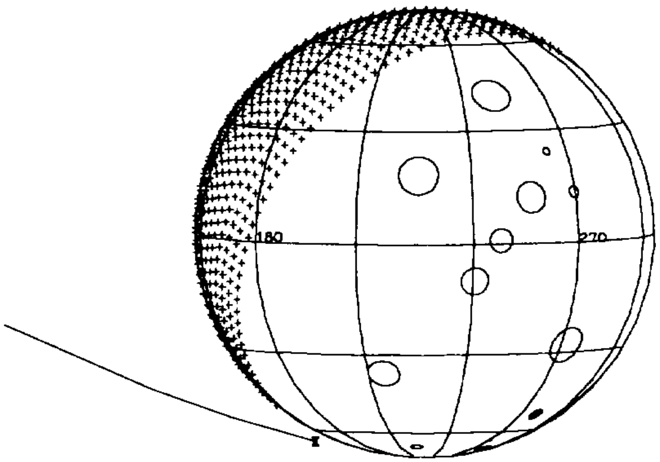
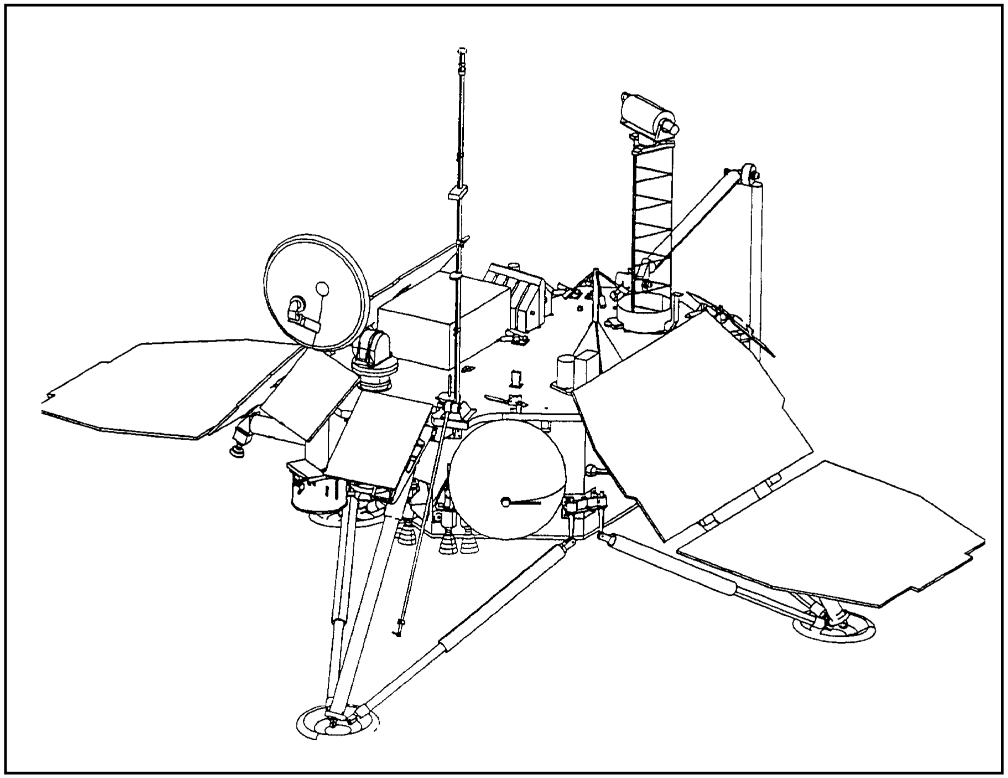
MARS SURVEYOR '98 PROJECT

LANDER MISSION PLAN and DATABOOK





August 8, 1997

LANDER MISSION PLAN AND DATABOOK - TABLE OF CONTENTS

5.0 MARS SURVEYOR 1998 LANDER MISSION PLAN

5.1 FLIGHT SYSTEM DESCRIPTION

5.1.1 Lander Bus - Cruise Stage, EDL and Propulsion Systems

Cruise Stage: The lander flight system consists of a separable cruise stage with a MDAC V–band launch vehicle separation interface, and propulsive lander/entry assembly. The cruise stage is jettisoned just prior to atmospheric entry, providing a clean aerodynamic shape for entry and a reduced ballistic coefficient. Cruise stage operational components include redundant star cameras and sun sensors for attitude determination, two solar array wings (2.6–m2 total area) for power generation, an X-Band medium gain transmit/receive horn antenna and one low gain receive patch antenna and a redundant pair of solid state power amplifiers (SSPA's) for telecommunications during cruise. Three–axis attitude control during cruise is provided using a redundant Inertial Measurement Units (IMU's) and four cruise reaction engine modules (REM's) located on the Lander. Each REM contains one aft-facing 5-lbf TCM thruster and one canted [20˚ out, 15˚ aft] 1-lbf RCS thruster.

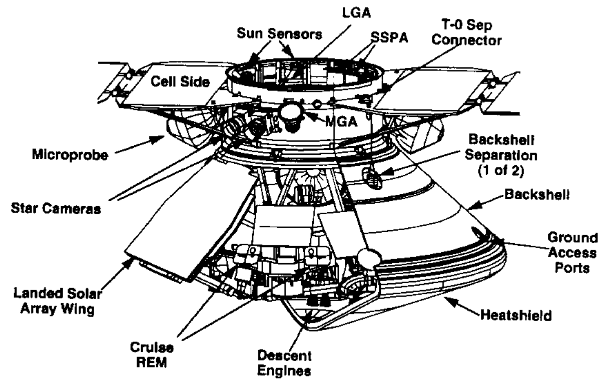
EDL System: The 2.4 m diameter heatshield structure and ablator makes use of the tooling developed for Pathfinder, sharing the same nose radius and cone angle. The ballistic coefficient is 58 to 62 kg/m^2, somewhat lower than Pathfinder. The Pathfinder parachute design is used to lower cost. As on Pathfinder, the parachute is deployed based on an on-board navigator velocity estimate, eliminating the long–range radar altimeter used on Viking. The parachute is mortar-deployed to ensure good separation for inflation in the freestream. After parachute deployment the heatshield is separated from the backshell, 3 landing legs are deployed, and the descent engines are warmed with short firing pulses. The MARDI descent imager starts operating shortly before heatshield separation. After a short parachute ride the flight software attitude control algorithms determine the optimum time to release the lander from the backshell/parachute to begin the powered descent phase.

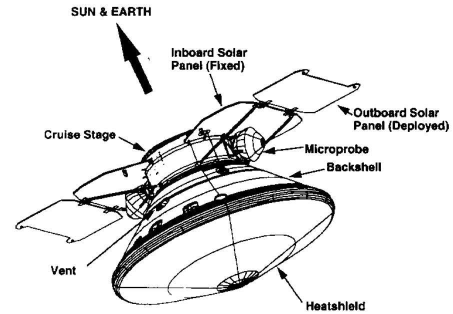
Propulsion System: Two diaphragm propellant tanks contain the 64 kg of purified hydrazine propellant used for both cruise maneuvers and attitude control as well as for lander powered descent. This is a pressure-regulated system with serially-redundant pressure regulators utilizing helium gas pressurant. For final descent, a Doppler radar provides accurate altitude and 3–D velocity estimates. Descent control is provided by twelve 266 N retro–engines arranged in three groups of four engines each. The engines are pulse modulated. As the lander descends to within 12 meters of the surface the spacecraft control system begins the 2.4 m/s constant velocity terminal descent phase. Landing engines are cutoff when any one of the lander footpads touches the planet surface. The AACS subsystem controls the orientation of the lander on landing, placing the X axis within 5 degrees of the desired azimuth [45˚ West of North, to maximize the solar array efficiency and minimize Direct To Earth (DTE) antenna blockage].

Go to TOC

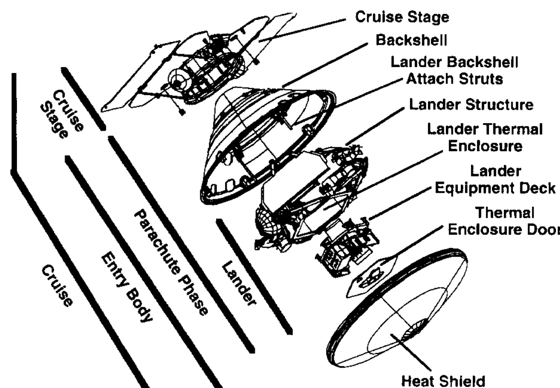
LANDER BUS - CRUISE STAGE, EDL & PROPULSION SYSTEMS

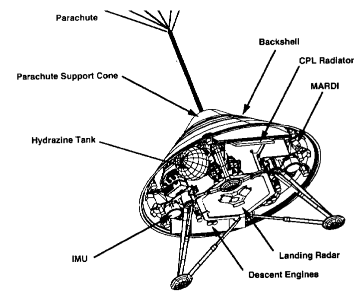
- **Cruise Stage:**
  - Redundant star cameras, sun sensors
  - Two solar arrays: 2.6 m^2 total area
  - X-Band transmit/receive horn MGA, 1 patch LGA, redundant pair of solid state power amplifiers (SSPA's)
  - 3 axis control: redundant IMU's, 4 reaction engine modules [REM's] located on Lander.
    - » Each contains 1 aft-facing 5-lbf TCM thruster and 1 1-lbf RCS thruster [canted outward 20° and aft 15°].



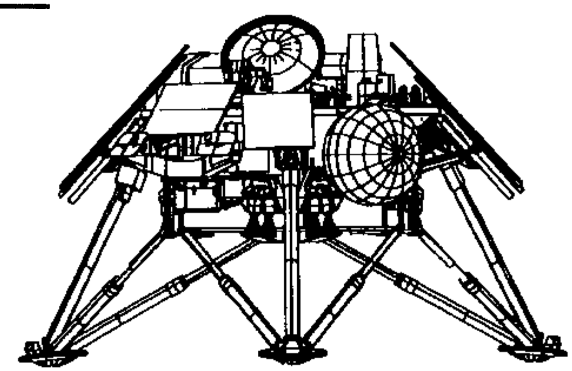


- **EDL System:**
  - 2.4 m diameter heatshield [ablator] based on PF design
  - Ballistic coefficient 58 - 62 kg/m^2 , PF parachute design.
  - Mortar parachute deployment based on IMU velocity estimate
  - Heatshield separates after parachute deployment, landing legs are deployed, descent engines are warmed with short pulses
  - MARDI starts operating just prior to heatshield separation
  - Fight software attitude control algorithms determine optimum time for lander release & start of powered descent phase.





- **Propulsion System:**
  - 2 diaphragm tanks [64 kg total hydrazine capacity] used for translational and rotation ΔV for all mission phases.
  - Pressure regulated with He pressurant
  - Final Descent:
    - » Doppler radar provides altitude & velocity estimates
    - » Twelve pulse modulated 266 N engines, 3 groups of 4 engines each
    - » 2.4 m/s constant vel terminal descent phase starts 12 meters above surface
    - » Engines cut off when any of the footpads touch the surface
    - » AACS subsystem controls landed orientation to place X axis within 5° of desired azimuth [45° West of North]



Terminal Descent Configuration

5.1.2 Lander Bus - Structure, Power/Thermal, Telecom

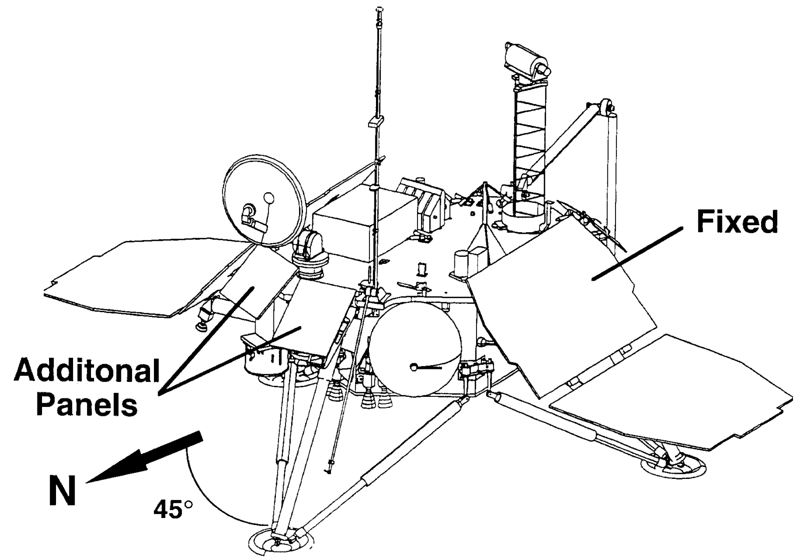
Structure: The Lander structure is constructed of a composite material consisting of honeycomb aluminum core with graphite-epoxy facesheets bonded to each side. A thin aluminum sheet is bonded to the composite to provide a Faraday cage around the thermal enclosure. The landing legs are made of aluminum and have compression springs to deploy the legs from the stowed position. Tapered, crushable, aluminum honeycomb inserts in each leg provide the shock absorption necessary for landing. The design has a thermally isolated component deck inside of a central thermal enclosure to control the thermal environment for spacecraft and Payload electronics. Located within this enclosure is the Command and Data Handling (C&DH) electronics, the Power Distribution electronics (PDDU), the Charge Control Unit (CCU), the Nickel-Hydrogen Common Pressure Vessel Batteries (CPV's), The X-Band and UHF telecommunication electronics, and the Capillary Pump Loop Heat Pipe (LHP) components. Imbedded within the component deck are the LHP evaporators which transfer heat from the aluminum facesheets of the component deck to the LHP radiators located outside of the thermal enclosure. Components used only during EDL are mounted external to the enclosure to maximize volume inside the thermal enclosure for on–surface functions (The gyroscopes, pyro firing electronics, radar and radar electronics are located outside the thermal enclosure).

Power and Thermal: For the landing footprint of 75° to 78° South latitudes the sun does not go below the nominal horizon for the season of the prime mission. However, a 10° terrain mask is assumed for power analyses and results in a defined day and night interval when the sun goes below the horizon mask. The solar array, consisting of 6 panels [4 fixed, 2 deloyed] provides power during the daytime for payload operations and recharges the batteries which provide nighttime heater power for the thermal enclosure. The C&DH and Power Distribution electronics have a low-power sleep mode to reduce energy consumption at night. The lander lifetime is limited by the size of the batteries. As the nights get longer and colder late in the summer the heater power required at night increases until the demand can no longer be satisfied by the 16 A-hr batteries. The batteries then freeze and the mission ends. Daytime operations are limited by the size of the arrays and the amount of power required to recharge the batteries. The duration of the payload and spacecraft daytime operations is approximately 8-9 hours at landing, but decreases as the sun goes lower in the sky. The power system is designed for full operation in a dusty atmosphere of opacity (Tau) = 0.5. Survival under full dust storm conditions (Tau = 1) TBD may be possible with advance planning but is not a design requirement.

Telecom: The primary telecom link for science data relay and spacecraft commanding is the UHF relay link to the '98 orbiter. A UHF link to Mars Global Surveyor is also available, for data relay only. Eight to ten UHF communication passes above 20° effective terrain mask can occur with each orbiter each day. An X–band, Direct-To-Earth link with a steerable dish is provided as a transmit/receive backup. The maximum duration of an X-Band transmit event is limited to one hour by the capability of the Loop Heat Pipe to transfer the heat energy from the X-Band Solid State Amplifier out of the thermal enclosure. The number of UHF and X-Band use cycles is limited by the amount of daytime power available.

Go to TOC

LANDER BUS - STRUCTURE, POWER/THERMAL, TELECOM



- **Lander Structure**
  - Composite: honeycomb Aluminum core with graphite-epoxy facesheets
  - Legs: spring-deployed, Aluminum, with crushable inserts
  - Thermally isolated component deck inside central thermal enclosure, contains C&DH, PDDU, CCU, Ni-H common pressure vessel batteries, telecom [X-band direct and UHF relay], heat pipe
  - Externally mounted componenets used during EDL are: gyros, pyro firing electronics, radar

- **Power and Thermal**
  - 6 Solar panels [4 fixed, 2 deployed] provide power during "daytime" - defined to be when sun is above 10˚ elevation.
    - » Sun does not go below nominal horizon for prime mission, for landing between 75S and 78S
    - » Batteries [16 A-hr] provide night-time heater power for thermal enclosure
  - C&DH and Power distribution electronics have low-power night-time sleep mode
  - Payload allocated 25 Watts continuous when operating
  - S/C daytime operations ~ 8-9 hrs [landing], decreases towards the end of the mission
  - Designed for full operation in atmosphere up to opacity of 0.5. Operation during dust storm [τ=1] TBD
  - Mission ends when batteries freeze

- **Telecom**
  - Primary link for data relay & commanding is the UHF link to the M98 orbiter, downlink via MGS also available
  - 8 - 10 UHF passes above 20˚ terrain mask available for each orbiter per day
  - X-band DTE w/ steerable dish available as command/relay backup. 1 hr duration suppotred by thermal limits
  - Number of UHF and DTE cycles per day limited by daytime power

5.1.3 Lander Payload - Mars Descent Imager [MARDI], LIDAR, New Millenium Microprobes

Mars Descent Imager (MARDI)

MARDI includes a single camera head consisting of optics, focal plane assembly and support electronics, and housing. Using a megapixel, electronically shuttered CCD, MARDI provides panchromatic images of the landing site with a resolution of 1.25 mrad/pixel. Images are taken starting just before heatshield jettison, and continue until landing. Under nominal circumstances approximately ten 1000 x 1000 pixel images will be acquired. Taken at altitudes less than 8 km above the surface, these images cover areas from 9 km to 9 m across and at resolutions of 7.5 m to 9 mm per pixel pair. MARDI is built by Malin Space Science Systems (MSSS), with Dr. Michael Malin (MSSS) as Principal Investigator.

LIDAR

The LIDAR [Light Detection and Ranging] is an upward viewing lidar mounted on the Lander deck. It consists of a sensor assembly, an electronics assembly, and the interconnecting cable assembly. The LIDAR is provided by the Space Research Institute (IKI) of the Russian Academy of Science, under the sponsorship of the Russian Space Agency (RSA). The Principal Investigator is S. Linkin.

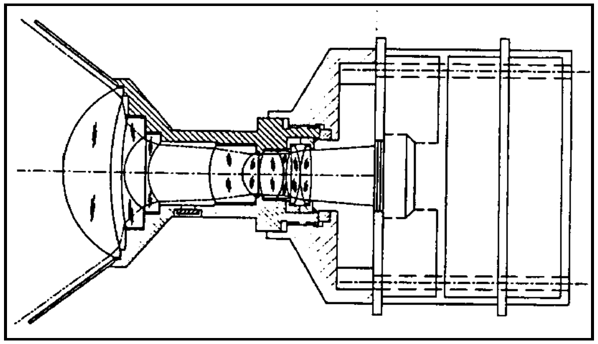
The LIDAR transmitter uses a pulsed GaAlAs laser diode which emits 400 nJ energy in 100 nsec pulses at a rate of 2.5 kHz and at 0.88 μm wavelength. The LIDAR has two sounding modes. During active sounding, light pulses are emitted and their return timed in order to locate and characterize ice and dust hazes in the lowest few kilometers (< 2-3 km). An acoustic device [microphone] will also be included as part of the LIDAR assembly.

New Millenium Microprobes

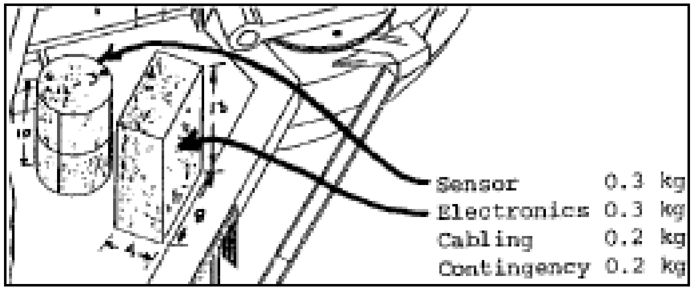
Two microprobes supplied by the New Millenium Project will be carried aboard the Lander cruise stage and will deploy themselves 15–20 seconds after separation of the cruise stage from the aeroshell. Each battery-powered microprobe penetrator will activate on separation, collect temperature, accelerometer, and engineering data during entry, and impact the surface at 180 m/s, destroying the integrated aeroshell. At impact the penetrator forebody penetrates > 0.3 m into the soil; a cable connects the forebody to the separable aft body which remains near the surface. The aft body contains batteries, a pressure sensor, sun detector, and a antenna for data relay through MGS. Immediately after impact, a soil sample will be taken, and the probes will begin listening for the MGS MR beacon. All data will be relayed via MGS during the probes' mission life, expected to be 2 sols [primary mission] to 30-45 sols [extended mission] in duration. Experiments include measurements of soil thermal conductivity, taken every few minutes during the first hour and once per hour thereafter, atmospheric pressure measurements taken once per hour, and a water detection experiment designed to sense the presence of ice and hydrated minerals.

Go to TOC

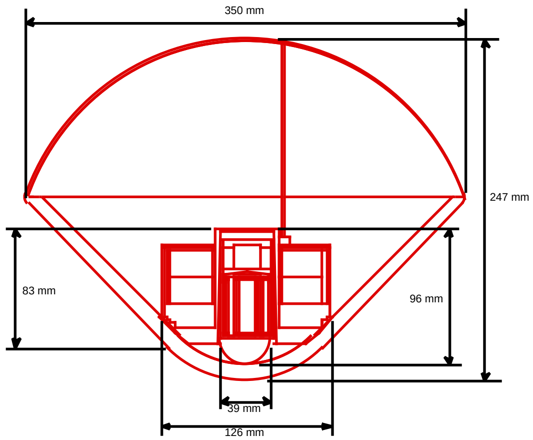
LANDER PAYLOAD - MARS DESCENT IMAGER [MARDI], LIDAR, NEW MILLENIUM MICROPROBES



- **Mars Descent Imager (MARDI)**
  - Images taken starting just before heatshield jettison, & continue until landing.
  - Megapixel, electronically shuttered CCD will take panchromatic images of the landing site at 1.25 mrad/pixel.
  - 10 1000x1000 pixel images will be taken, covering areas from 9 km to 9 m across at resolutions of 7.5 m to 9 mm per pixel pair.
  - Built by Malin Space Science Systems, Dr. Michael Malin Principal Investigator.



- **LIDAR [Light Detection and Ranging]**
  - Upward viewing lidar mounted on the Lander deck.
  - Provided by Space Research Institute (IKI) [Russian Academy of Science] under sponsorship of the Russian Space Agency (RSA). S. Linkin PI
  - LIDAR transmitter uses a pulsed GaAlAs laser diode
  - 2 sounding modes:
    - Active sounding: light pulses emitted and thier return timed to locate and characterize ice and dust hazes below 2-3 km
    - Acoustic device [microphone]



- **NEW MILLENIUM MICROPROBES**
  - 2 probes separate from cruise ring 15 -20 sec after cruise stage jettison
    - Separation turns on the probes.
    - Temperature, accelerometer, engineering data recorded during descent.
  - Impact ~7 min later at ~180 m/s. Aeroshell destroyed on impact.
    - Forebody penetrates > 0.3 m
    - Aft body containing batteries, pressure sensor, sun detector, and antenna remains on surface
  - Immediately after impact, a soil sample is acquired
  - Begin listening for MGS beacon. All data relayed via MGS.
  - Primary Mission: 2 Sols, Extended Mission: 30-45 Sols
  - Experiments: Soil thermal conductivity, Atmospheric pressure, Water detection

5.1.4 Lander Payload - Mars Volatiles and Climate Surveyor [MVACS]

MVACS is an integrated payload with four major science elements: a Stereo Surface Imager, a Robotic Arm with Camera, a Meteorological package of pressure, temperature, wind, and water vapor sensors, and a Thermal and Evolved Gas Analyzer. Dr. David Paige (UCLA) is the Principal Investigator for the MVACS.

Stereo Surface Imager (SSI): The mast-mounted SSI provides panoramas of the Lander site, characterizes the general environment at the landing site, and provides imaging support for other payload elements, especially operations of the RA and TEGA, and for the spacecraft, as needed. The SSI is essentially a clone of the Mars Pathfinder IMP; it is a multi-spectral imager accessing several wavelengths between 0.4 and 1.1 microns. This multi-spectral capability, together with onboard calibration targets, provides true color images. SSI also images magnetic targets on the Lander deck to characterize the magnetic properties of surface material. Narrow-band imaging of the sun provides line-of-sight optical depths of atmospheric aerosols and (slant column) water vapor abundances. Stereo imaging is provided by the dual optical lens systems focusing onto a single CCD.

Robotic Arm (RA); Robotic Arm Camera (RAC):
A two-meter RA with an articulated end member is used to dig trenches at the site, to acquire samples of surface and subsurface materials, and to support operations of an attached RA Camera. The RAC will image the surface and subsurface at close range to reveal fine-scale layering if present and to characterize the fine-scale texture of the samples and trench sides. The light-weight RA also supports a probe for measuring surface and subsurface temperatures.

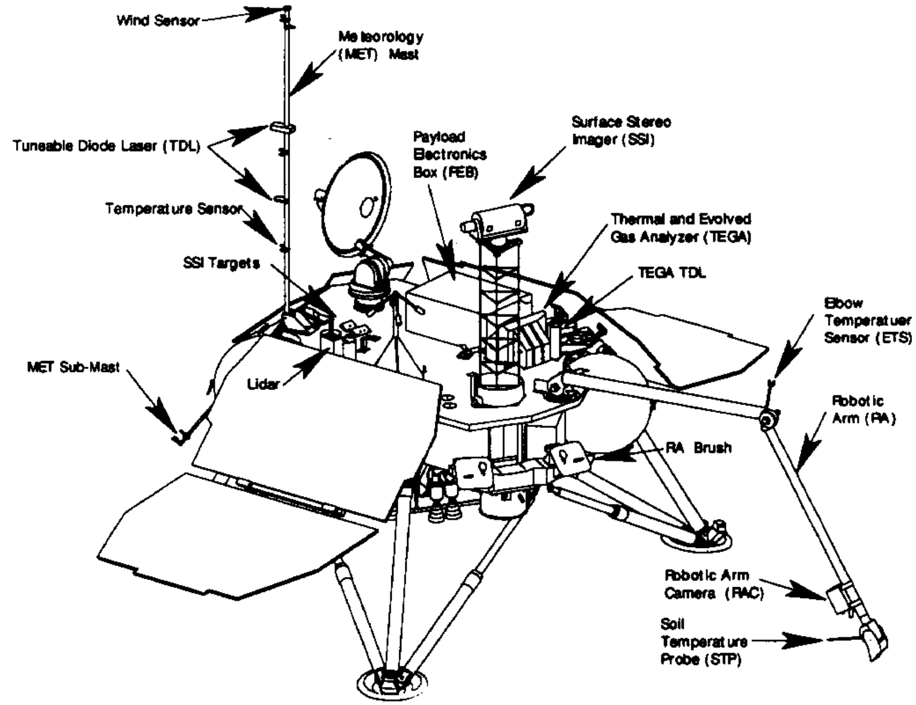
Meteorological Package (MET): Mounted on a 1.2-m mast, the MET package includes a wind (speed and direction) sensor, several temperature sensors, and Tunable Diode Lasers (TDL) which measure water vapor amounts and specific isotopes of water and carbon dioxide. A secondary mast (0.9 m in length) is attached to the main MET mast, and supports a wind speed and two temperature sensors near the surface saltation layer. Pressure sensors are mounted within the spacecraft. Once on the surface the MET sensors are read at periodic intervals, as power permits.

Thermal and Evolved Gas Analyzer (TEGA): TEGA uses differential scanning calorimetry (DSC) combined with gas-specific sensors to determine the concentrations of ices, adsorbed volatiles and volatile-bearing minerals in surface and subsurface samples acquired and imaged by the Robotic Arm (RA). The RA deposits the sample on a grated screen over a chute which fills the sample receptacle. This receptacle is then mated with a cover to form the oven in which the sample is heated; a paired (empty) oven provides a calibration for the heating run. Evolved gases are wafted to sensors which quantify the rate of discharge of oxygen, carbon dioxide and water vapor. Once used, the ovens cannot be used again. TEGA is designed to receive eight surface (soil) samples during the Lander mission.

Go to TOC

LANDER PAYLOAD - MARS VOLATILES AND CLIMATE SURVEYOR [MVACS]

- **Stereo Surface Imager [SSI]**
  - Mast-mounted stereo color imager, clone of PF IMP
    - » Multispectral capability [0.4 - 1.1 microns]
    - » Dual optics focusing on single CCD
  - Provides panoramas of site and imaging support for other payload elements, especially the Robotic Arm and TEGA
  - Images magnetic targets on deck
    - » Magnetic characterization of surface material
  - Narrow-band imaging of Sun
    - » Line of sight optical depths of aerosols
    - » Slant column water vapor abundances
- **Robotic Arm [RA]; Robotic Arm Camera [RAC]**
  - 2-meter arm with articulated end member, camera, and temperature probe
  - Digs trenches, to acquire samples of surface and subsurface materials, and support operations of the RAC
  - RAC images surface and subsurface to reveal fine-scale layering if present and characterize fine-scale texture of the samples and trench sides



- **Meteorological Package [MET]:**
  - Mounted on 1.2-m mast: wind (speed and direction) sensor, temperature sensors, and Tunable Diode Lasers (TDL) which measure water vapor amounts and specific isotopes of water and carbon dioxide.
  - Secondary mast (0.9 m) is attached to the main MET mast: wind speed & 2 temperature sensors near the surface saltation layer.
  - Pressure sensors are mounted within the spacecraft.
  - On the surface, MET sensors are read at periodic intervals, as power permits.
- **Thermal and Evolved Gas Analyzer [TEGA]:**
  - Uses differential scanning calorimetry (DSC) combined with gas-specific sensors to determine the concentrations of ices, adsorbed volatiles and volatile-bearing minerals in surface and subsurface samples acquired and imaged by the Arm.
  - **Operation:** RA deposits the sample in a receptacle, which is then mated with a cover to form the oven; Evolved gases are wafted to sensors which quantify the rate of discharge of oxygen, carbon dioxide and water vapor. Once used, the ovens cannot be used again. Eight surface [soil] samples can be analyzed.

5.2 LANDER MISSION OVERVIEW

5.2.1 Overall Mission Description

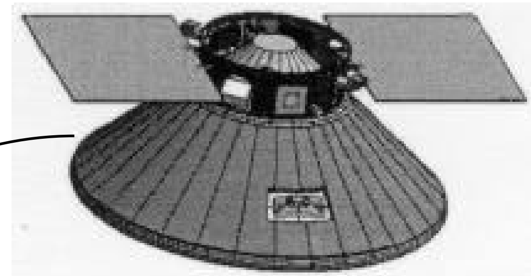
The MSP 98 Lander will be launched on a Delta 7425 in January 1999, and will arrive at Mars in December 1999. Burnout of the 3rd stage will be followed by yo-yo despin of the entire stack, followed by spacecraft separation. At this point both the spacecraft and upper stage will have been injected onto a Type 2 trajectory whose aimpoint is biased away from the nominal entry aimpoint, to assure that the upper stage has less than a 1E-4 probabilty of impacting Mars, as required by Planetary Protection regulations. After separation, the solar panels will be deployed and pointed to the sun, and initial acquisition achieved by the DSN. Throughout cruise, contact will be maintained via the Medium Gain Antenna. The solar panels will be pointed at the sun [with a small offset in inner cruise]. Approximately 15 days after launch, the largest Trajectory Correction Maneuver [TCM-1] will be executed. This maneuver will remove launch vehicle injection errors and the spacecraft's injection aimpoint bias. Depending on the size of the maneuver, it may be necessary to divide this into two smaller maneuvers. Provisions have been made to execute up to 3 additional small TCM's during the remainder of cruise, plus a contingency 5th TCM seven hours prior to entry for final control of the entry angle and landing footprint, if needed. Precision approach navigation will be effected via near simultaneous tracking of the approaching Lander and an orbiter at Mars [either the MSP98 Orbiter or MGS].

After a direct atmospheric entry, the Lander will be slowed by a Mars Pathfinder-heritage aeroshell and parachute, and a controlled propulsive landing effected. For launch during the Lander's primary launch period, landing will occur between 75˚ and 78˚S, on the southern polar layered terrain. The first landed day's activities will include deployment of the solar panels, functional checkout, and establishment of communication with the Orbiter and time critical science activities. Routine science activities will commence, at the earliest, on the second day following landing. The Lander will be equipped with a UHF relay for downlink via the MSP98 Orbiter and/or MGS, and command uplink via the MSP98 Orbiter. A direct to Earth [DTE] link will also be available for Lander commanding and as a backup downlink.

The Lander will carry the Mars Volatiles and Climate Surveyor (MVACS) instrument suite, which will perform in situ investigations to address the science theme "Volatiles and Climate History", the Mars Descent Imager (MARDI), and a LIDAR instrument supplied by the Russian Space Agency. The Lander will search for near-surface ice and possible surface records of cyclic climate change, and characterize physical processes key to the seasonal cycles of water, carbon dioxide and dust on Mars. The duration of the landed science phase is expected to last no more than approximately 90 days.

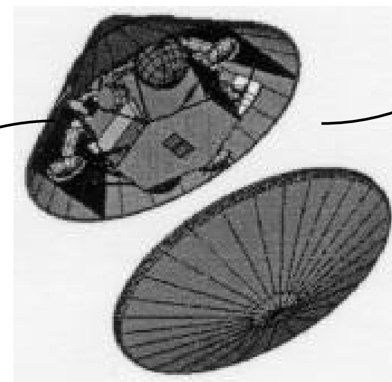
Go to TOC

OVERALL MISSION DESCRIPTION



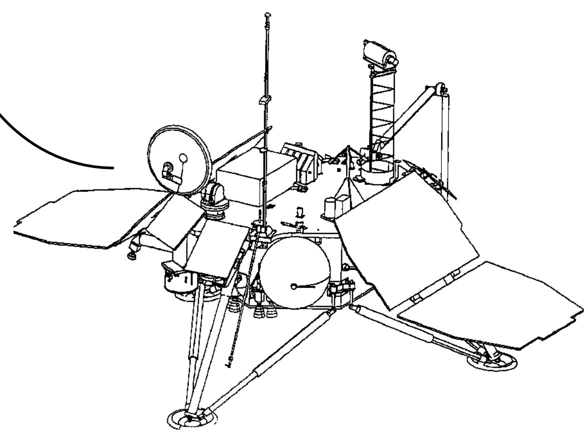
Cruise
- 5 TCM's [Contingency TCM-5 7 hrs before Entry]
- Comm via MGA/LGA
- Near simultaneous tracking w/ Mars orbiter starting E-30d

S/C Initialization
- Deploy Solar Arrays
- Safe Mode for Sun/Earth Acquisition
- Initial DSN Acquisition



Entry, Descent & Landing
- Direct entry
- Propulsive Landing

Launch
- 615 kg Launch Mass
- Delta II 7425 Vehicle



Landed Operations
- Commanding via UHF to M98 Orbiter or DTE link
- Data relay via M98 Orbiter, MGS, or DTE link
- Landed mission duration: up to ~ 90 days

5.2.2 Mission Phases

Launch and Boost & S/C Initialization Phases: The launch phase extends from Liftoff - 20 hours through liftoff. The Boost and s/c Initialization Phase covers Liftoff until initial DSN contact.

Cruise Phase: The cruise phase extends from spacecraft initialization to Entry - 30 hours. It includes initial checkout of the spacecraft, required trajectory correction maneuvers (TCMs) and calibrations, and initiation of the pre-entry episode.

Entry, Descent, and Landing Phase: The entry, descent, and landing [EDL] phase extends from Entry - 30 hours until cutoff of the descent engines.

Landed Operations Phase: The landed operations phase extends from descent engine cutoff through the end of science data taking. Phase duration will be a function of lander capabilities.

Go to TOC

MISSION PHASES

- **Launch and Boost & S/C Initialization Phases:**
  - **Launch:** Liftoff - 20 hours to liftoff.
  - **Boost and s/c Initialization:** Liftoff until initial DSN contact.
- **Cruise Phase:**
  - From spacecraft initialization through Entry - 30 hours
  - Includes initial checkout of the spacecraft, TCMs and calibrations
- **Entry, Descent, and Landing [EDL]:**
  - From Entry - 30 hours until cutoff of the descent engines
- **Landed Operations Phase:**
  - From descent engine cutoff through end of science data taking
  - Phase duration is a function of lander capabilities

5.2.3 Lander Launch/Arrival Period

The MSP98 Lander launch period is divided into an 8 day Primary period [1/3/99 - 1/10/99] followed by a 6 day Secondary launch period [1/11/99 - 1/16/99]. A Contingency launch period [1/17/99-1/27/99] is also supported. All lander trajectories are Type 2, which allow high southern latitude accessibility during southern Spring. Additional information on trajectory states can be found in Appendix B.1 - Lander Mission Database.

Lander design, including ablator thickness and thermal design, and propellant loads are based on conditions during the Primary launch/arrival period. The Secondary and Contingency intervals are characterized by reduced probabilities of achieving mission goals, including site elevation requirements.

Primary Launch Period [1/3/99 - 1/10/99]: The choice of the Lander's Primary launch interval is based on a number of factors. In order to avoid conflict with the Orbiter launch, the start of the Lander launch period must occur no earlier than January 2, 1999. In addition, the arrival date must be no earlier than December 3, 1999, which corresponds to a solar longitude [Ls] of 256˚. This is the earliest arrival consistent with Lander survival and operation in the thermal environment expected at the high Southern landing latitudes. The date for the open of the Primary launch period which satisfies these requirements and also keeps the launch energy [C3] acceptably low is January 3, 1999. Across the 8 day primary period, the arrival date is kept fixed, primarily to keep arrival V_∞ low for improved approach navigation accuracy. A fixed arrival date also simplifies Lander operations planning. With this stategy, the maximum C3 and V_∞ for the Primary interval both occur on the first day of the Launch period. The history of the Delta launch vehicle indicates that a high probability [approximately 98% or higher] exists that launch will occur during the Primary interval.

Entry Angle and Landing Latitude: For a flight path angle of -13.25˚, the nominal landing latitude is approximately 76˚S at the start of the Primary launch period, and 75˚S at the end of Primary. The Landing footprint is approximately ± 1.5˚ for an entry angle corridor of 0.45˚ [3σ]. [See B.1, the Lander Mission Database for more data.] The probability of staying within the required entry angle corridor of ±0.25˚ is TBD for the Primary launch period. The range of acceptable longitudes is approximately 170˚W - 235˚W, corresponding to ice-free conditions at the landing latitude. For planning purposes, the nominal landing latitude is assumed to be 210˚W.

Secondary Launch Period [1/11/99 - 1/16/99]: During the 6 day Secondary period which follows the Primary interval, the nominal launch/arrival strategy is to follow a contour of constant latitude, to maintain approximately the same lattitude access available at the end of the Primary interval. As the following graphic illustrates, by the latter half of the Secondary launch period, the arrival V_∞ will start exceeding the maximum V_∞ encountered during the Primary interval. This will tend to degrade approach navigation accuracy [leading to larger landing ellipses] and lead to higher heat loads. For launches towards the very end of the Secondary period, it may become necessary to sacrifice latitude access in order to keep heating loads within limits.

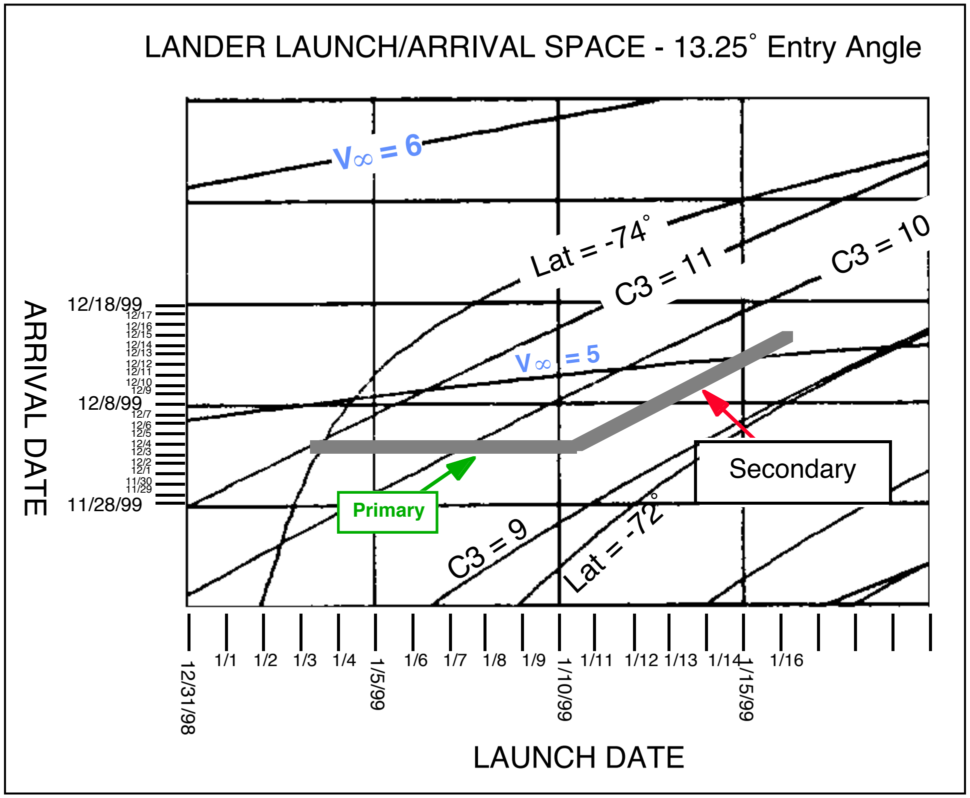
Contingency Launch Period [1/17/99 - 1/27/99]: Launch beyond the end of the Secondary period is feasible, by following a launch/arrival strategy which does not increase arrival V_∞ beyond the limit imposed by the ablator thickness. As the following graph indicates, this leads to landing sites at more Northern latitudes.

Go to TOC

LANDER LAUNCH/ARRIVAL PERIOD

** This page under Change Control **

- **14 Day Launch Period: 1/3/99 - 1/16/99**
  - **Type 2 trajectories allow access to high South latitudes during Southern Spring.**
  - **Primary Period: 1/3/99 - 1/10/99** [8 days]
    - » Lander design based on conditions during Primary
    - » Start of Primary chosen to keep C3 < ~ 11, for constant arrival date 12/3/99
      - 12/3/99 corresponds to Ls = 256˚, Earliest arrival consistent with lander thermal design at landing latitudes
      - Keeps arrival V∞ low for improved approach Nav
      - Constant arrival date simplifies planning
    - » Landing Site:
      - For nominal fpa = -13.25˚, Nominal Landing Latitude = 76˚ [open primary] - 75˚ [close primary]
      - ~ ± 1.5˚ footprint for entry corridor = 0.45˚ [3σ]
      - Probability of staying within required ±0.25˚ entry angle corridor = TBD
      - Range of longitudes [ice-free] ~ 170˚ - 230˚W. Nominal site currently placed at 210˚W



Latitude contours are approximate - intended to show trends only

  - **Secondary Period: 1/11/99 - 1/16/99** [6 days]
    - » Reduced probability of meeting mission goals [e.g. landing site elevation]
    - » Follows contour of constant latitude as long as feasible

- **Contingency Period: 1/17/99 - 1/27/99 is also supported** [bound V∞, landing sites move Northward]
  - **SUMMARY**

	Day in Launch Period	Launch Date	Arrival Date	Depart C3 [km^2/s^2]	Arrival Vinf [km/s]	Landing Ls [deg.]	Landing Sun angle [deg.]	Landing True Solar Time	Landing Latitude [deg.]
Open of Primary	1	1/3/99	12/3/99	11.17	4.84	256.3	18.3	4:14:33	76S
Close of Primary	8	1/10/99	12/3/99	9.76	4.76	256.3	17.5	4:10:10	75S
Close Secondary	14	1/16/99	12/15/99	9.71	5.08	263.5	16.5	3:36:35	~ 75S

5.2.4 Summary of Mission Events and DSN Tracking Requirements

** This page under Change Control **

Shown on the following 3 pages is a text summary of the timing of major mission events and associated DSN tracking requirements. Summaries are provided for the open and close of the Primary Launch Period, and the end of the Secondary Launch Period. 34m HEF antennae are baselined throughout, although limited use of the 34m BWG is feasible and required for some portions of the mission, to accommodate DSN usage conflicts. In addition, some modification of the nominal tracking profile is occasionally required in order to accommodate conflicts with other missions using the same DSN assets. Expected BWG use and modifications to nominal tracking schedules is detailed in Appendix B.8. The 70m net is also being requested for Entry±5 days. [Note: 70m support is also being requested for the Orbiter during the entire Lander surface mission.]

Go to TOC

Lander Open Primary Launch Period

Phase	Sub-Phase	Event		Start Date	Start DOM	End Date	End DOM	# Days	Hrs/ Pass	Passes/ Day	Passes/ Week	Total Hrs	Note
									DSN REQUIREMENTS				
		Launch		**1/3/99**	0								
Cruise		Launch to Launch + 7	Launch + 7 d	1/3/99	0	1/10/99	7	7	8	3	21	168	A
Cruise		Cruise		1/10/99	7	1/15/99	12	5	4	1	7	20	
Cruise		TCM1, entry		1/15/99	12	1/18/99	15	3	4	1	7	12	
Cruise		TCM1, maneuver	TCM1 @ Launch + 15 d	1/18/99	15	1/19/99	16	1	4	1	7	4	
Cruise		TCM1, exit		1/19/99	16	1/22/99	19	3	4	1	7	12	
Cruise		Cruise		1/22/99	19	1/30/99	27	8	4	1	7	32	
Cruise		TCM2, entry		1/30/99	27	2/2/99	30	3	4	1	7	12	
Cruise		TCM2, maneuver	TCM2 @ Launch + 30 d	2/2/99	30	2/3/99	31	1	4	1	7	4	
Cruise		TCM2, exit		2/3/99	31	2/6/99	34	3	4	1	7	12	
Cruise		Cruise		2/6/99	34	2/12/99	40	6	4	1	7	24	
Cruise		Payload Checkout, Calibration Campaig	Launch+ 40 d	2/12/99	40	2/19/99	47	7	4	1	7	28	B
Cruise		Cruise		2/19/99	47	9/4/99	245	198	4	1	7	791	
Cruise		Payload Checkout, Calibration Campaig	Entry - 90 d	9/4/99	245	9/11/99	252	7	4	1	7	28	B
Cruise		Cruise		9/11/99	252	10/1/99	272	20	4	1	7	80	
Cruise		TCM3, entry		10/1/99	272	10/4/99	275	3	4	1	7	12	
Cruise		TCM3, maneuver	TCM3 @ Arrival - 60 d	10/4/99	275	10/5/99	276	1	4	1	7	4	
Cruise		TCM3, exit		10/5/99	276	10/8/99	279	3	4	1	7	12	
Cruise		Cruise to Arrival - 45 d	Ends at Arrival - 45 d	10/8/99	279	10/19/99	290	3	4	1	7	12	
Cruise	Approach	Increased tracking levels	Starts at Arrival - 45 d	10/19/99	290	11/3/99	305	15	4	3	21	180	A
Cruise	Approach	Dual-s/c tracking	Starts at Arrival - 30 d	11/3/99	305	11/28/99	330	25	4	3	21	300	A,D
Cruise	Approach	Add 70m coverage	Starts at Arrival - 5 d	11/28/99	330	11/29/99	331	1	4	3	21	12	A,B,D
Cruise	Approach	TCM4, maneuver	TCM4 @ Arrival - 4 d	11/29/99	331	11/29/99	331	0	4	3	21	0	A,B,D
Cruise	Approach	cruise		11/29/99	331	12/1/99	333	3	4	3	21	36	A,B,D
Cruise	Approach	continuous coverage	Starts at Arrival - 2 d	12/1/99	333	12/3/99	335	4	8	3	21	96	B,D
Cruise	Approach	TCM5, maneuver	TCM5 @ Arrival - 0.3 d	12/3/99	335	12/3/99	335	1	8	3	21	12	B,D
Entry		Entry		**12/3/99**	335	12/3/99	335	0	8	3	21	0	B,D
Primary Mission		Day 1		12/3/99	335	12/4/99	336	1	8	3	21	24	B,D
Primary Mission		end continuous coverage	Ends at Arrival + 2 d	12/4/99	336	12/5/99	337	1	8	3	21	24	B,D
Primary Mission		End 70m coverage	Ends at Arrival + 5 d	12/5/99	337	12/8/99	340	3	1	1	7	3	B,C
Primary Mission		Remainder	Ends at Arrival + 88 d	12/8/99	340	2/29/00	423	83	1	1	7	83	C
		Primary Mission EOM				**2/29/00**	423	0			Grand Total	2037	

Notes

A: S/C transmitter operation limited to 4 hrs on: 5 hrs off or equivalent ratio
B: 70m D/L support required in addition to 34 m coverage for uplink
C: This 10 hr interval must be correlated with Lander site local "day". Overlap with 1 hr Orbiter daily contacts TBD. [See Orbiter req.]
D: Interval of Near-simultaneous Orbiter and Lander tracking. Lander tracks must be coordinated with Orbiter tracks, from same HEF antenna.

** This page under Change Control **

Lander End Primary Launch Period

Phase	Sub-Phase	Event		Start Date	Start DOM	End Date	End DOM	# Days	DSN REQUIREMENTS Hrs/ Pass	Passes/ Day	Passes/ Week	Total Hrs	Note
		Launch		**1/10/99**	0								
Cruise		Launch to Launch + 7	Launch + 7 d	1/10/99	7	1/17/99	14	7	8	3	21	168	A
Cruise		Cruise		1/17/99	14	1/22/99	19	5	4	1	7	20	
Cruise		TCM1, entry		1/22/99	19	1/25/99	22	3	4	1	7	12	
Cruise		TCM1, maneuver	TCM1 @ Launch + 15 d	1/25/99	22	1/26/99	23	1	4	1	7	4	
Cruise		TCM1, exit		1/26/99	23	1/29/99	26	3	4	1	7	12	
Cruise		Cruise		1/29/99	26	2/6/99	34	8	4	1	7	32	
Cruise		TCM2, entry		2/6/99	34	2/9/99	37	3	4	1	7	12	
Cruise		TCM2, maneuver	TCM2 @ Launch + 30 d	2/9/99	37	2/10/99	38	1	4	1	7	4	
Cruise		TCM2, exit		2/10/99	38	2/13/99	41	3	4	1	7	12	
Cruise		Cruise		2/13/99	41	2/19/99	47	6	4	1	7	24	
Cruise		Payload Checkout, Calibration Campaig	Launch+ 40 d	2/19/99	47	2/26/99	54	7	4	1	7	28	B
Cruise		Cruise		2/26/99	54	9/4/99	245	191	4	1	7	763	
Cruise		Payload Checkout, Calibration Campaig	Entry - 90 d	9/4/99	245	9/11/99	252	7	4	1	7	28	B
Cruise		Cruise		9/11/99	252	10/1/99	272	20	4	1	7	80	
Cruise		TCM3, entry		10/1/99	272	10/4/99	275	3	4	1	7	12	
Cruise		TCM3, maneuver	TCM3 @ Arrival - 60 d	10/4/99	275	10/5/99	276	1	4	1	7	4	
Cruise		TCM3, exit		10/5/99	276	10/8/99	279	3	4	1	7	12	
Cruise		Cruise to Arrival - 45 d	Ends at Arrival - 45 d	10/8/99	279	10/19/99	290	3	4	1	7	12	
Cruise	Approach	Increased tracking levels	Starts at Arrival - 45 d	10/19/99	290	11/3/99	305	15	4	3	21	180	A
Cruise	Approach	Dual-s/c tracking	Starts at Arrival - 30 d	11/3/99	305	11/28/99	330	25	4	3	21	300	A,D
Cruise	Approach	Add 70m coverage	Starts at Arrival - 5 d	11/28/99	330	11/29/99	331	1	4	3	21	12	A,B,D
Cruise	Approach	TCM4, maneuver	TCM4 @ Arrival - 4 d	11/29/99	331	11/29/99	331	0	4	3	21	0	A,B,D
Cruise	Approach	cruise		11/29/99	331	12/1/99	333	3	4	3	21	36	A,B,D
Cruise	Approach	continuous coverage	Starts at Arrival - 2 d	12/1/99	333	12/3/99	335	4	8	3	21	96	B,D
Cruise	Approach	TCM5, maneuver	TCM5 @ Arrival - 0.3 d	12/3/99	335	12/3/99	335	1	8	3	21	12	B,D
Entry		Entry		**12/3/99**	335	12/3/99	335	0	8	3	21	0	B,D
Primary Mission		Day 1		12/3/99	335	12/4/99	336	1	8	3	21	24	B,D
Primary Mission		end continuous coverage	Ends at Arrival + 2 d	12/4/99	336	12/5/99	337	1	8	3	21	24	B,D
Primary Mission		End 70m coverage	Ends at Arrival + 5 d	12/5/99	337	12/8/99	340	3	1	1	7	3	B,C
Primary Mission		Remainder	Ends at Arrival + 88 d	12/8/99	340	2/29/00	423	83	1	1	7	83	C
		Primary Mission EOM				**2/29/00**	423	0			Grand Total	2009	

Notes

A: S/C transmitter operation limited to 4 hrs on: 5 hrs off or equivalent ratio
B: 70m D/L support required in addition to 34 m coverage for uplink
C: This 10 hr interval must be correlated with Lander site local "day". Overlap with 1 hr Orbiter daily contacts TBD. [See Orbiter req.]
D: Interval of Near-simultaneous Orbiter and Lander tracking. Lander tracks must be coordinated with Orbiter tracks, from same HEF antenna.

** This page under Change Control **

Lander End Secondary Launch Period

Phase	Sub-Phase	Event		Start Date	Start DOM	End Date	End DOM	# Days	DSN REQUIREMENTS Hrs/ Pass	Passes/ Day	Passes/ Week	Total Hrs	Note
		Launch		**1/16/99**	0								
Cruise		Launch to Launch + 7	Launch + 7 d	1/16/99	13	1/23/99	20	7	8	3	21	168	A
Cruise		Cruise		1/23/99	20	1/28/99	25	5	4	1	7	20	
Cruise		TCM1, entry		1/28/99	25	1/31/99	28	3	4	1	7	12	
Cruise		TCM1, maneuver	TCM1 @ Launch + 15 d	1/31/99	28	2/1/99	29	1	4	1	7	4	
Cruise		TCM1, exit		2/1/99	29	2/4/99	32	3	4	1	7	12	
Cruise		Cruise		2/4/99	32	2/12/99	40	8	4	1	7	32	
Cruise		TCM2, entry		2/12/99	40	2/15/99	43	3	4	1	7	12	
Cruise		TCM2, maneuver	TCM2 @ Launch + 30 d	2/15/99	43	2/16/99	44	1	4	1	7	4	
Cruise		TCM2, exit		2/16/99	44	2/19/99	47	3	4	1	7	12	
Cruise		Cruise		2/19/99	47	2/25/99	53	6	4	1	7	24	
Cruise		Payload Checkout, Calibration Campaig	Launch+ 40 d	2/25/99	53	3/4/99	60	7	4	1	8	32	B
Cruise		Cruise		3/4/99	60	9/16/99	256	196	4	1	9	1009	
Cruise		Payload Checkout, Calibration Campaig	Entry - 90 d	9/16/99	256	9/23/99	263	7	4	1	8	32	B
Cruise		Cruise		9/23/99	263	10/13/99	283	20	4	1	9	103	
Cruise		TCM3, entry		10/13/99	283	10/16/99	286	3	4	1	7	12	
Cruise		TCM3, maneuver	TCM3 @ Arrival - 60 d	10/16/99	286	10/17/99	287	1	4	1	7	4	
Cruise		TCM3, exit		10/17/99	287	10/20/99	290	3	4	1	7	12	
Cruise		Cruise to Arrival - 45 d	Ends at Arrival - 45 d	10/20/99	290	10/31/99	301	3	4	1	7	12	
Cruise	Approach	Increased tracking levels	Starts at Arrival - 45 d	10/31/99	301	11/15/99	316	15	4	3	21	180	A
Cruise	Approach	Dual-s/c tracking	Starts at Arrival - 30 d	11/15/99	316	12/10/99	341	25	4	3	21	300	A,D
Cruise	Approach	Add 70m coverage	Starts at Arrival - 5 d	12/10/99	341	12/11/99	342	1	4	3	21	12	A,B,D
Cruise	Approach	TCM4, maneuver	TCM4 @ Arrival - 4 d	12/11/99	342	12/11/99	342	0	4	3	21	0	A,B,D
Cruise	Approach	cruise		12/11/99	342	12/13/99	344	3	4	3	21	36	A,B,D
Cruise	Approach	continuous coverage	Starts at Arrival - 2 d	12/13/99	344	12/14/99	346	4	8	3	21	96	B,D
Cruise	Approach	TCM5, maneuver	TCM5 @ Arrival - 0.3 d	12/14/99	346	12/15/99	346	1	8	3	21	12	B,D
Entry		Entry		**12/15/99**	346	12/15/99	346	0	8	3	21	0	B,D
Primary Mission		Day 1		12/15/99	346	12/16/99	347	1	8	3	21	24	B,D
Primary Mission		end continuous coverage	Ends at Arrival + 2 d	12/16/99	347	12/17/99	348	1	8	3	21	24	B,D
Primary Mission		End 70m coverage	Ends at Arrival + 5 d	12/17/99	348	12/20/99	351	3	1	1	7	3	B,C
Primary Mission		Remainder	Ends at Arrival + 76 d	12/20/99	351	2/29/00	422	71	1	1	7	71	C
		Primary Mission EOM				**2/29/00**	422	0			Grand Total	2274	

Notes

A: S/C transmitter operation limited to 4 hrs on: 5 hrs off or equivalent ratio
B: 70m D/L support required in addition to 34 m coverage for uplink
C: This 10 hr interval must be correlated with Lander site local "day". Overlap with 1 hr Orbiter daily contacts TBD. [See Orbiter req.]
D: Interval of Near-simultaneous Orbiter and Lander tracking. Lander tracks must be coordinated with Orbiter tracks, from same HEF antenna.

** This page under Change Control **

5.2.5 Lander ΔV and Propellant Mass Summary

** This page under Change Control **

Propellant required by the Lander during its mission life has been calculated using end-to-end Monte Carlo simulations. Propellant loading is based on accommodating 99% of the simulated cases for the start of the launch period, which has the highest arrival V_∞ across the primary. The maximum Lander wet mass is assumed to be 615 kg, based on the maximum allowable entry mass and the requirement to carry the New Millenium microprobes. The site elevation goal is 5 km ± 1 km uncertainty.

Analysis: A high fidelity Monte Carlo simulation has been used to determine propellant needs for the Lander. This simulation uses 2000 approach states and entry masses as inputs. These data include dispersions in the approach state due to various error sources, including orbit determination, maneuver execution, and ΔV imparted by attitude thrusters. Entry dispersions due to uncertainties and variability in the atmosphere are modeled using the statistical model in MarsGRAM 3.4, with inputs tailored to simulate more accurate GCM atmosphere profiles. A wind profile [source: R. Zurek] where maximum windspeed is a function of altitude is also modeled. The mgnitude of the wind is selected randomly and held constant for each case in the simulation. Entry aerodynamics, including angle of attack, are modeled as well. The clock angle and magnitude of the angle of attack [within a ±1˚ envelope] are selected randomly and held constant for each case. Other modeled effects include IMU errors, errors in propagation of the onboard navigation state, variability in characteristics of the terminal descent propulsion system, and radar errors.

The following table summarizes ΔV and mass drop data for the Lander.

Go to TOC

LANDER ΔV AND PROPELLANT MASS SUMMARY

** This page under Change Control **

- **REQUIREMENTS:**
  - Propellant loading based on Lander launch at the start of primary period [highest V_∞ during primary]
    - » 99% of cases accommodated
  - **615** kg maximum wet mass at launch - dictated by maximum allowable entry mass of Lander and requirement to carry New Millenium microprobes.
  - Site elevation = 5 km ± 1 km uncertainty

- **ANALYSIS: High Fidelity Monte Carlo Simulation**
  - 2000 Approach states used as inputs - dispersions due to orbit determination errors, maneuver execution errors, ΔV imparted by attitude thruster firings.
  - Statistical Atmosphere [MarsGRAM 3.4 with modifications for simulating GCM results]
  - Zurek wind profile: maximum magnitude a function of altitude
    - » Magnitude and direction randomly selected & held constant for each case
  - Entry arodynamics, including angle of attack
    - » Maximum angle of attack = ± 1°. Clock angle, magnitude randomly selected & held constant for each case
  - IMU errors & propagation of onboard navigation state modeled
  - Terminal Descent propulsion & radar errors included

Event	ΔV or Mass Drop			Mass after Event [kg]			Burn Time [seconds]		
	95% Low	Mean	95% High	95% Low	Mean	95% High	95% Low	Mean	95% High
TCM-1 [m/s]	9.51	30.24	60.10	597.5	605.7	611.4	75.16	230.19	452.00
TCM-2 [m/s]	0.04	0.42	1.08	596.3	604.7	610.4	0.32	3.11	8.00
TCM-3 [m/s]	0.02	0.20	0.57	595.4	603.7	609.4	0.09	1.26	3.96
TCM-4 [m/s]	0.01	0.04	0.08	594.4	602.7	608.5	0.06	0.67	1.75
TCM-5 [m/s]	0.03	0.10	0.20	593.4	601.7	607.5	0.05	0.49	1.28
Cruise RCS Usage [kg]		4.7			included in above				
Entry (cruise stage jettisoned)		76.7		516.8	525.0	530.8	-	-	-
Descent (heat shield jett)	[illegible]								
Terminal descent (bshell,chute jett)		TBS		TBS	TBS	TBS	TBS	TBS	TBS

TO BE UPDATED

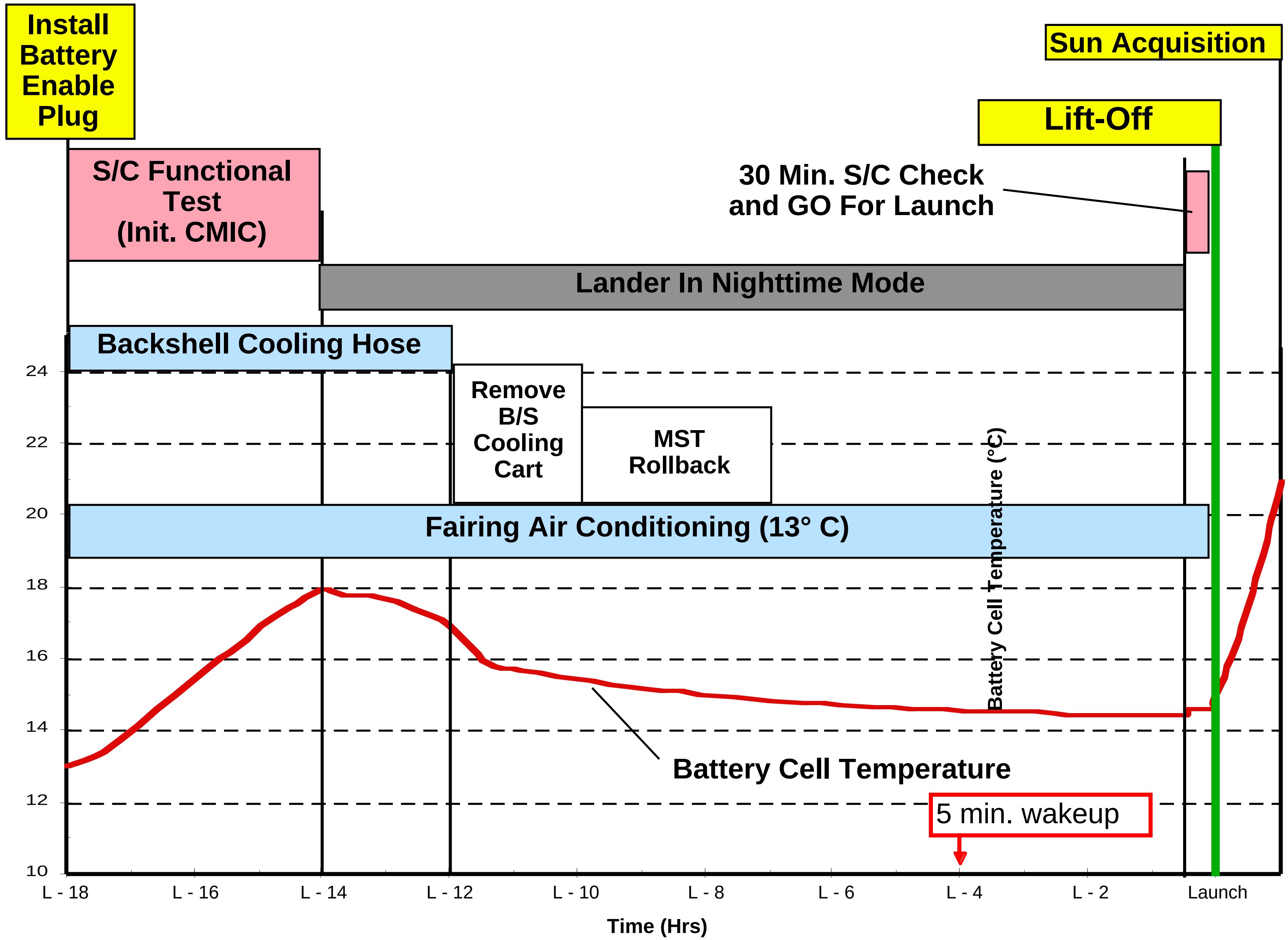
5.3 LANDER LAUNCH AND BOOST & S/C INITIALIZATION PHASES

5.3.1 Lander Countdown and Pre-launch SOE

The following timeline illustrates the timing of events prior to Launch. The Lander is placed in nighttime mode during this time to manage internal temperatures.

Go to TOC

LANDER COUNTDOWN AND PRE-LAUNCH SOE



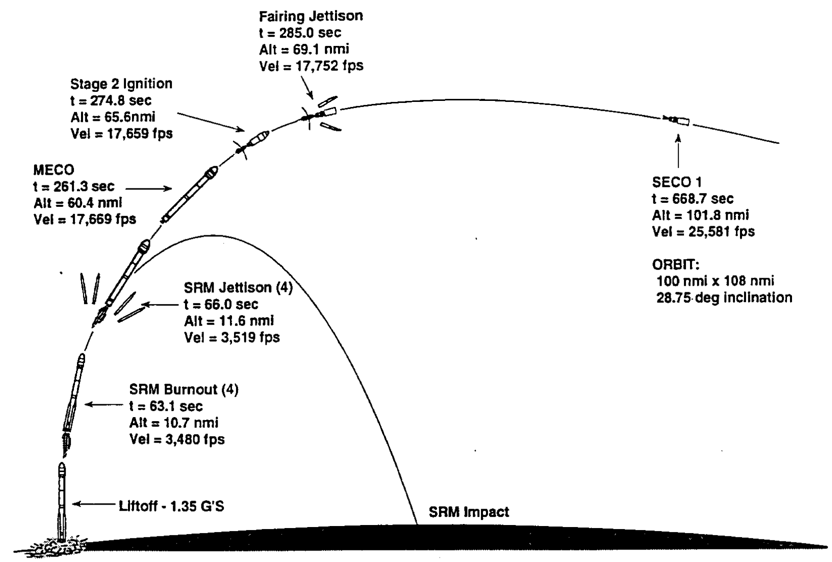
5.3.2 Lander Launch Events Summary

Go to TOC

LANDER LAUNCH EVENTS SUMMARY

Event	Time (sec)
Stage I Liftoff	0.000
Main Engine Cutoff (MECO)	261.3
Stage I–II Separation	269.3
Stage II Ignition Signal	274.8
Jettison Fairing	285.0
First Cutoff–Stage II (SECO 1)	668.7
Restart Stage II	1827.3
Second Cutoff–Stage II (SECO 2)	1846.7
Start Stage III Ignition Time Delay Relay	1896.7
Fire Spin Rockets	1896.7
Jettison Stage II	1899.7
Stage III Ignition	1936.7
Stage III NCS Enable	1936.7
Stage III Burnout (TECO)	2023.8
NCS Disable/Yo-Yo Despin Initiation	2306.7
Spacecraft Separation	2311.7

Note: Assumes a “short-coast” trajectory for launch on 3 January 1999.

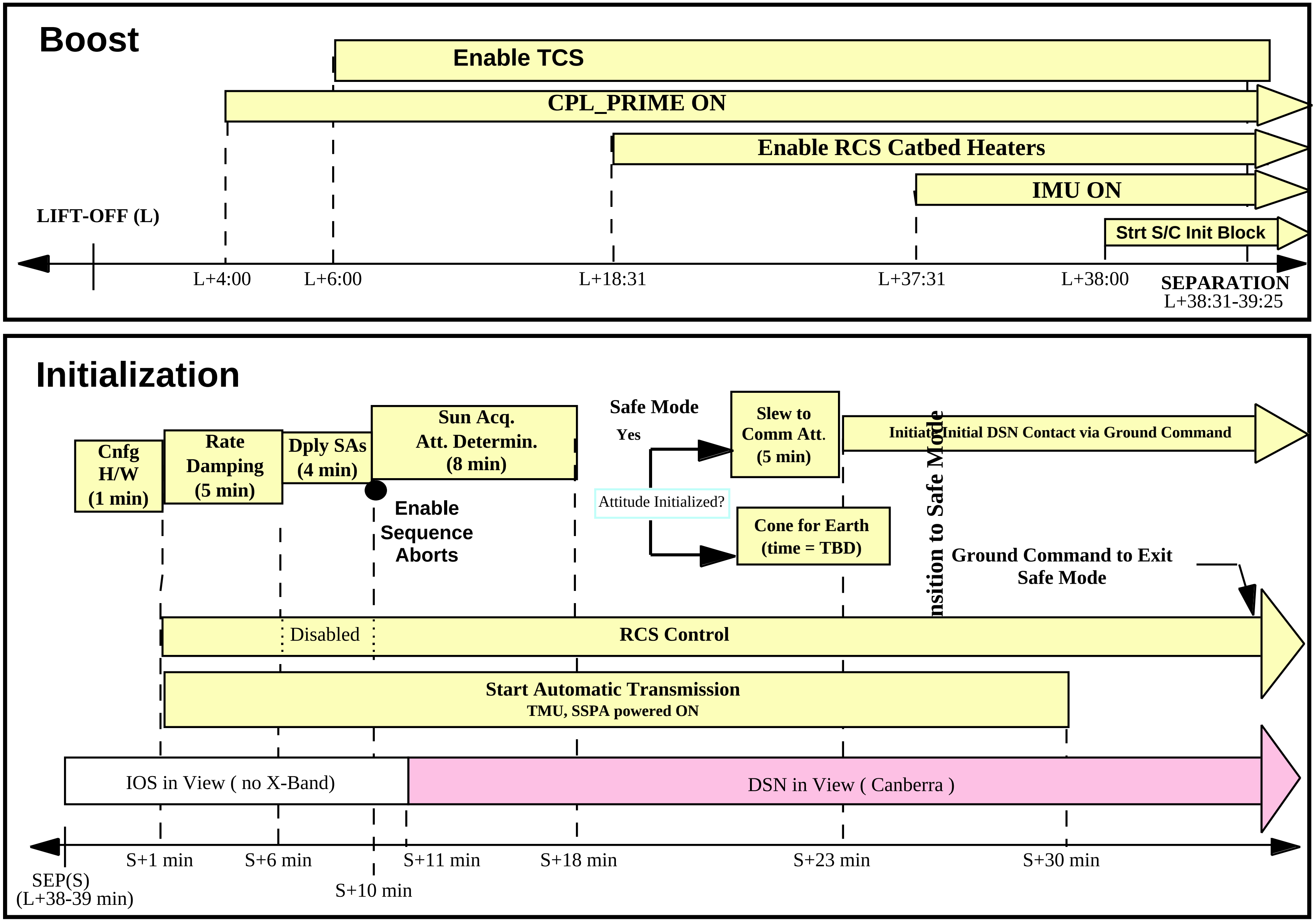


5.3.3 Lander Boost and Spacecraft Initialization Timeline

Shown below are the boost and Initialization sequence of events. See Appendix B.2 for initial DSN and Air Force Tracking Station acquisition geometry data.

Go to TOC

LANDER BOOST AND SPACECRAFT INITIALIZATION TIMELINE



LL-8

5.4 LANDER CRUISE PHASE

5.4.1 Lander Cruise Navigation

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Radiometric tracking requirements during cruise involve the use of two way coherent doppler and ranging according to the schedule described in the following table. As indicated, for the first 30 days after launch a minimum of one 4 hour pass per day is required. During quiescent cruise, only one 4 hour pass per DSN complex per week is required for radiometric tracking. [One 4-hour DSN track is baselined per day for purposes of spacecraft monitoring.] For TCM's 1 - 3, one 4 hour pass per day would be required during a 7 day interval centered about the TCM. For the track occuring during the 24 hour interval centered at TCM, the entire pass must be visible from a single DSN station. [Note: The analysis described in Appendix B.7 assumed 3 4-hr passes per day during the 24 hours centered on each TCM. Subsequent analyses confirm that a single 4-hr pass is sufficient.]

Pre-Entry Tracking - Near Simultaneous Orbiter/Lander Tracking: Additional tracking is required for the 45 days prior to Entry; during this time, approximately three 4-hour passes per day are required for the higher precision navigation required prior to Entry. TBD: In addition, in order to improve entry angle control, a program of near-simultaneous tracking between the Lander and an orbiter at Mars [either the MSP98 Orbiter or MGS] is required starting 30 days before Entry. This technique reduces the effects of error sources common to both spacecraft, such as station-dependant biases, Earth orientation errors, and errors in media and solar plasma modelling. Lander tracks would immediately precede or follow an orbiter track from the same HEF antenna. During much of this interval, the Lander would enjoy greater flexibility in scheduling its tracks, compared with an orbiter, especially the MSP98 Orbiter, which would be in Aerobraking at this time. As a result, the Lander tracks would have to be scheduled to fit in with the Orbiter tracks, while satisfying the Lander transmitter on/off cycle [4 hrs on/5 hrs off during cruise]. The baseline assumes use of the MSP98 Orbiter. MGS would be used as a backup in case the MSP98 Orbiter is not available. A strawman integrated tracking schedule and estimate of D/L data volume can be found in Appendix B.9.

5.4.2 TCM's

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Although the Lander trajectory does not require any deterministic deep space maneuvers to reach Mars, statistical Trajectory Correction Maneuvers [TCM's] are required to shape the cruise trajectory. Up to five TCM's are planned to occur, at Launch + 15 days, Launch + 30 days, Entry - 60 days, Entry - 4 days, and a contingency maneuver at Entry - 7 hours. At injection, the probability of impact of the upper stage is less than 1E-4, as required by Planetary Protection regulations. [See the MGS Planetary Protection Plan.] It is not necessary to bias the injection aimpoint away from the nominal to satisfy this requirement. As a result, the primary purpose for TCM-1 is to correct injection errors. TCM-1 constitutes 98% of the total TCM ΔV required during a mission, and will be broken into two maneuvers, separated by a repressurization interval, if the required value of TCM-1 is greater than 24 m/s.

The following page includes a table of the 95% high, mean, and 95% low values of each TCM and the summary statistical ΔV for the beginning of the Primary launch period. Propellant loading is based on an end-to-end Monte Carlo analysis of propellant usage, including the effects of maneuver execution errors and orbit determination errors.

Go to TOC

LANDER CRUISE NAVIGATION

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- **Navigation Cruise Tracking Requirements** [Two-way Coherent Doppler and Ranging]**:**

Mission Event	NavTracking Requirements	Comments
Launch to Launch + 30 days	1 4-hr pass/day	
Quiescent Cruise	3 4-hr passes/week	One pass per complex per week required for navigation. [One 4-hour pass per day baselined for s/c monitoring.]
TCM entry [TCM-3.5 days to TCM] TCM [24 hrs centered on TCM] TCM exit [TCM to TCM + 3.5 days]	1 4-hr pass/day 1 4-hr pass/day 1 4-hr pass/day	<-Pass must be visible from single DSN station
Approach [Entry-45 days to Entry]	3 4 hr passes/day	

- **Pre-entry Tracking - Near Simultaneous Orbiter/Lander Tracking [TBD]:**
  - Begins 30 days before Entry, required for precision entry angle control
  - Lander tracks are placed immediately before or after an orbiter track [M98 or MGS] from same HEF antenna
    - » Reduces effects of error sources common to both spacecraft [station-dependant biases, Earth orientation errors, and errors in media and solar plasma modelling]
    - » Lander would have to accommodate orbiter tracking schedule [esp. M98 Orbiter, Aerobraking during this time]
    - » Baseline assumes use of MSP98 Orbiter. MGS would be used as a backup.
      - Example Integrated tracking schedule & D/L data volume estimates in Appendix B.9

- **Trajectory Correction Maneuvers:**
  - Probability(Mars impact) of upper stage < 1E-4 [Planetary Protection] without the need to bias injection aimpoint
  - TCM-1 corrects injection dispersions
  - **TCM's for Open of Primary Launch Period: [to be updated]**

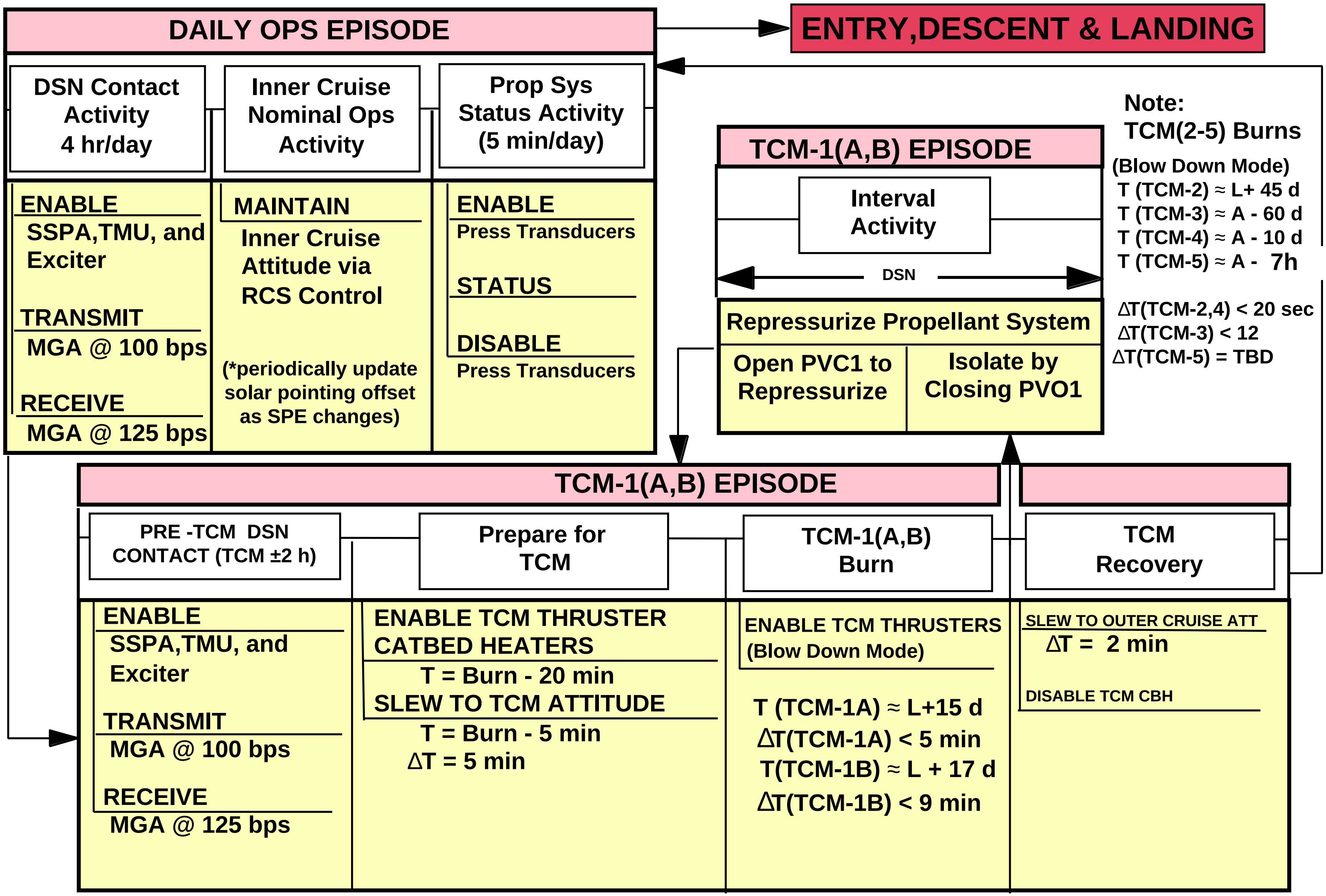
TCM #	Placement	95% Low ΔV [m/s]	Mean ΔV [m/s]	95% High ΔV [m/s]	Comments
1	Launch + 15 days	9.86	30.28	59.90	Will be broken into 2 maneuvers if > 24 m/s
2	Launch + 30 days	0.08	0.41	1.07	
3	Entry - 60 days	0.01	0.17	0.53	
4	Entry - 4 days	0.03	0.09	0.18	
5	Entry - 7 hrs	0.04	0.16	0.36	Contingency maneuver
Totals		**10.29**	**31.10**	**61.20**	

5.4.3 TCM Sequence of Events

Illustrated below is the sequence of events for a Lander TCM. TCM-1 is large enough that it may be necessary to split the maneuver into two parts, repressurizing the propulsion system in between. This repressurization would be performed during a communications pass. Subsequent maneuvers would be performed in blow-down mode.

Go to TOC

TCM SOE - *To Be Updated*



5.4.4 Lander Payload Cruise Checkout, Characterization, and Calibration Campaigns

5.4.4.1 Overview

Constraints: Checkouts and calibrations of the Lander instruments must be de-conflicted with Lander and Orbiter mission-critical events. No science checkouts, calibrations, or playback of data will be performed within ±3 days of a Lander TCM or within 45 days of Entry, consistent with Lander power limitations. None of the Lander science cruise calibrations affect the orientation of the spacecraft**.**

Checkout, Characterization, and Calibration Campaigns: A single sequence will perform all required science checkouts and calibrations. This sequence will run twice, at approximately Launch + 40 days and Entry - 90 days. Each campaign will last 7 days, during which all payload checkout and calibration activities, and playback of all data will be performed. 70m tracking support will be requested for these intervals, allowing the lander to communicate at a D/L data rate of 2100 bps [TBD]. Engineering checkout activities will be incorporated into the sequence. This sequence is initiated by ground command. Selected portions of this sequence [blocks] can be re-run via ground command as well.

Monthly Checkouts: A single sequence will perform monthly MET and TEGA checkouts.

Go to TOC

LANDER PAYLOAD CRUISE CHECKOUT, CHARACTERIZATION, & CALIBRATION CAMPAIGNS - OVERVIEW

- **Science Payload Calibration Constraints:**
  - Checkouts and calibrations must be de-conflicted with Lander and Orbiter mission-critical events.
  - No calibrations, checkouts, or playback of data within 3 days of a Lander TCM or 45 days of Entry, consistent with Lander power limitations
  - Checkouts and calibrations do not affect orientation of the s/c

- **Checkout, Characterization, and Calibration Campaigns:**
  - 2 Campaigns, each 7 days long [assumes 70m support]
    - » Launch + 40 days, Entry - 90 days
  - All payload activities and playback of data contained within the 7 day interval
  - Single sequence will perform all checkouts and calibrations
    - » Run the same sequence for each campaign
    - » Incorporate engineering checkout activities
    - » Initiated by ground command. Selected blocks [portions of the sequence] can be re-run.
  - 70m tracking support will be requested, allowing Lander D/L at 2100 bps [TBD]

Monthly Checkouts
  - Single sequence performs monthly MET and TEGA checkouts

5.4.4.2 Lander Payload Cruise Checkout and Calibration Operations

MARDI Dark Current Measurements: Dark current measurements and checkouts must be performed by MARDI during the Cruise Phase, there being no way to take these measurements after landing. For each picture, the Survival Heater is powered OFF, and the MARDI main power is turned ON and remains ON for an hour for detector readout. Afterward, the Survival Heater is powered back ON and then the MARDI main power is turned OFF. Each full dark current picture generates 8 Megabits of data.

MET Health check: It is desired that this activity be run in conjunction with a DSN contact. It could be activated as a ground uplinked command. The length of time the MET is powered on per checkout is 30 minutes per check. The MET requires 4 W. Each MET health check generates 0.0576 Mbits of science data.

MET Pressure Sensor checks: The MET package should be turned on at least once a month, to return a temperature calibration of the pressure sensor at near vacuum. Without this calibration the science team would have a limited understanding of the calibration of the MET pressure sensor. The length of time the MET is powered on is 10 minutes per check. The MET requires 4 W. Each MET pressure sensor check generates 0.0192 Mbits of science data.

SSI Dark Current Measurements: The time needed to acquire these data is five minutes. The SSI requires 10 W. Each dark current measurement generates 6 Megabits of science data.

RAC Dark Current Measurements: The time needed to acquire the data is five minutes. The RAC requires 15 W. Each dark current measurement generates 6 Megabits of science data.

TEGA Checkouts: Each checkout takes 30 minutes (TBD). The TEGA requires 10 W. The health and status check generates 0.06 Megabits of science data.

TEGA Valve Exercise [TBD]: The TEGA valves must be exercised once per month during cruise, to prevent sticking, which would render a chamber unusable. The TEGA is powered on for 30 minutes and a predefined science sequence run. The loss of one or more of the eight TEGA chambers would represent a significant impact to meeting the science goals.

Go to TOC

LANDER PAYLOAD CRUISE CHECKOUT AND CALIBRATION OPERATIONS

- **MARDI Dark Current Measurements:**
  - All MARDI checkouts/calibrations must be performed during cruise.
  - Survival Heater is powered OFF, MARDI main power is turned ON, remains ON for an hour for detector readout. The Survival Heater is then powered back ON and then the MARDI main power is turned OFF.
  - Each dark current measurement generates 8 Megabits of data.

- **MET Health checks:**
  - Desired to be run in conjunction with a DSN contact.
  - MET powered on 30 minutes per check, requiring 4 W.
  - Each MET health check generates 0.0576 Mbits of science data.

- **MET Pressure Sensor checks:**
  - MET package should be turned on at least once a month
  - Observations: temperature calibration of the pressure sensor at near vacuum.
  - MET powered on is 10 minutes per check, requiring 4 W.
  - Each MET Pressure Sensor check generates 0.0192 Mbits of science data.

- **SSI Dark Current Measurements:**
  - Duration: five minutes. The SSI requires 10 W.
  - Each dark current measurement generates 6 Megabits of science data.

- **RAC Dark Current Measurements:**
  - Duration: five minutes. The RAC requires 15 W.
  - Each dark current measurement generates 6 Megabits of science data.

- **TEGA Checkouts:**
  - Duration: 30 minutes (TBD). The TEGA requires 10 W.
  - The health and status check generates 0.06 Megabits of science data.

- **TEGA Valve Exercise [TBD]:**
  - TEGA valves must be exercised once per month during cruise, to prevent sticking
  - TEGA is powered on for 30 minutes and a predefined science sequence run.

5.4.4.3 Cruise Data Playback Strategy

Data Priorities and Data Volume Allocations: APID tables are used to control the priority of data return. During nominal cruise, Engineering receives 100% of the available downlink. During Checkout/Calibration Campaigns, Science receives 30% [TBD] of the available downlink.

Science Data Volume during Checkout/Calibration Campaigns: Science data volume returned during the campaign is calculated assuming one 4 hour DSN contact per day, a data rate of 2100 bps, 30% usage percentage [TBD], and 15% overhead. Thus, daily data volume = 2100 bits/sec * 3.92 hours /day (interleaved portion of one DSN pass, assuming 5 minutes for lockup at 2100 bps) * 3600 sec/hr * 0.3 * [1-.15] = 7.55 Mbits per day. This data volume assumes the use of a 70m station.

Go to TOC

CRUISE DATA PLAYBACK STRATEGY

- APID tables used to control the priority of data return.
- **Downlink Data Volume Allocations:**
  - **Nominal cruise: Engineering receives 100% of available downlink**
  - **Checkout/Calibration Campaigns: Science receives 30% [TBD] of available downlink**
- **Science Data Volume during Checkout/Calibration Campaigns:**
  - Assumptions: 4 hour DSN contact per day, data rate =2100 bps, 30% usage percentage, 15% overhead.
  - Daily data volume = 2100 bits/sec * 3.67 hours /day (interleaved portion of one DSN pass, w/ 5 minutes for lockup) * 3600 sec/hr * 0.3* [1-.15] = **7.55 Mbits** per day.
  - Assumes use of a 70m station

5.4.5 Pre-Entry Timeline

Pre-Entry Navigation: The state vector used as initial conditions for inertial navigation starting 10 minutes before entry interface will be uploaded to the spacecraft prior to TCM-4. As the state vector estimate is refined using data from subsequent tracking passes, other opportunities will exist to upload these data to the spacecraft. Uploads of improved state estimates are planned [schedule TBD] during the last 4-hour pass before Entry [DSN#1], and during the 1 hour pass starting at Entry - 5 hours [DSN#3].

DSN #1, Preparations for TCM-5: Fourteen hours before Entry, the final 4-hour Lander tracking pass begins. If a 5th TCM is required, [~10% of the time] TCM-5 maneuver data [deltaV vector and time of the maneuver] would be updated on the ground. At some point during this pass, the best TCM-5 maneuver, based on data up to that point, will be calculated and uploaded to the spacecraft during the latter portion of the pass. The estimated state vector for the point 10 minutes before Entry [IMU initial conditions] will be updated during this pass as well. The final tracking data are received on the ground 14 minutes after the end of this pass, allowing more than 90 minutes on the ground for the final orbit determination and TCM-5 maneuver generation prior to radiation of the maneuver parameters on the next pass [DSN#2].

Safe Mode: At approximately Entry - 12 hours [TBD], the software architecture controlling the spacecraft safemode response is disabled. It remains disabled until after landing. Sequence abort response is disabled and comm loss timers are set to exceed the duration of EDL.

DSN #2: At Entry - 7 hours 25 minutes before Entry, a second DSN pass starts, which lasts 30 minutes. Any changes to the TCM-5 maneuver data would be sent during this pass. If this contact does not occur, due to ground or spacecraft problems, TCM-5 would be executed using the maneuver sequence uploaded during the latter part of the previous DSN contact.

TCM-5 maneuver: If needed, TCM-5 occurs at Entry - 7 hours.

DSN #3: At Entry - 5 hours, a third DSN contact starts, which lasts one hour. This contact is used for health and status monitoring, post-burn tracking, and performing the final state vector update for inertial guidance.. During this DSN contact, at Entry - 4h 40 min., a series of valves open, venting the descent engines. A pyro fires at Entry - 4h 30 m to pressurize the descent engines.

DSN #4: At Entry - 25 minutes, the fourth and final DSN contact starts, which lasts 15 minutes. It is used to report status of the propulsion system. Starting approximately 20 minutes before Entry the TCM catbed heaters are enabled. The MARDI software is initialized 15 minutes prior to Entry.

Inertial Nav, Cruise Stage Jettision: Approximately 10 minutes before entry, the spacecraft is commanded to begin inertial navigation. Its 1 minute 20 sec. slew to the entry attitude starts approximately 6 minutes before Entry. The cruise stage is jettisoned 5 minutes prior to Entry. [The new Millenium microprobes are jettisoned from the cruise stage shortly thereafter.] The Lander is then commanded to Inertial Hold mode with a $\pm 1^\circ$ attitude error.

Entry: Entry Interface occurs at a radius of 3522.2 km. Thirty-three to 37.5 seconds later, Hypersonic operations begins when a g-level of 0.03 g's is sensed on the x axis. Landing occurs approximately 4 and a half minutes after entry interface.

Go to TOC

PRE-ENTRY TIMELINE

- **PRE-ENTRY NAVIGATION:**
  - State vector at Entry-10 minutes [initial conditions for inertial nav] uploaded to s/c before TCM-4, refined w/ subsequent tracking.
  - State vector updates planned for DSN#1, DSN#3. [Schedule TBD]

- **DSN#1 [ENTRY - 14:00 TO ENTRY - 10:00]**
  - Final Lander tracking pass before contingency TCM-5
  - If TCM-5 is required, maneuver data [ΔV vector, time of maneuver] are updated on the ground. The best TCM-5 maneuver, based on data up to that point, is calculated & uploaded during the latter portion of the pass.
  - Final tracking data received on the ground 14 minutes after the end of pass
    - » Allows ≥ 90 minutes on the ground for final orbit determination, TCM-5 maneuver generation prior to radiation of the maneuver parameters on the next pass [DSN#2].
  - **Entry - 12 hours [TBD]: s/w architecture controlling s/c safemode response is disabled.**
    - » Remains disabled until after landing. Sequence abort response is disabled, comm loss timers set to exceed EDL duration
  - State vector update for inertial guidance.

- **DSN #2 [ENTRY-7:55 TO ENTRY-7:25]**
  - If needed, TCM-5 maneuver data are updated. [If this contact does not occur, TCM-5 executes using existing on-board data.]

- **CONTINGENCY TCM-5 MANEUVER at Entry - 7 hours**.

- **DSN #3 [ENTRY - 5:00 TO ENTRY - 4:00]**
  - Health and status monitoring, post-burn tracking, final state vector update for inertial guidance.
  - **Entry - 4:40,** descent engines vented.
  - **Entry - 4:30**, pryo valve fires to pressurize the descent engines.

- **DSN #4 [ENTRY - 0:25 TO ENTRY - 0:10]**
  - Report status of propulsion system.
  - **Entry - 0:20**, TCM catbed heaters are enabled.
  - **Entry - 0:15**, MARDI software initialized.

- **INERTIAL NAV, CRUISE STAGE JETTISION:**
  - **Entry - 0:10**, begin inertial navigation.
  - **Entry - 0:06**, begin 1 minute 20 sec. slew to entry attitude
  - **Entry - 0:05**, jettision cruise stage [New Millenium µprobes are jettisoned from the cruise stage shortly thereafter.]
  - Lander commanded to Inertial Hold mode with ±1˚ attitude error.

- **ENTRY INTERFACE [Radius = 3522.2 km]**
  - **Entry + 33-37.5 sec: Hypersonic operations** begin when 0.03 g sensed on the x axis.
  - **Entry + 4 min 33 sec: Landing**

5.5 ENTRY, DESCENT, AND LANDING PHASE

5.5.1 Entry Overview

Entry interface is defined by convention to occur when the spacecraft's radial distance is 3522.2 km. The velocity at this point is 6.91 km/s for launch at the beginning of the Primary arrival period.

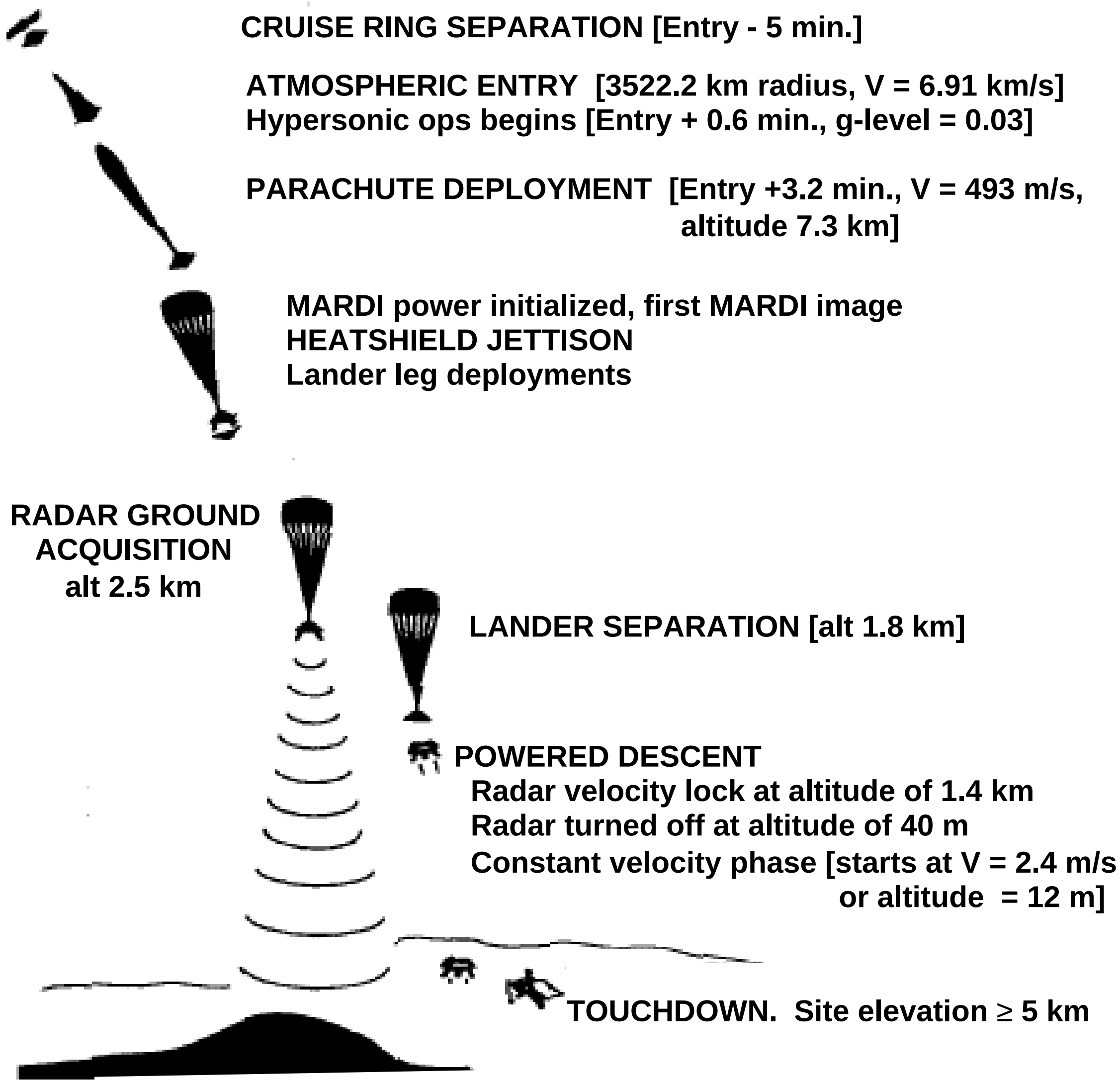
Hypersonic Operations: Hypersonic operation begins approximately 33-37.5 seconds later, when a deceleration level of 0.03 g is sensed by the accelerometers on the X axis. During hypersonic entry, RCS and TCM thrusters controlled by the onboard IMU's maintain aeroshell attitude to within 1˚ of the nominal zero angle of attack. During this phase, the spacecraft encounters the maximum heat load and g-forces [up to 12 g's]. Near the end of this interval, the landing radar is powered on to standby mode and the aeroshell is rolled to the radar best-lock attitude.

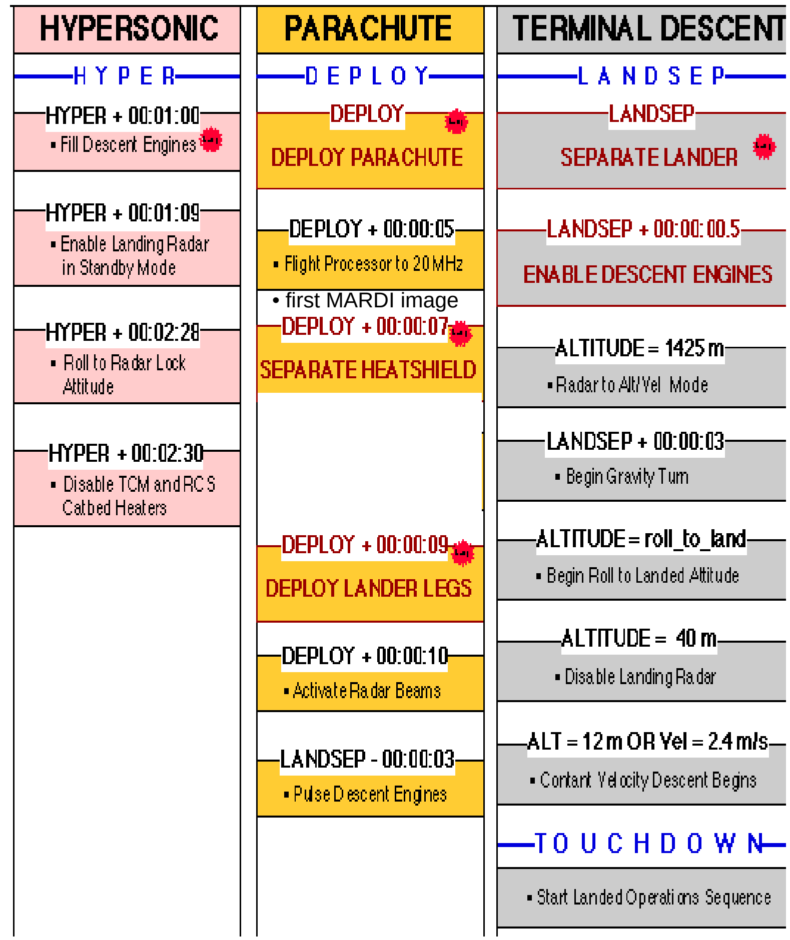
Parachute Episode: The parachute is deployed at an inertial velocity of approximately 493 m/s. This occurs approximately 3.2 minutes after start of hypersonic operations, & 7.3 km above the surface. Seven seconds following parachute deployment, the forward heatshield is separated. Prior to heatshield jettison, MARDI main power is initialized. The first fractional MARDI image occurs 0.3 sec. prior to heatshield jettison. Subsequent images occur at fixed times from descent events. Twenty-three seconds after heatshield jettison the lander legs are deployed, and 1.5 seconds after that the landing radar beams are activated. The radar acquires ground altitude lock about 44 seconds after activation, at an altitude of approximately 2500 m. At this point the Lander is descending at terminal velocity.

Terminal Descent: Shortly after radar altitude lock, the entry thrusters are inhibited, and the lander is separated from the backshell. This event is triggered by an altitude/velocity trigger. At this point the lander is 1.8 km above the surface and is traveling at approximately 80 m/s. About 0.5 second after separation the lander descent engines are started, and the lander begins a gravity turn, during which the Lander descends at a constant deceleration level, its thrusters pointed 180˚away from the velocity vector. Attitude is maintained during this phase by pulse-modulating the descent thrusters. The Lander rolls to its terminal descent attitude, intended to provide the proper azimuth orientation on landing. Radar velocity lock occurs 1425 m above the surface. When the radar determines that the spacecraft is 40 m above the surface, the radar is turned off. Guidance from this point to landing is all inertial. Once the spacecraft achieves either an altitude of 12m or a velocity of 2.4 m/s, the constant velocity phase begins. The descent engines are turned off when touchdown is detected by sensors in the footpads. The engines are on for a total of approximately 40 seconds during terminal descent.

Go to TOC

ENTRY OVERVIEW





** starburst = pyro firing*

5.6 LANDED SCIENCE PHASE

5.6.1 Commanding and Data Return Strategy

Commanding: Nominally, commanding during the Lander Support Phase is accomplished via the MSP98 Orbiter. Lander commands are double wrapped on the ground and sent to the Orbiter, where the CCSDS header is stripped off and the Lander commands placed in a buffer until a scheduled UHF pass occurs over the landing site. Each communications pass with the MSP98 Orbiter is currently configured as a "hybrid", which allows for both command uplink to the lander and telemetry downlink from the Lander to the Orbiter during each pass. During the first part of each pass, the Lander is configured to receive commands sent from the Orbiter. Once the command uplink portion of the pass is finished, the Lander comm system is reset to transmit command receipt verification and telemetry to the Orbiter. The switchover from command to telemetry downlink is performed autonomously on the Lander once the command load is complete. The X-band uplink data rate from Earth to the Orbiter is 125 bps nominal [up to 500 bps] during the entire Lander Support Phase. The Orbiter-to-Lander UHF data rate is 8 kbps, and the Lander-to-Orbiter UHF telemetry rate is 128 kbps. Commands may also be sent direct from Earth, via either the MGA or LGA antennae. MGA and LGA data rates are included in Appendix B.10.

Data Return and Data Volume: Earth return data volume allocations during the Lander Support Phase are described in the Orbiter Mission Plan, Section 4.6, Lander Support Phase, repeated below for convenience:

Subphase 1: 12/3/99 - 1/2/00 [Dedicated Lander Relay Support] During this subphase, Lander support is the Orbiter's highest priority; Lander science receives the majority of the 150-160 Mbits of science the MSP98 Orbiter can downlink every day. [At this point the Orbiter is communicating at 9.9 kbps.] MSP98 Orbiter science receives whatever remains in terms of D/L data volume [<10 Mbits/day], and ops resources. PMIRR and MARCI initializations occur during this subphase, TBD days after Lander landing. In both cases, this involves turning on the main power and loading the payload software. For PMIRR, this also involves opening the radiator door, and allowing the instrument to cool down. The opening of PMIRR's radiator door must occur after all significant maneuvers have been executed.Other Orbiter activities during this time include standard housekeeping, and instrument health checks. TBD: any remaining Orbiter science D/L capability may be used for MARCI imaging on a best efforts basis.

Subphase 2: 1/3/00 - 1/31/00 [Overlapping Observations] During this subphase, a coordinated campaign of science observations is planned to occur between the MSP98 Orbiter, MSP98 Lander, and MGS. The MSP98 Orbiter downlink data rate is still 9.9 kbps. During this time, Lander science receives 110 Mbits of the 160 Mbits of science data the MSP98 Orbiter can downlink each day. MSP98 Orbiter science receives the remaining downlink volume [approx 40-50 Mbits/day]. At this point, PMIRR begins observations at its standard data rate (~250 bps, including quaternions), and MARCI begins global mosaics & targeted medium-angle camera imaging.

Subphase 3: 2/1/00 - 2/29/00 [Overlapping Observations] At the start of this subphase, the MSP98 Orbiter D/L data rate drops to 5.7 kbps, and MGS begins its Relay phase. During this time, MGS becomes the primary Lander data relay path. The MSP98 Orbiter payload operates at a moderate level [approximately 70 Mbits/day], and the Lander receives whatever remains of the MSP98 Orbiter D/L data volume capacity [~20 Mbits/day] and ops resources [e.g. U/L planning]. It is requested that MGS delay its planetary protection raise maneuver until 3/1/00, to avoid any interruption in Lander support.

Appendix B.5 - Post-Landing Geometry and Data Return includes graphs and tables describing representative data relay opportunities and data volumes for the landed science mission.

Go to TOC

COMMANDING AND DATA RETURN STRATEGY

- **Commanding:**
  - Nominal commanding via MSP98 Orbiter.
    - » Lander commands double wrapped on the ground & sent to the Orbiter, where CCSDS header is stripped off and the Lander commands are placed in a buffer until UHF pass.
    - » Each communications pass with MSP98 Orbiter is a "hybrid"
      - During the first part of each pass, the Lander is configured to receive commands sent from the Orbiter. Once command uplink is finished, Lander comm system is autonomously reset to transmit command receipt verification and telemetry to the Orbiter.
  - Commands may also be sent direct from Earth, via MGA or LGA.
  - Lander X-band LGA Receiver is powered in receive mode for 1 hour daily to receive emergency DFE commands.
- **Data Rates during Lander Support Phase:**
  - X-band uplink data rate from Earth to the Orbiter = 125 bps [up to 500 bps]
  - Orbiter-to-Lander UHF data rate = 8 kbps
  - Lander-to-Orbiter UHF telemetry rate = 128 kbps.
  - DTE data rates in Appendix B.10
- **Data Return Strategy:** see Orbiter Mission Plan, Sec 4.6, Lander Support Phase [summarized below for convenience]:
  - » **Subphase 1: 12/3/99 - 1/2/00 [Dedicated Lander Relay Support]**
    - M98 Orbiter supports Lander commanding, telemetry relay at 9.9 kbps
    - Lander support is highest priority; receives majority of 150-160 Mbits science D/L per day
    - PMIRR and MARCI initialization occur during this subphase, TBD days after Lander landing.
    - M98 Orbiter receives whatever remains in terms of D/L data volume [<10 Mbits/day], ops resources
  - » **Subphase 2: 1/3/00 - 1/31/00 [Overlapping Observations w/ Orbiter, MGS]**
    - M98 Orbiter supports Lander commanding, telemetry relay at 9.9 kbps
    - Lander receives 110 Mbits of the 160 Mbits science D/L per day
    - M98 Orbiter payload operates at reduced level - approx 40-50Mb/day
  - » **Subphase 3: 2/1/00 - 2/29/00 [Overlapping Observations]**
    - M98 Orbiter supports Lander commandgin; D/L drops to 5.7 kbps. MGS primary Lander relay [MGS now in Relay phase]
    - M98 Orbiter payload operates at moderate level - approx 70 Mbits/day
    - Lander receives remainder in terms of M98 Orbiter D/L data volume [~20 Mbits/day], ops resources [e.g. U/L planning]
- **Appendix B.5 - Post-Landing Geometry and Data Return** includes graphs and tables describing representative data relay pportunities and data volumes for the landed science mission.

5.6.2 Sol 0,1 Design Reference Missions - Assumptions and Goals

** This page under Change Control **

Design Reference Missions are used to measure mission and spacecraft performance during critical or stressing situations, and assess effects of changes in the sequence of events or s/c capabilities. They will also be used to establish system-level testing sequences. For the MSP98 Lander, scenarios have been developed for Sol 0 and1, and for the first day of a 2-day TEGA operations sequence.

Objectives During Sol 0,1: The primary objectives are to perform all deployments, collect and return critical engineering data for characterization of the environment and assessing the condition of the Lander, and return high priority science data, specifically MARDI descent images, SSI images, and MET TDL data.

Assumptions: The Sol 0,1 sequence of events is resident on-board at landing, and is intended to run without the need for additional commanding through Sol 1. It uses conservative assumptions on power output and allowable battery depth of discharge. Specifically, it assumes one string out on the Lander cruise array prior to cruise stage separation. The scenario is designed to accommodate a 16˚ tilt adverse either in terms of maximum DOD [tilt to the West] or energy balance [tilt to the South]. It is required that all science payload activities accommodate 20% power loads growth, and that a loads growth margin of 12% be maintained for spacecraft activities. On top of this, a 10% power margin on insolation is allocated for analytical power modelling uncertainties, and 5% on insolation allocated for layout and shadowing effects. [The actual number of Watts represented by each of these allocations is TBD.] The maximum allowable depth of discharge during Sol 0,1 is 58%, and it required that the battery reach a full state of charge at least once per sol.

Power Profile: The power profile for the Sol 0,1 design reference mission is shown in Appendix B.5.6 of the Lander Mission Databook.

Go to TOC

SOL 0,1 DESIGN REFERENCE MISSIONS - ASSUMPTIONS AND GOALS

- **Design Reference Missions:**
  - Basis for assessing mission and spacecraft performance during critical or stressing situations, and evaluating effects of changes in the sequence of events or s/c capabilities.
  - Basis for establishing sequences used in system level testing.
  - **Sol 0,1 Activities**
  - **TEGA Day 1**
- **Objectives During Sol 0,1:**
  - **Perform deployments**
  - **Collect and return critical engineering data:**
    - Characterize the environment
    - Assess the condition of the Lander
  - **Collect and return high priority science data**
    - MARDI descent images
    - SSI images
    - MET TDL data
- **Assumptions:**
  - **Sol 0,1 Sequence of Events is resident on-board at landing. No need for additional commanding during Sol 0.**
  - **Uses conservative assumptions on power output and allowable battery depth of discharge:**
    - 1 string out on Lander cruise array prior to cruise stage separation
    - 16° adverse tilt in terms of max DOD [Westward tilt] or energy balance [Southern tilt]
    - Power Growth Contingencies:
      - Science payload loads growth: 20% on loads. = TBD Watts
      - Spacecraft subsystems loads growth: 12% on loads. = TBD Watts
      - Analytical power modeling uncertainty: 10% on insolation. = TBD Watts
      - Solar array output reduction for layout and shadowing: 5% on insolation. = TBD Watts
    - Maximum allowable depth of discharge: 58%
    - Battery must reach full charge at least once per sol.

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5.6.2.1 Sol 0 Design Reference Mission - Morning

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Sol 0 activities start with touchdown detection and shutdown of the main engines, at 4:14 AM Local True Solar Time on December 3, 1999, for landing at 77S, 210W, and launch at the start of the Primary Lander launch period. [Landing occurs at 4:10 AM LTST 12/3/99 for launch at the end of the Primary interval, and 3:36 AM LTST 12/15/99 for launch at end of the Secondary period.] Immediately after landing, Safe Mode and sequence abort capability are re-enabled, and pyro valves are fired to isolate the Helium tank. The CPU rate, which was set to 20 Mhz shortly before Entry, is reset to 5 Mhz. The first science data taken are MET data, starting approximately 5 seconds after landing, and continuing at intervals throuhgout the morning. MARDI is turned off 60 seconds after landing.

Deployments: After waiting 2 minutes to allow time for dust kicked up by the landing to settle, the solar arrays are deployed [duration 3 minutes]. Three minutes after landing the MGA is deployed and initialized, and a slew to Earth point is begun, in preparation for the first DTE contact. This slew may take up to 16 minutes to complete. A vertical scan is taken by the SSI prior to its boom deployment. The MET and SSI masts are then deployed; these deployments take seconds once the pyros are fired.

Gyrocompassing: Starting 5 minutes after landing, during the MGA slew, gyrocompassing is performed for approximately 10 minutes, to determine the location and horizontal tilt of the Lander. Once gyrocompassing is complete and the Lander position and orientation are better determined, the MGA pointing may have to be readjusted. The IMU is powered off upon completion of the gyrocompassing interval.

DTE Link: A two-way DTE link is etablished via the MGA approximately 20 minutes after landing. Landing occurs while the Earth is above 18° local site elevation for the nominal landing location, so it should be possible to establish two-way communications once the deployments are finished and the MGA is properly aimed. A 34m HEF is used for uplink to the Lander, and a 70m dish used for telemetry downlink. The DTE link lasts 20 minutes and is used to download Lander engineering telemetry, EDL accelerometer data, post-landing MET data, and possibly some imaging. Once the DTE link is finished, the Lander is configured to listen-only mode via the LGA.

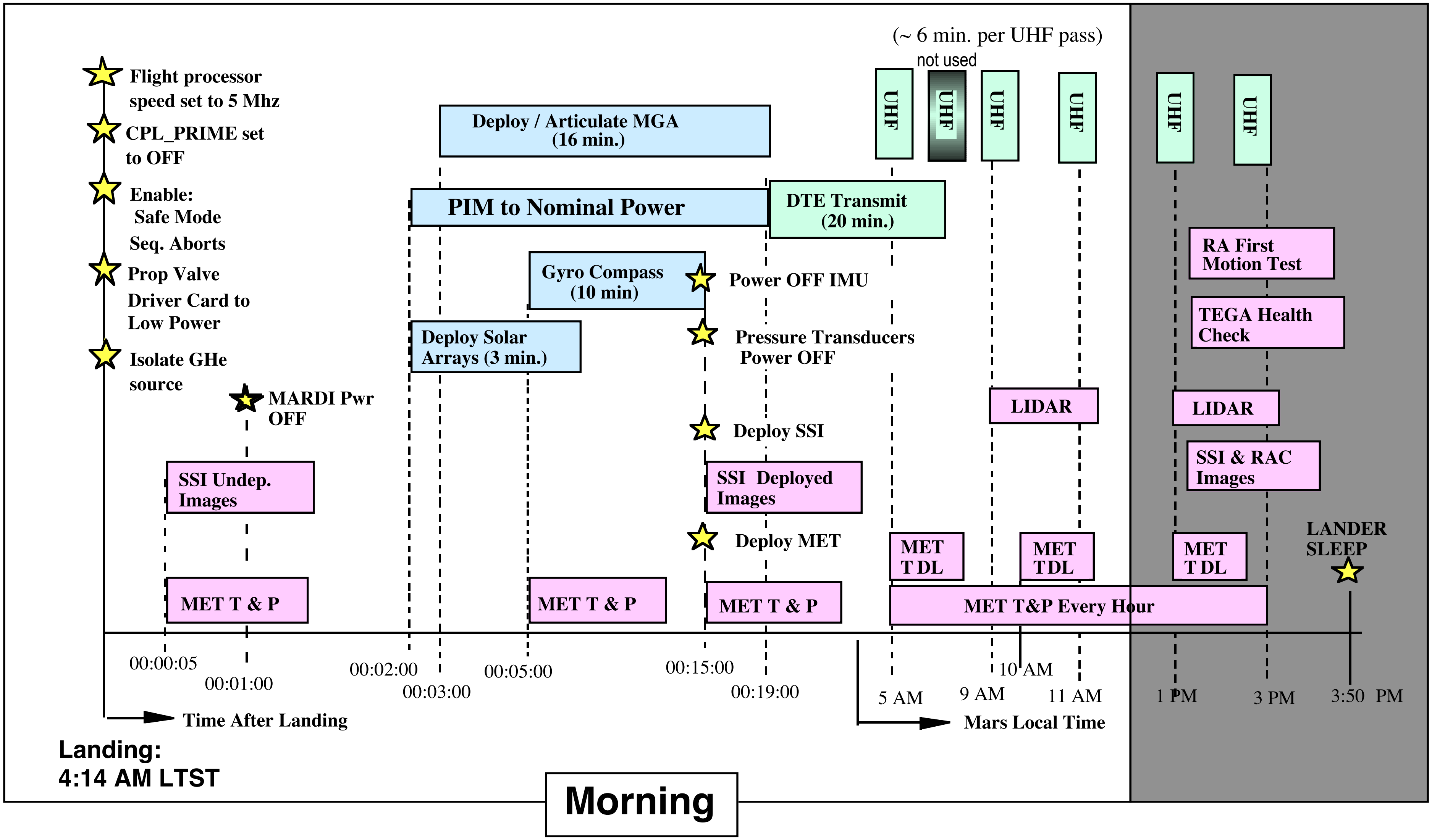
Science Activities and Data Transfer: Shortly after landing, transfer of the uncompressed MARDI data from volatile DRAM to flash memory is begun. MET observations are planned 5 seconds after landing, 5 minutes after landing, and 15 minutes after landing. [The last occurs after MET mast deployment]. MET temperature and pressure observations occur every hour from 5 AM to the last UHF pass about 3 PM. MET TDL observations are also planned. LIDAR acvitities are planned to start 9 AM local time.

First UHF Pass: High rate downlink of Lander data via a UHF pass with the MSP98 Orbiter is planned to occur some time after the DTE link. The timing and duration of this pass depends on the phasing of the Orbiter, which will have completed aerobraking only days prior to Lander Entry, the energy balance on the Lander, and the latitude and longitude of the landing site. The first opportunity for a pass occurs no later than two hours after landing, and its duration is 4.5 - 8 minutes for landing at 74-77S, 210W. [See Appendix B.5 - Pass Variability with Longitude and Mean Anomaly for additional information.] Data relayed during this pass includes engineering telemetry, MET data taken since the DTE link, some MARDI data and possibly some SSI imaging.

Additional UHF Passes: Additional MSP98 Orbiter overflight opportunities occur circa 7, 9, and 11 AM LMST before noon on Sol 0. The passes at 7 AM and 11 AM are used for additional telemetry downlink.

Go to TOC

SOL 0 DESIGN REFERENCE MISSION - Morning



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5.6.2.2 Sol 0 Design Reference Mission - Afternoon

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Lander Status Assessment: Activities in the afternoon of Sol 0 depend on the status of the Lander as determined by on-board monitoring. The battery charge state, solar array output, lander tilt, and measured temperatures may all be used by the Lander to determine the course of action to follow during the afternoon. [Throughout the Lander's landed lifetime, battery DOD is monitored at regular intervals, and compared with a predicted DOD profile. Fault protection is automatically initiated if the battery DOD exceeds the allowed limit.] If a nominal or favorable power/thermal situation is sensed, a nominal sequence of events is undertaken, including science and several UHF passes for data relay. The presence of an unfavorable power/thermal environment may cause the Lander to enter a "no frills" mode of operation, where minimal science is performed, or in the extreme, enter sleep mode.

"Nominal Operations" Science: The presence of a nominal or favorable lander tilt, combined with nominal solar array and battery performance and temperatures within expected limits, leads to a continuation of activities started in the morning, as illustrated on the next page.

Payload activites include the first motion test of the Robotic Arm out of its passive restraint, a TEGA health check, LIDAR observations, and additional SSI and RAC images. Hourly MET temperature and pressure observations continue, and one additional set of MET TDL observations are planned prior to the final UHF pass.

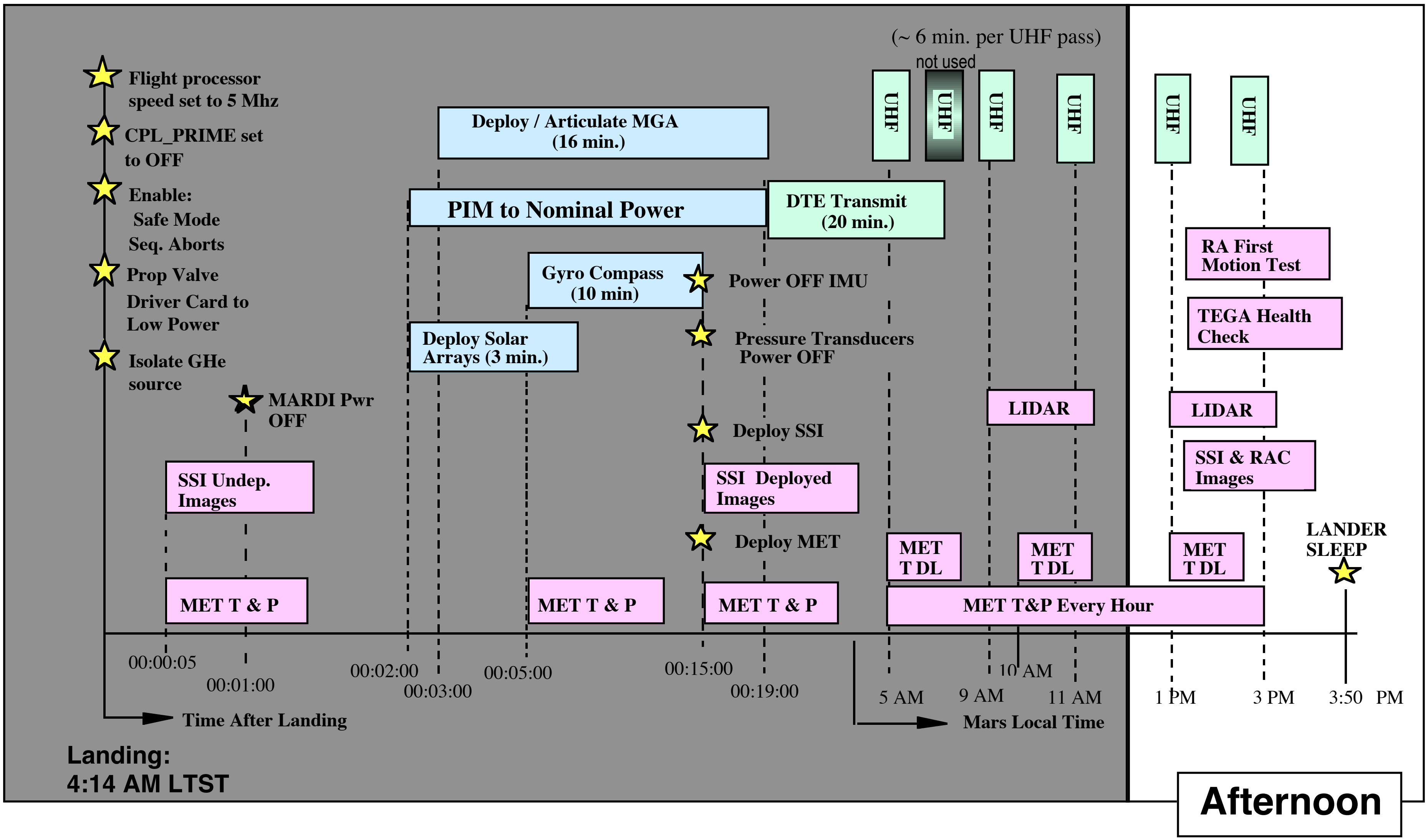
UHF Passes: Nominally, two additional UHF passes with the MSP98 Orbiter, occurring circa 1 PM and 3 PM LMST, are used to relay science data in the afternoon of the first landed sol. The highest priority is returning the remaining MARDI data, a portion of which was sent up during the morning UHF passes. High priority SSI and MET data are also returned during the afternoon passes. Some of the MSP98 Orbiter passes may be "hybrids", consisting of an interval for sending commands to the Lander, and a separate interval during the same pass for command receipt verification and telemetry return to the Orbiter. As a result, any of these UHF passes could be used to support Lander commanding if needed, but sufficient time would have to be allowed to send the Lander commands to the Orbiter first.

Preparation for Night-time and Sol 1: At some point during the afternoon of Sol 0, the MGA is driven to a position suitable for supporting a DTE link the next day. About 3:50 PM, the Lander is placed in a reduced power sleep mode for night-time operations. Approximately 30 minutes before power-down, any data remaining in DRAM are transferred to flash memory.

"No Frills" Science: In the event a power/thermal situation is sensed which, although unfavorable, is still amenable to operation in a waking mode, science data taking would be severely limited. One scenario limits science to the use of the MET TDL sensors, and four images taken 90° apart in azimuth, to provide an overview of the Lander environment.

Go to TOC

SOL 0 DESIGN REFERENCE MISSION - Afternoon



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5.6.2.3 Sol 0,1 Night-time and Sol 1 Design Reference Missions

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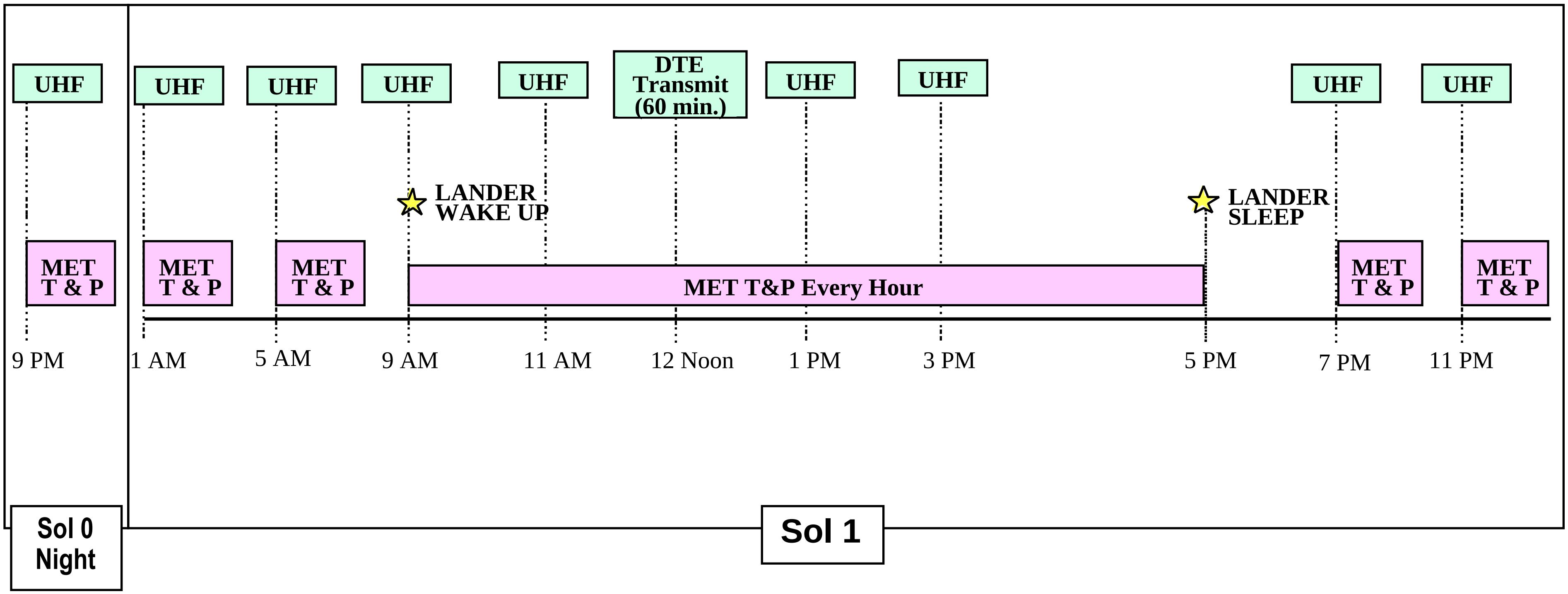
Sol 0,1 Night-time Activities: The Lander CPU and MET systems are activated several times duging the first "night" to obtain temperature and other data during the colder portions of the diurnal cycle. Nominally, the MET package is activated for a few minutes for temperature and pressure observations, at approximately 9 PM, 1 AM, and 5 AM local time. Each such activation is followed by a UHF pass for downlinking the data. LIDAR may also be activated during this interval.

Sol 1 Day-time Activities: After the first night, the Lander is powered up for the next sol's activities, the highest priority for which is returning any remaining MARDI data. At wakeup, circa 9 AM LMST, the CPU boots at 20 Mhz for 2 minutes, then shifts to 5 Mhz. Primary data relay and commanding occur via several passes of the MSP98 Orbiter, but a 1-hr DTE link is also planned in the afternoon. Science activities during Sol 1 include regular MET temperature and pressure observations. [Note: this Design Reference Mission is based on conservative assumptions regarding environmental conditions and s/c performance. If sufficient power and D/L capabilities are available during Sol 1, additional activities may be commanded. Other potential activities for Sol 1 include digging for surface samples and an abbreviated TEGA run. A payload scenario for Sol 1 under nominal conditions is shown in the Databook, section B.5.7.

Go to TOC

SOL 0 NIGHT-TIME AND SOL 1 DESIGN REFERENCE MISSIONS



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5.6.3 TEGA Day 1 Design Reference Mission

The first day in the 2-day TEGA operations scenario defines another Lander Design Reference Mission used for assessing mission and system performance and developing system-level test sequences.

Assumptions: It is assumed the solar array has a 0° tilt and that the earliest this scenario would be used is Ls = 256° [start of the landed science phase]. Like the Sol 0,1 Design Reference Mission, it is required that all science payload activities accommodate 20% power loads growth, and that a loads growth margin of 12% be maintained for spacecraft activities. On top of this, a 10% power margin is allocated for solar array output modelling uncertainties, and 5% allocated for layout and shadowing effects. The maximum allowable depth of discharge during the sequence is 70%, and it required that the battery reach a full state of charge at least once per sol.

Power Profile: The power profile for this Design Reference Mission is shown in Appendix B.5.6.

Science Objectives: Quantify volatile reservoirs - determine quantity of volatiles present as ice and / or adsorbed in soil; detect volatile-bearing minerals; determine isotopic ratios of volatiles present in soil. [Variant: identify volatiles condensing on ground at night - requires performing payload activity sequence during early morning hours.]

Payload Activities:

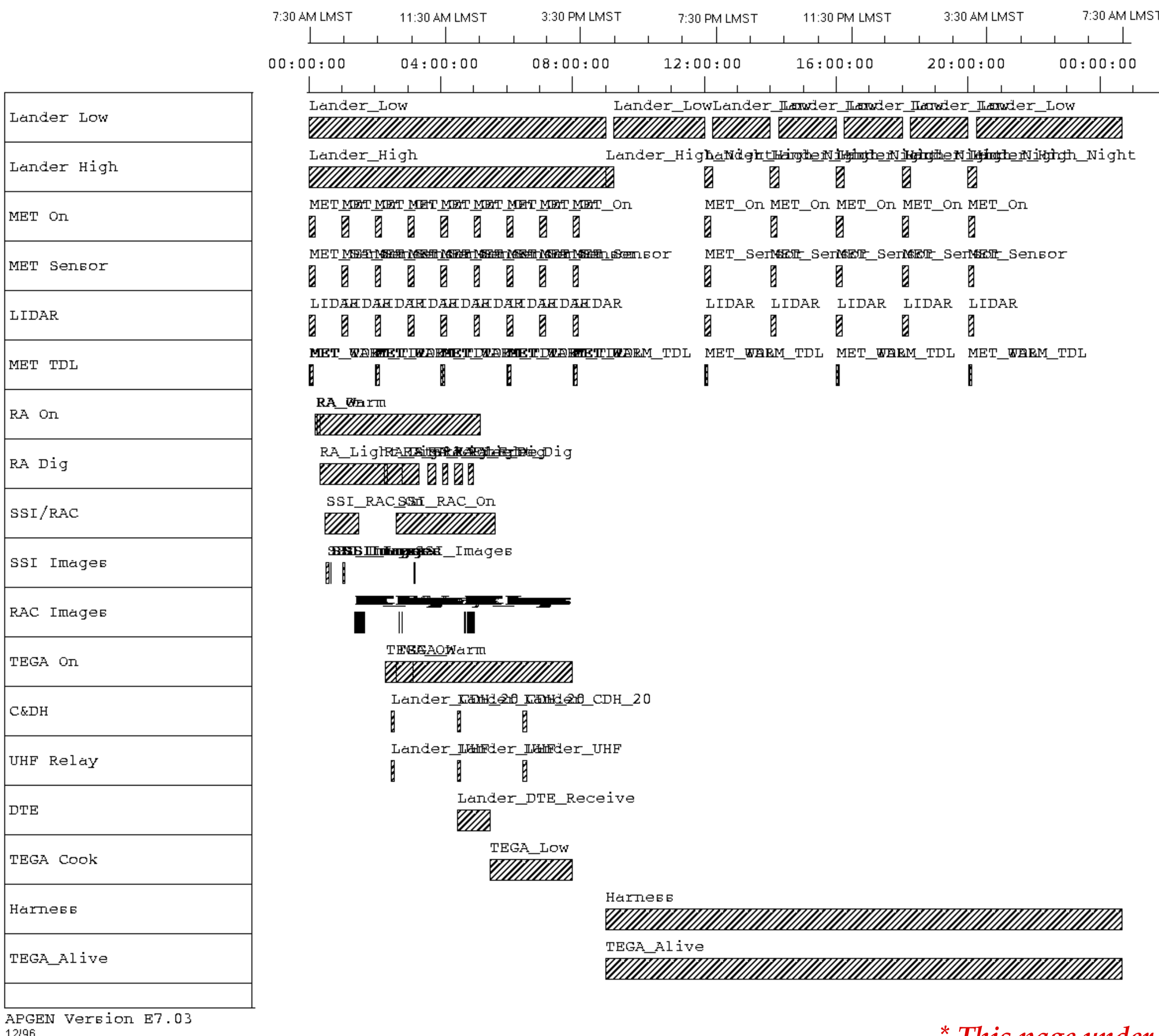
Robotic Arm, Imagers, TEGA: Prior to TEGA Day 1 the Robotic Arm [RA] will have excavated the trench to within a few cm of the desired depth. On TEGA Day 1 the RA excavates the remaining few cm. At preplanned pauses the SSI and RAC are used to image the trench and its interior. Near the end of the dig sequence, the TEGA is powered on for warm-up and calibration. A sample is scooped by the RA, imaged with the RAC, and delivered to one of the TEGA ports. After verification that the sample has been received [TEGA checks this autonomously using a LED indicator] the low temperature [up to 300K] cook sequence begins. If the sample has not been successfully delivered, another attempt is made. The number of attempts will be pre-planned. The RA returns to the trench to measure soil temperature with the Soil Temperature Probe. [These temperature measurements are acquired by the MET package.] At the end of the TEGA low temperature cook sequence the TEGA is powered off for the night; the sample remains in the oven to cool overnight. On the next day TEGA runs the high temperature [1300K] cook sequence.

MET and LIDAR: The MET package is powered on at the beginning of the Lander's day, and takes data per a modified "Daily Weather" measurement cycle. LIDAR measurements are also planned during this interval.

The following graphic illustrates the payload sequence of events during TEGA Day 1. Two time scales are shown: Local mean solar time at the landing site, and standard hours from the start of the Lander's day.

Go to TOC

TEGA DAY 1 DESIGN REFERENCE MISSION



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