of each instrument will require PI support at JPL. Dates for support will be dependent on actual delivery dates, but in general, will begin with delivery and extend for 2 months and involve project instrument engineers support by PI system engineers.

9.2.2 Functional Testing of Payload Module and Rover

Functional Tests are conducted initially with the flight rover integrated with the payload. These tests will be based upon a V&V matrix of requirements and will, in general consist of tests aimed at proving out the MSL surface system requirements. Items such as instrument placement, traverse, sample processing and handling, and day and night operations will be tested.

This period of functional tests using the FM instruments will be conducted throughout the early months of ATLO until Integrated System Test begins. See Figure 9.3 for the ATLO flow schedule. On-site or remote PI support for these tests will be scheduled for these activities. PIs should anticipate twenty days of on-site support (which will likely be discontinuous) and one month of remote support during this period.

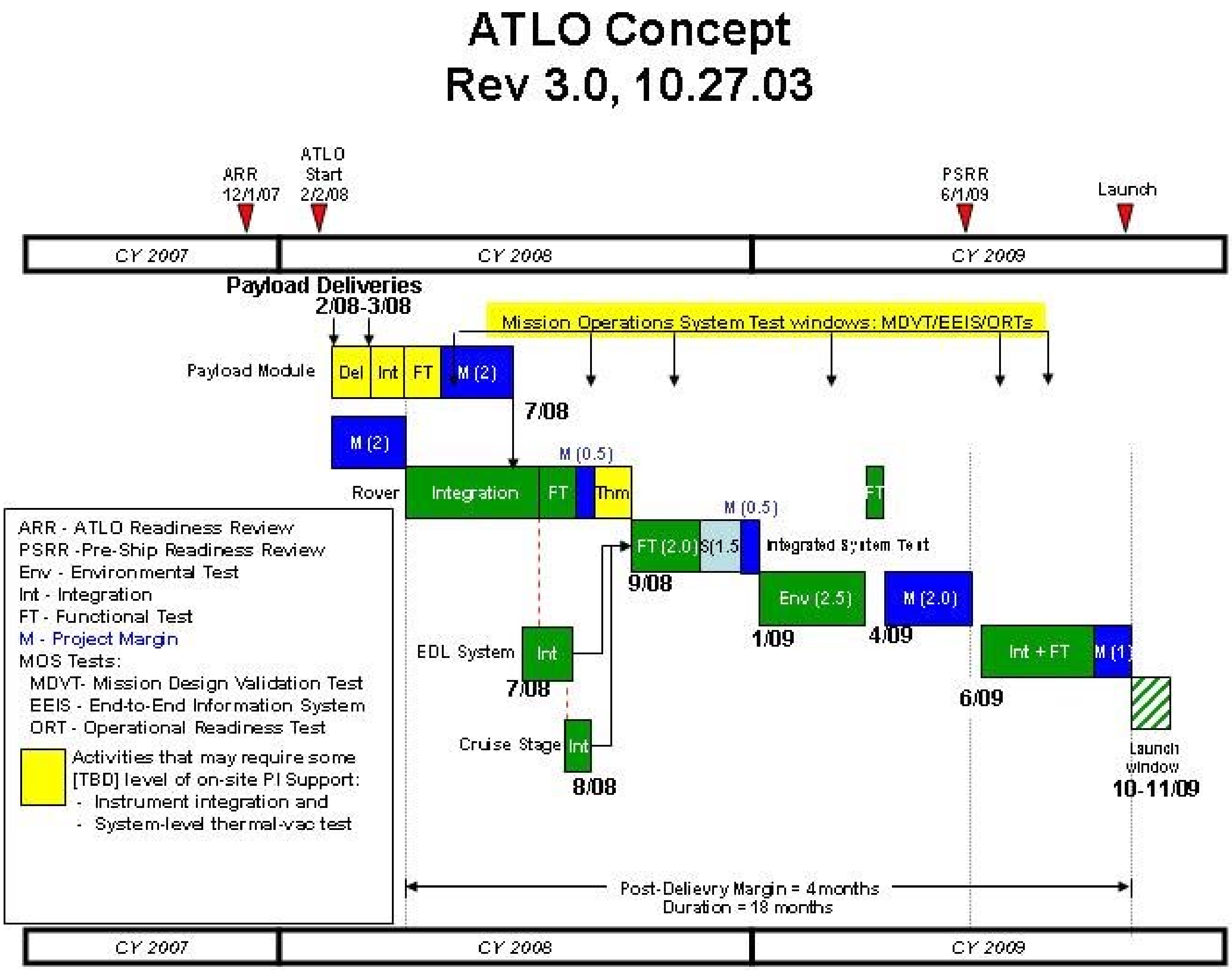


Figure 9.3: ATLO Flow

9.3 INTEGRATED SYSTEM TEST

Integrated system test is conducted with the carrier, EDL and surface systems integrated. The elements of the spacecraft will be linked electrically as they will in flight, but remain "unstacked", and then functionally tested. Most of these tests will not involve instrument operations.

As shown in Figure 9.3, EDL and Cruise Stage integrations take place in parallel with the rover integration and test.

9.3.1 System Environmental Tests

System level environmental tests are specified in the MSL Environmental Requirements Document (ERD), (to be available at AO release.)

The fully integrated MSL rover will undergo thermal-vacuum test to verify the thermal design and thermal models for surface operations. This test will include instrument operations and follows Functional Test of the rover; see Figure 9.3.

The fully integrated Flight System (Carrier system, EDL System and Rover) will be tested using, as a minimum, random vibration, acoustic, thermal-vacuum, pyro-shock, and EMI/EMC tests. These tests are conducted in a cruise configuration and consequently will require minimal payload support. See the box labeled "Env (3)" in Figure 9.3.

9.4 OPERATIONAL READINESS TESTS (ORTS)

Throughout ATLO there will be opportunities to conduct tests of the Flight System using the Ground System and Mission Operations System Procedures. These "plugs-out" tests draw on operations personnel to "fly" the spacecraft in a configuration that mimics flight for all mission phases (launch, cruise, EDL, and surface).

Instrument operators will participate in these tests and follow procedures as if the vehicle was post-launch. These are tests of personnel, procedures, and ground equipment as well as flight equipment and software. Level of PI participation should be planned as 10 days at JPL and 10 days of remote operations.

9.5 KENNEDY SPACE CENTER OPERATIONS - PRELAUNCH PHASE

Kennedy Space Center (KSC) Operations begin prior to the spacecraft leaving JPL. A small crew will be at KSC to make sure everything is ready to receive the spacecraft and attendant personnel.

Functional tests will be executed following arrival of the spacecraft. These tests will be primarily aimed at checking out the flight and ground systems and will include rehearsal to integrate the power source. Any radiation sources required by the instruments will also be installed during KSC operations.

About seven days before lift off, the spacecraft power source will be encapsulated with the rover in the aeroshell. The full flight system would then be encapsulated into the launch vehicle shroud for mating with the launcher.

Once mated, the final closeout of the flight system will be performed in preparation for launch.

Except for any special close-outs, and support of final functional tests by remote access, PI support will not be required during this phase.

10. COST GUIDELINES

A budget guideline of $85 M RY has been established for Phases A-D development of the NASA selected MSL instrument payload (all classes 1-4). This guideline includes all investigation reserves and covers all phases of development activity through Launch plus 30 days. In addition, $50 M RY has been budgeted for PI Investigations during the MSL operations phase including reserves to cover the period from launch +30 days through landing, 670 sols of prime mission surface operations and approximately six months of data analysis and archiving of mission data.

The funding profile available for MSL PI investigations is shown in Table 10.0. Funding requests consistent with this profile and the following guidance should be reflected in the cost plans for each proposal involving instrument development. For the phase A/B period (running from start of contract until successful preliminary design review/confirmation of the investigation; see Section 7.3), the funds available for the instrument development are constrained. The total available funding for the Phase A/B period (including reserve) is expected to be no more than $10 M RY (estimating 70-85% for class 1, 10-20% for class 2, and 5-10% for class 3; selections of class 4 instrument investigations would be funded by decreasing the weighting of other selected types slightly). Investigations that successfully complete Phase A/B and are confirmed through the Preliminary Design Review /Confirmation Review process will then be funded ~ $75 M RY for Phase C/D, with the funding to be distributed among the Type 1-4 investigations as indicated above. These limits include all financial obligations, including any contracts for long lead items needing to be placed during the two periods. Phase E funding is also shown in the table. This is a preliminary estimate for Phase E, but should be used as a guideline for proposal submission.

Table 10.0: Funding Allocations to MSL Payload

Total Allocation ($M RY)	FY'05	FY'06	FY'07	FY'08	FY'09	FY'10	FY'11	FY'12	FY'13
Phase A/B	10								
Phase C/D		24	28	17	5	1			
Phase E						9	17	12	12

Finally, note that 1 to 2 percent of the MSL total run-out cost for each selected instrument investigation (see Section 5.3 of the AO) is to be reserved for Education and Public Outreach activities. It is expected that the bulk of these activities and their funding will come in the operational phase (Phase E) of the MSL mission.

Cost realism and overall cost effectiveness are important criteria in the selection of the Principal Investigator Instruments, and a favorable funding profile is one that reduces the funding requirements needed in the early years. However, a realistic schedule for development is required, including the identification and proposed development of long-lead items.

10.1 RESERVE STRATEGY

The MSL project's current plan for managing the cost reserve would allocate a portion of the proposed reserves to be managed directly by each PI team while the remaining reserves would be held at the Payload System level, and managed in common for the overall payload. The release of amounts beyond that assigned to the PI for direct management to any specific payload element will be based on a PI's request to a review/decision process led by the Payload Manager with key inputs from the Project Scientist and the PIs/Project Science Group, as appropriate. This approach will emphasize the balance between overall risk posture of the payload system against that of individual instruments with consideration of maintenance of prudent reserves based on cost-to-go. Significant commitments of reserve to any particular instrument issue will be reviewed and traded by the PSG, especially when such issues involve exercise of potential descopes. Detailed assignment to PI directed vs. Payload-level directed reserves will be made as part of the negotiations of the Experiment Implementation Plans during Investigation Phase A/B.

Funded Schedule Reserve is to be included in the Investigation's flight hardware delivery flow. Given the nominal development timeline, a schedule reserve of 10 weeks at delivery of flight hardware is considered prudent. Investigation Proposals should describe their rationale for schedule reserve and other mitigations in the context of specific identified risks to delivery of Flight Units for integration and test. While a specific recommendation for schedule reserve to be carried against EM delivery is not given, Investigations are encouraged to consider and describe ways to insure timely delivery of EM hardware capable of supporting both testbed activities and pathfinder activities leading to FM integration flows.

APPENDIX A - ACRONYM LIST

AGP	Additional General Provisions
AIDS	Assembly Instruction Data Sheets
Amp	Ampere
AO	Announcement of Opportunity
ARR	ATLO Readiness Review
ATLO	Assembly Test and Launch Operations
cm	Centimeter
CM	Configuration Management
CPU	Central Processing Unit
CR	Confirmation Review
CDR	Critical Design Review
Co-I	Co-Investigator
Code M	Human Exploration and Development of Space
Code S	Space Science
Code U	Office of Biological and Physical Research
DDD	Displacement Damage Dose
DHMR	Dry Heat Microbial Reduction
DOF	Degree of Freedom
DSMS	Deep Space Mission Systems
DSN	Deep Space Network
DTE	Direct to Earth (Telecom)
EAC	Estimate at Completion
EDL	Entry Descent & Landing
EEE	Electrical, Electronic and Electromechanical
EIDP	End Item Data Package
EIP	Experiment Implementation Plan
EM	Engineering Model
EMC	Electromagnetic Compatibility
Engr/HK	Engineering/Housekeeping
EOP	Experiment Operations Plan
ER	Established Reliability
ERD	Environmental Requirements Document
ETAS	Environmental Test Authorization and Summary
FDD	Functional Description Document
FHLP	Flight Hardware Logistics Program
FM	Flight Model
FMECA	Failure Modes, Effects and Criticality Analysis
FMR	Financial Management Report
FPR	Financial Progress Report
FRD	Functional Requirements Document
FS	Flight Spare
FSW	Flight Software
FTE	Full Time Equivalent
FY	Fiscal Year
g	gravity
GDS	Ground Data System
GIDEP	Government-Industry Data Exchange Program
gm	gram
GP	General Provisions
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
Gy	Grey
HGA	High Gain Antenna
HRCR	Hardware Readiness Certification Review

HRS	Heat Rejection System
Hz	Hertz
IA	Instrument Arm
IAR	Instrument Accommodation Review
ICD	Interface Control Documents
IDR	Instrument Delivery Review
IIM	Instrument Interface Meeting
I-ORR	Instrument Operations Readiness Review
I-PDR/CR	Instrument Preliminary Design Review/Confirmation Review
JPL	Jet Propulsion Laboratory
KBS	KiloBytes per Second
kg	kilogram
km	kilomtere
KSC	Kennedy Space Center
LET	Linear Energy Transfer
m	meter
MA	Mission Assurance
MDS	Mission Data System
MEPDMP	Mars Exploration Program Data Management Plan
MeV	Mega-electornvolt
MIPL	Multi-Mission Image Processing Laboratory
MIUL	Material Identification and Usage Lists
mm	Millimeter
MMO	Mission Management Office
MMR	Monthly Management Review
MOA	Memorandum of Agreement
MOLA	Mars Orbital Laser Altimeter
MOS	Mission Operations System
MOU	Memorandum of Understanding
MPE	Mission Planning and Execution component
MRO	Mars Reconnaissance Orbiter
MSA	Mission Support Area
MSL	Mars Science Laboratory
MSPSP	Missile System Pre-Launch Safety Package
MTO	Mars Telecom Orbiter
MUA	Material Usage Agreement
N/A	Not Applicable
NASA	National Aeronautics and Space Administration
NEPA	National Environmental Policy Act
NPD	NASA Policy Directive
NPG	NASA Procedures and Guidelines
oct	Octave
ODY	Odyssey
ORT	Operational Readiness Test
OSHA	Occupational Safety & Health Administration
OSS	Office of Space Science
PCB	Payload Checkout Bench
PDR	Preliminary Design Review
PDS	Planetary Data System
PEM	Plastic Encapsulated Microcircuits
PF	Protoflight
PFR	Problem Failure Report
PI	Principal Investigator
PIP	Proposal Information Package
PM	Payload Module
PP	Planetary Protection

ppm	Parts Per Million
PRT	Platinum Resistance Thermometers
PSA	Parts Stress Analysis
PSG	Project Science Group
PSIG	Project Science Integration Group
QA	Quality Assurance
QUAL	Qualification
RDF	Radiation Design Factor
RHU	Radioisotope Heater Units
RPS	Radioisotope Power Supplies
RSM	Remote Sensing Mast
RSS	Remote Sensing Science
R-WEB	Remote Warm Electronics Box
RY	Real Year
SAA	Sample Acquisition Arm
S/C	Spacecraft
SDMP	Science Data Management Plan
SA-SPAH	Sample Acquisition and Sample Preparation and Handling
sec	second
SEE	Single Event Effects
SEL	Single Event Latchup
SEU	Single Event Upset
SFC	Spacecraft Flight Computer
SOPC	Science Operations and Planning Computer
SPAH	Sample Preparation and Handling
SRCR	Software Requirements Certification Review
SRD	Science Requirements Document
SW	Software
TBR	To Be Reviewed
TBS	To be Supplied
TCM	Trajectory Correction Maneuver
TID	Total Ionizing Dose
TL	Team Leader
TPR	Technical Progress Report
UHF	Ultra-High Frequency (Telecom)
V&V	Verification and Validation
V	Volt
W	Watt
WEB	Warm Electronics Box
Whr	Watt-Hour

APPENDIX B - GENERAL ROVER SPECIFICATIONS

Mass:	approx 900 kg
Wheelbase (front to rear):	2.7 m
Wheel Size:	~ 0.7 m diameter, 0.4 m width
Track Width:	2.75 m (outside of wheel to outside of wheel)
Maximum Obstacle Height:	0.75 m rock
Top Deck Height:	1.5 m above ground
Mast Instrument Platform Height:	2.0 m to 3.5 m above ground
2 Arms:	5 degree of freedom (DOF)
One Sol Range:	Terrain dependent (50 m Nominal)
Guidance, Navigation & Control Sensors:	Cameras, LN-200, Sun Sensor
Effective Stereo Range (Navcams)	~50 m
RPS Power:	220 W continuous (2 RPSs)
Thermal Control:	Pumped RPS waste heat / electric heaters
DTE Link Performance:	~50 Mbit/sol
UHF Link Performance:	50-1000 Mbit/sol (link dependent)
Landed Operational Lifetime:	687 Days/670 sols (baseline)

APPENDIX C - ENGINEERING DATA TO BE MADE AVAILABLE TO SCIENCE

Descriptions of the sensors/systems are included in the PIP, to the limited extent that they are understood, to facilitate PI understanding of the variety of engineering data that may be available to science data analysis on the ground. In all cases, only a small percentage of the data generated by the MSL sensors listed below is normally included in telemetry.

(1) EDL Radar

(a) [TBS]

(2) Entry Atmospheric Science (Acceleration/Attitude)

(a) Entry, Descent & Landing Telemetry

1. Parachute telemetry
2. Accelerometers
3. Temperature Sensors

(3) Mechanical properties of rocks and regolith from SA/SPAH

(a) Arm Telemetry
1. [TBS]

(b) Drill Telemetry
1. [TBS]

(c) Crusher Telemetry
1. [TBS]

(4) Mechanical properties of regolith and rocks from wheels

(a) Mobility/Wheel Telemetry
1. ω, current, other

(5) Engineering cameras (Navigation and Hazard)

(a) Navcams (2)
1. Provide terrain context for traverse and science planning and scan platform mounted instrument pointing.
2. 360-degree field of regard at <1 mrad/pixel angular resolution.
3. Stereo ranging out to 50 meters (30 cm stereo baseline).
4. Broadband, visible filter.
5. 45-degree field of view ($\pm 22.5^o$)
6. 1 Mpixel CCD Array
7. 16 Mbits per image

(b) Hazcams (4)
1. Provide image data for the onboard detection of navigation hazards during a traverse.
2. Provide terrain context immediately forward and aft of the rover (in particular the area not viewable by the Navcams) for traverse planning.
3. Support arm-mounted instrument placement operations.
4. Support Rover fine positioning near arm-mounted instrument targets.
5. Wide field of view (120^o), 2 mrad/pixel angular resolution.
6. Stereo ranging immediately in front of the rover (10 cm stereo baseline) to an accuracy of ± 5 mm [TBD].
7. Broadband, visible filter.

(6) Accelerometers

(a) Gravity vector relative to base body orientation

(7) Rate Sensors (gyros)

(a) Mars spin rate and vector

(8) Other Sensors

(a) Platinum Resistance Thermometers (PRT) Telemetry
   1. [TBS]
(b) Radio Science
   1. [TBS]

APPENDIX D - REQUIRED INFORMATION SUMMARY

[TO BE SUPPLIED]

APPENDIX E - GETTING ON CONTRACT / SAMPLE CONTRACT

[TO BE SUPPLIED]

APPENDIX F - UNIQUE ACCOMMODATION ISSUES

[TO BE SUPPLIED]

APPENDIX G – DATA ANALYSIS, REPORTING AND ARCHIVING REQUIREMENTS

PIs and TLs shall process, distribute, analyze, archive, and disseminate scientific information in a timely and orderly way to the scientific community and to the public in accordance with the MSL Project Data Management Plan.

Requirements for this management of investigation data are based on the NASA *Mars Exploration Program Data Management Plan* (MEPDMP, Rev 3.0, March, 2002), augmented by policies and requirements articulated in the MSL *Announcement of Opportunity* (*AO XX-XXX-XX: Mars Science Laboratory*).

These requirements apply to all science investigations and investigators that are part of the MSL mission:

Principal Investigators (PI) and Team Leaders (TL) shall abide by the policies and meet the requirements regarding science data management as articulated in the MEPDMP.

Each PI/TL will lead the management of the investigation's data, including the dissemination of data and data products and of the investigation's results to the scientific community and to the public in a timely and orderly way.

Each investigation will develop data management plans in accordance with the MSL and MEP data policies; these plans will be reflected in, or part of, plans and budgets required by the Project (e.g., EIP, EOP).

Investigators will provide in a timely manner data management inputs required by the Project; these include, but are not limited to, material needed for the MSL Data Management & Archive Plan.

PI/TL will plan for early release of data and data products, in conformance with the MSL Data Management & Archive Plan and MEPDMP (see Sec. 6: *Policies for Release of Data and Public Information*).

Investigators shall plan for, and implement, the timely archival of data and data products in the Planetary Data System.

It is NASA policy that PI do not have exclusive use of data taken during the course of their investigation for any proprietary period. It is recognized that some time is required (nominally less than six months) for data products to be generated and validated.

In order to engage the public more fully, investigators may be required to release subsets of recent, particularly interesting data on a daily to weekly basis, as appropriate, or during special campaigns to be defined by the MSL Project Science Group and Project Management.

In addition, NASA, through the MSL Project Office, reserves the right to direct the acquisition of data, to direct or conduct data processing, and to release data needed for mission operations, programmatic planning, and support of public engagement.

APPENDIX H – ADDITIONAL DETAILS ON FLIGHT SOFTWARE

This appendix expands upon the information presented in Section 3.2.

Figure FSW-a and the following paragraphs expand upon the support supplied to instruments within the SFC flight software. This expansion is given to aid in the understanding of new capabilities for improved sequence and data acquisition coordination provided as part of the baseline accommodations. It also provides clarification of the requirements for interaction with the MSL system engineering and flight software staff to analyze and understand the specific needs for each instrument accommodation. It provides the context for the set of instrument engineering support requirements listed in Section 3.2.6.

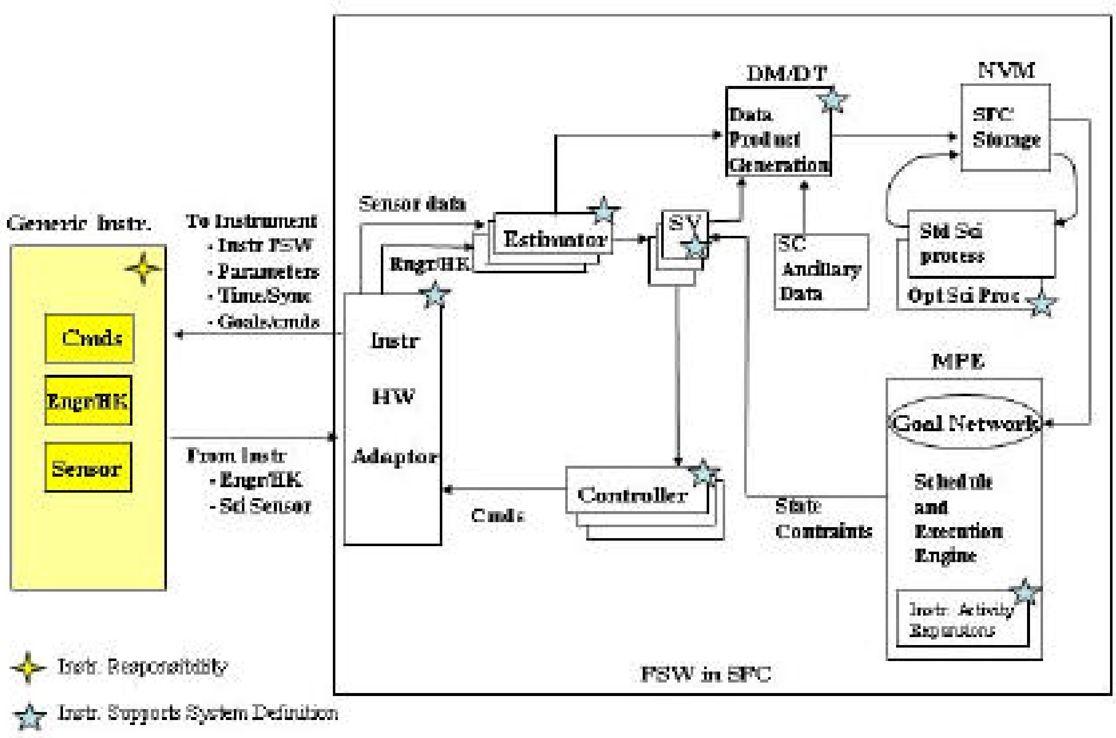


Figure H-1: Baseline instrument/FSW processing accommodation approach - expanded

The baseline flight software will provide the following capabilities to be applied to instrument control and data acquisition:

The SFC FSW will provide a **Hardware Adapter** which includes device drivers for communicating with the instrument over the selected bus or optional specialized interface. These drivers will use standard bus protocols as defined in Section 3.4, Payload Interface Definitions.

Data sent to the instrument will include:

- Commands
- S/C Time
- Instrument FSW Parameters
- Instrument FSW Program Loads

Data received from the instrument will include:

- Instrument Engineering and/or Housekeeping data

- Instrument Science Data

Based on the specific needs of each instrument, the HW Adapter also makes the data available to one or more FSW estimators, which prepare the data for use in the FSW Data Management/Data Transport Processes (DM/DT). Typically, engineering/HK data would be handled separately from sensor data.

Based on the specific needs of each instrument, the FSW **estimators** determine the instrument state, as needed for on-board synchronization and control. This state is represented as a set of FSW State Variables. Estimators also build instrument data products. Another function of an estimator would be to monitor instrument "heartbeat" in standard fashion, leading to detection of instrument problems that may lead to updating the instrument health state. Instrument **State Variables** are used throughout the FSW for coordination of information. Based on the specific needs of each instrument, state variables will be defined as needed to support on-board data handling, instrument coordination and control. For a typical instrument these may include:

- Operational state
- Health state
- Power Consumption and Power Switch states
- Temperature state

Based on the specific needs of each instrument, **Data Products** are generated encapsulating the sensor data, the engineering/HK data, and the state variable data. Products of the same type will have the same storage and downlink policies. Policies determine how the data will be handled (i.e. how long to keep data in RAM, compression or other processing specified, how much to keep, when and at what priority to downlink the data, etc.) If different storage and downlink policies are required, additional product types will be needed (at extra cost to the PI). If desired, spacecraft ancillary data (pointing information, etc.) can be added to instrument data products. A baseline instrument would have one raw data product, and one state data product. Instrument proposers are not required to specify telemetry packetization or framing requirements; these will be handled by the FSW. Instrument system engineers will be expected to work with FSW system engineers to specify the packaging of instrument data into data products. This is part of the instrument system engineering support cited above.

Based on the specific needs of the selected payload, **additional science data processing** may be provided. The baseline will include application of one data processing algorithm, not yet selected, to the instrument data. This algorithm will be selected by the science team, and will be available for application to all instrument data. This may be, for example, a generic lossless compression algorithm. Other data processing algorithms may be proposed by the PI, and negotiated with the project as instrument-unique accommodations. Some examples might include:

- Specialized lossless or lossy data compression (before, or after storage in the non-volatile memory)
- Data prioritization
- Data summarization, selection, or editing

Instrument **goals** and instrument **commands** are created by the science team as part of the MOS development process, and selected, parameterized, coordinated, verified, and uplinked to the spacecraft as needed, but usually no more than once per day. A goal is a constraint (or direction) levied on a state variable for a temporal period. It coveys intent, and is achieved on-board in a closed loop manner by the state variable, controller, hardware adapter, instrument, and estimators in the FSW. A command conveys no intent, and there is no closed loop. Controllers issue commands to the hardware adapter, which then forwards them to the instrument which carries out the command. Goals may be **elaborated** (expanded) during ground definition, or on-board the spacecraft into additional **subgoals** and commands. Based on the specific needs of each instrument, elaborations will be created which embody the PIs desired goal or command expansions, and/or convey information (rules, behavior) about how the instrument should be controlled. Elaborations are roughly equivalent to the sequence/activity/block expansions used in sequence generation on other JPL spacecraft. A baseline set of typical instrument goals, or commands might include:

- Goal on operational state (for mode, data rate, etc.) - FSW continues to try to achieve this goal, based on the received instrument engineering/HK derived operational state variable, until all tactics (methods) for achieving the goal have been exhausted, at which point the goal will fail, and be reported to the system.
- Goal on instrument bus rate (with subgoal for allocation of bandwidth)
- Goal on instrument data storage allocation

- Goal on instrument power allocation. Ground and flight software will have the ability to specify power consumed by the instrument's ON/OFF power state and instrument mode state and to determine if that power level is consistent with other demands on spacecraft power and energy.
- Command to a specific instrument sensor gain – command is passed to the instrument through the hardware adapter. No further action is taken.
- Non- interactive commands (those defined to have no "side-effects" that are visible outside of the instrument). Possible interactions which would preclude this classification include changes in power consumption, changes in data rates, interference with other instruments or rover engineering activities.
- Background goal to safe and/or shutdown instruments in response an “unhealthy” instrument health state.

Data catalog and data management capabilities. The data catalog is a serialized data storage container for Data Products and meta data about the catalog contents. Both the flight and ground systems will have a similar data catalog. The data catalog can be queried by the user (software or team member) to retrieve data for use or for display.

Software to prioritize data product types for storage and downlink. The capabilities will apply to both science and engineering data. Flight software will also provide the capability to invoke instrument compression/data-reduction algorithms in response to storage and downlink priorities.

Software Source Materials

The mission load (all executable surface system and payload flight software and data) is generated as an integrated load image, including initial/nominal values for all updatable mission data/system files. To develop the mission load, source code for compilation, materials for binding, and the data/file load must be provided in a timely fashion to support software development integration in the PCB, assembly and integration tests during science payload integration, and mission readiness tests at the launch site.

The delivery of ground operations and data analysis software should include source code, executable, compilation, executable generation instructions, and test files as well as any supporting documentation required to properly use the software.

APPENDIX I – ADDITIONAL DETAILS ON GROUND OPERATIONS AND DATA SYSTEM SOFTWARE

This appendix supplies additional details supporting the GDS Section 6.0.

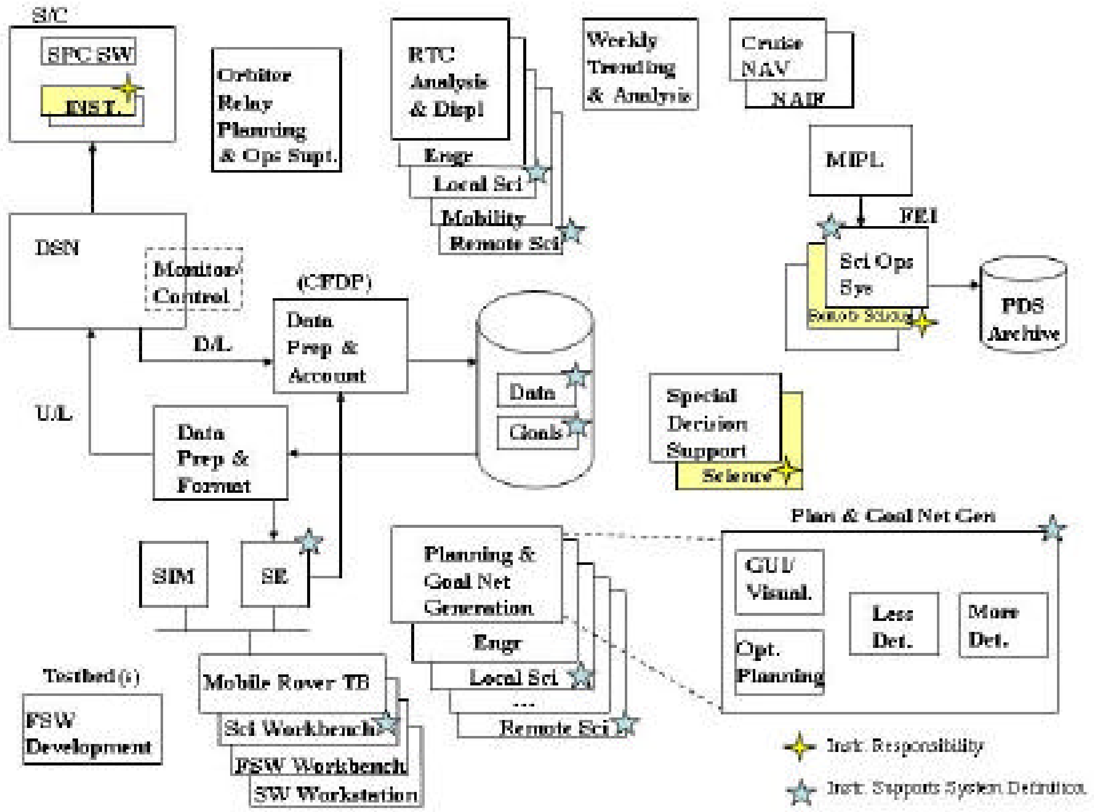


Figure I-1: Functional representation of the ground data system software

Uplink Development Software Set

The uplink development SW is used in the Mission, Strategic, and Tactical processes identified in the MOS section. During the uplink development process, unique experiment/activity names and target names will be defined and associated with the new goals. These names will also be associated with the data products generated by the goals. The names and goal/data associations help to bind the data with the original experiment intent and provide meaningful labels for data retrieval. The uplink development software is expanded into three parts. First, the Planning SW (TBR) is used at the Mission and/or Strategic levels to aid in the overall selection of upcoming activities and goals based on mission and science priorities. It is typically used as an optimizing planner whose accuracy is constrained by very high level modeling, but is adequate to seed the next level of planning software with a set of science activities that are roughly consistent with the priorities and constraints. The planning software may, or may not be based on the MDS architecture, but its outputs will be compatible with inputting to the next program, and its models must be consistent with the Goal Net Generation Software. Next, the Less Detailed Planning and Goal Net generation software is MDS based, and is used at both the Strategic and Tactical planning levels. This SW will be designed to take high level inputs from science and engineering teams, and will provide a rapid assessment of the expanded goal net compatibility with high level constraints and resource allocations. The models used at this level will be more accurate than the generalized planner software, but must be consistent with higher level models. Next, the More Detailed Planning and Goal Net Generation software takes inputs from the science and engineering teams (using the less detailed goal net), plus full definition of all options and parameters. It then expands and verifies the resulting goal net. Normally, this is the final goal validation step in the Planning and Goal Generation Suite prior to conversion into a format suitable for transmission to the spacecraft. Again, the projection and verification models used must be consistent with the higher level models. Further, these uplink planning models should also be consistent with the simulation models discussed in Section 3.6 below. Finally, a Graphical user interface to visualize rover activities on surface imagery will be provided to aid in reviewing the goal networks.

It is planned that all Uplink Development Software can be operated separately by different teams at JPL, or at Remote PI facilities. However, final runs will emphasize goal integration across subsystems and will normally be run at JPL. The input and review process will support Remote Teams. This SW will be compatible with the MSL "generic" workstation configuration.

Instrument behavior and data are needed for the uplink and common areas of the GDS (those areas dealing with all instruments and subsystems). Portions of this support are also common to that described under the Flight System Computational Resources and Flight Software, Section 3.2.6. This support includes:

- Definition of Instrument SW Interface protocols
- Definition of Instrument Telemetry and Data Products
- Definition of Instrument Commands, Goals, Goal Elaborations (expansions)
- Definition of Instrument models (behavior/modes/flight rules) for uplink planning and goal integration
- Definition of Instrument resource utilization (Power, Data, Bandwidth, CPU, etc.)

MSL simulations

Simulations will be used for software development and first-time or unique operations (sequence development, goal/activity expansions, etc.) tasks. Simulations will stand in when hardware is not available and consequently, can represent nearly any component in the MSL design including instruments.

Several testbeds/V&V environments are envisioned for the project and all will need models (simulations) of instruments. Some of the testbeds/V&V environments are:

1. Workstation simulations
2. Payload Checkout Bench
3. Static Testbed

Workstation simulations (think Linux/Sun box) are pure software simulations of the flight system and payload -these sims once certified can be delivered to PIs for their development and test program. The Payload Checkout Bench (PCB) is a combination of EM or FLT grade hardware plus the simulations required to integrate instruments and SA/SPAH and FSW; more on this in Section 9.0. The static Testbed is a full, dual string, EM-grade spacecraft used to do end-to-end system tests; instruments can either be simulated or integrated in this environment.

MSL will have more test environments; however, virtually all will require simulations. Instrument support for development of simulations includes (Do the PIs deliver models?):

Required Instrument Simulation SW and data

- Software only behavioral models to support testbed simulations when the instrument hardware is not present
- Definition of Bit-level (interface) models
- Instrument SE, capable of providing sensor stimulus and/or data insertion
- Typical instrument sensor data consistent with various instrument modes and data products

TELEMETRY ANALYSIS AND DISPLAY SOFTWARE

The Telemetry Analysis and Display Software is the primary query and display system used by the engineering and science teams to review the engineering data from the spacecraft. Standard displays and plotting capability will be provided to operate on typical engineering telemetry data (State Variables and Value Histories). Individual subsystems can define special "viewers" for more complex data products. This data can also be "linked" to subsystem provided analysis programs for specialized data analysis (such as trend analysis, hardware calibrations, etc.)

Required Instrument definition of Telemetry Display and Analysis SW

- Definition of any unique display requirements
- Definition of special instrument data viewers for the instrument
- Definition of special instrument data analysis routines to be linked to the display data

INSTRUMENT DATA PROCESSING SOFTWARE

Instrument Data Processing Software is defined by the PI to prepare his experiment data for review, publication, or archiving. These programs can be resident at JPL or at the PI provided facilities. It is anticipated that portions of this software will also be used as part of the Tactical U/L process to facilitate decision making.

Required Instrument Data Processing Software may include:

- Data compression/decompression requirements and/or algorithms
- Extraction of Health and Safety data for review
- Extraction of Sensor Data needed for Tactical Decision Making
- Data preparation for archiving
- Extraction and/or analysis of other data needed for Mission Operations

Decision Support Software

It is expected that most of the software support for tactical decision making will be included in the uplink planning and goal integration programs, the telemetry analysis and display programs, or in the instrument data processing program sets. However, for some mission activities (such as rover driving) specialized decision support software may be required (where do I drive tomorrow).

Required Instrument Decision Support Software may include:

- For fast, tactical decision making, some proposers may require specialized analysis software over and above the Instrument Data Processing Software. Cost of this software should be included in the proposal.

Deep Space Mission Systems (DSMS) Software

Deep Space Mission Systems (DSMS) Software is adapted at JPL from multi-mission software providing standard services. These services include cruise navigation support software, Mars Orbiter Relay Planning software, Downlink Data Preparation software (GIF, TIS, TDS, etc.), and Data Accountability software. The Data Management software and Data Archiving software will provide product cataloging, a central data repository, and access to all project downlink data and uplink products needed by other software programs. Where needed (such as data management, and data transport), MDS Architecture based programs provide applications built upon the DSMS base. DSMS adapted software is also used for formatting and transporting spacecraft command data (goal networks) files to the Deep Space Network (DSN) stations for transmission to the spacecraft. This software is developed and operated at JPL, but can provide data to/from Instrument Teams located at JPL or Remote sites.

Required Instrument support includes:

- Full definition of Data Products for Data Catalog and Data Management handling

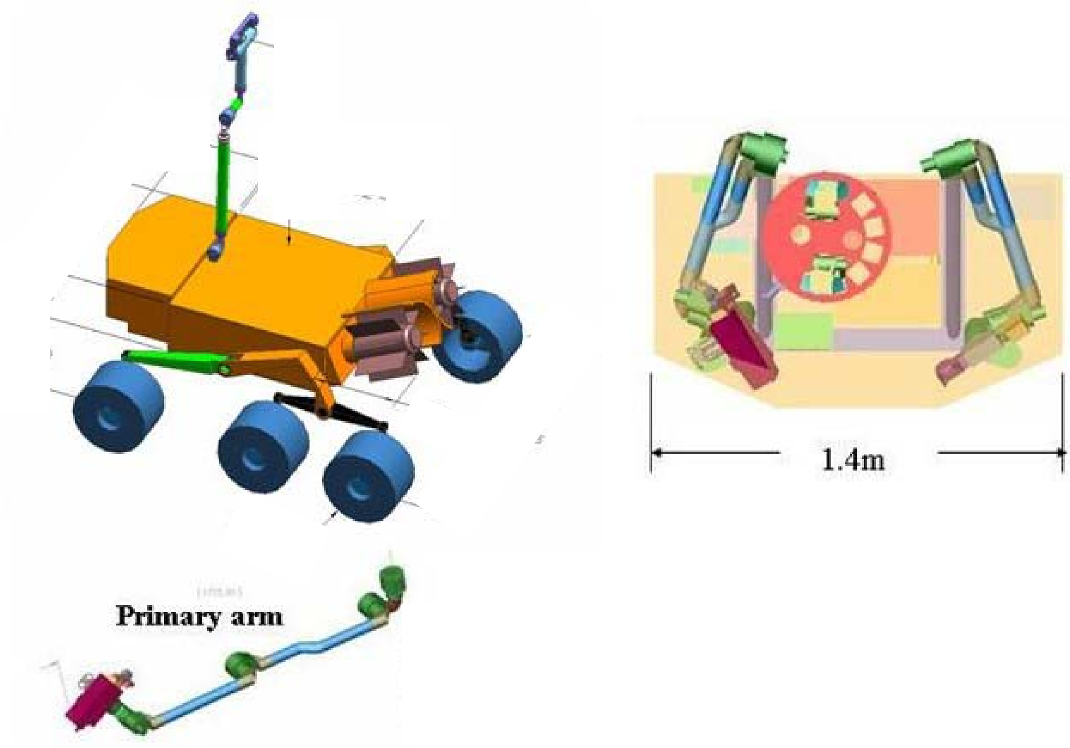


Figure 3.2.2: Models show rough order of magnitude volumes available in the Analytical Laboratory payload module and on arms