

Mars Surveyor '98 Project

Mission Plan and Databook

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August 8, 1997

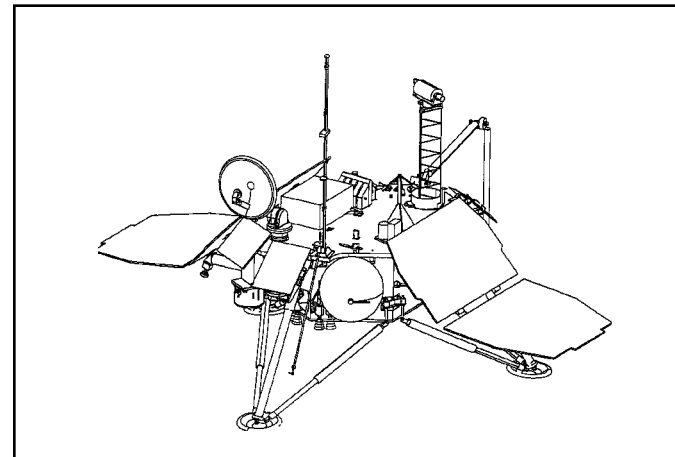
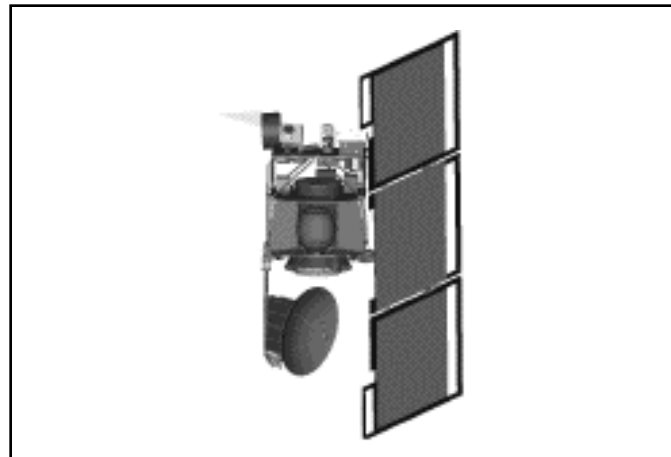
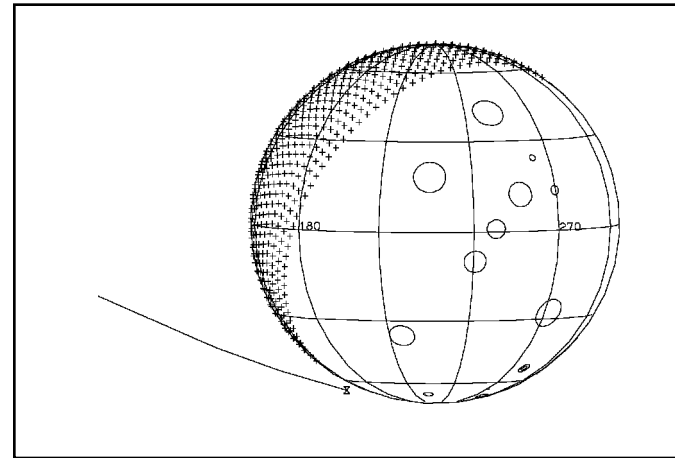
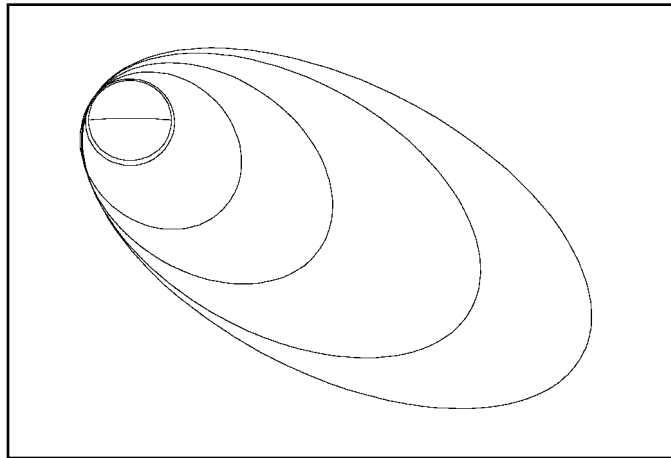


**Jet Propulsion Laboratory
California Institute of Technology**

MARS SURVEYOR '98 PROJECT

MISSION PLAN and DATABOOK

M98-1-2001



August 8, 1997

MARS SURVEYOR '98 PROJECT

MISSION PLAN and DATABOOK

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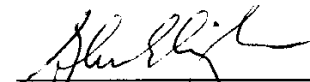
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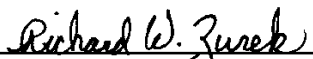
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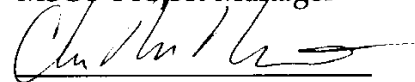
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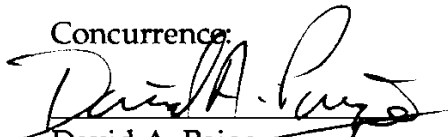


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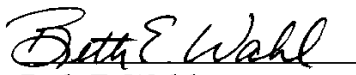


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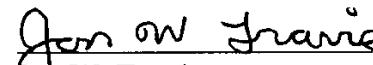
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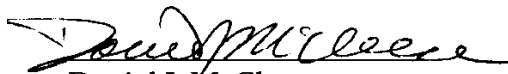
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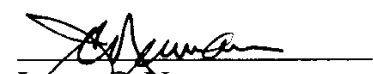
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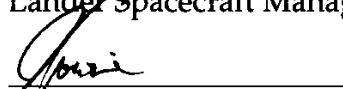
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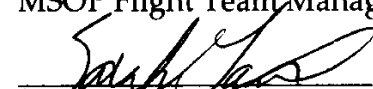
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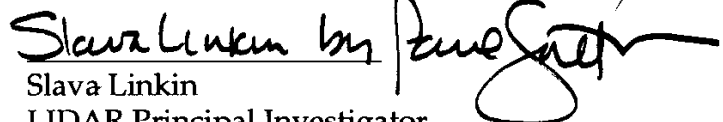
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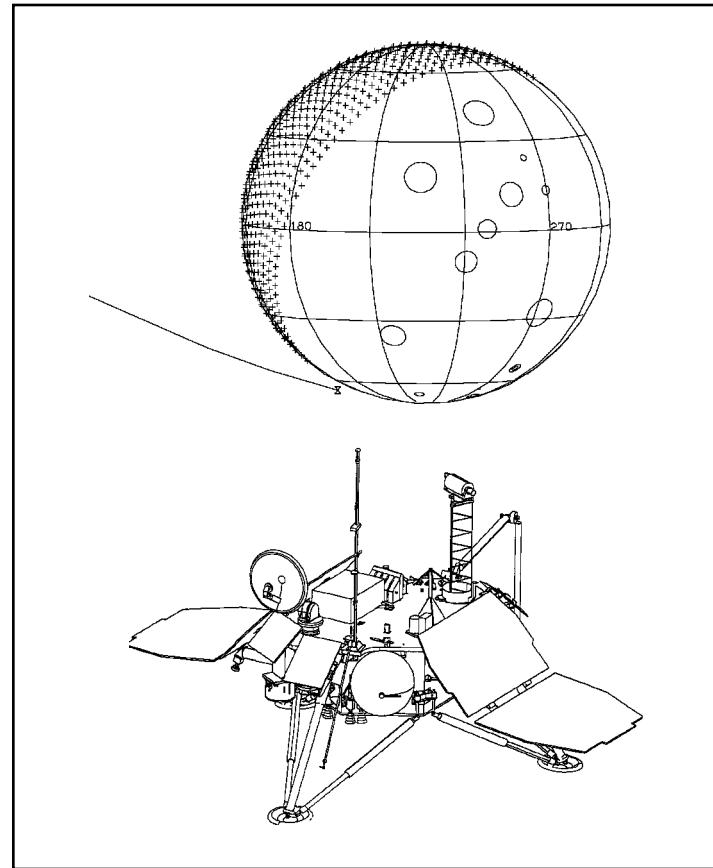
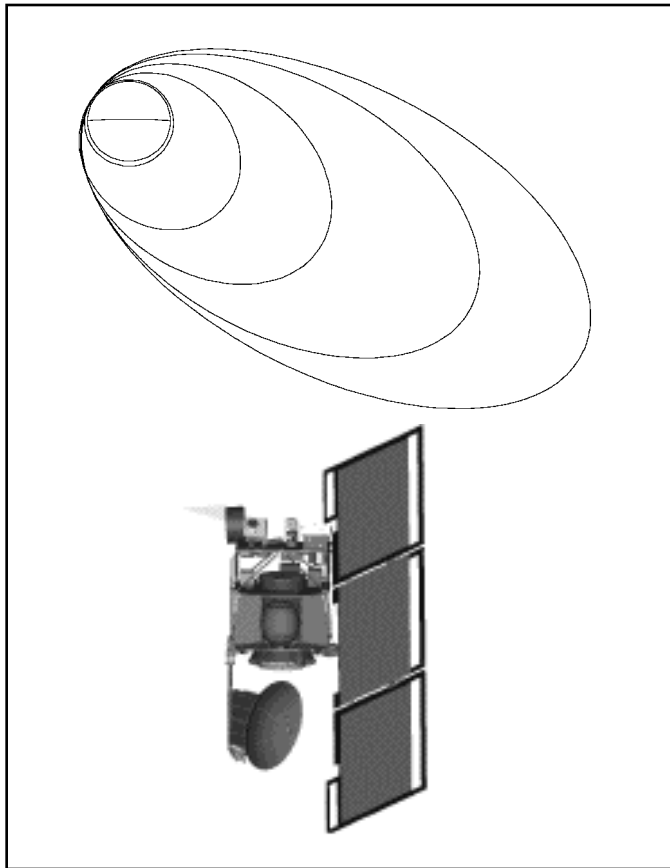


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August 8, 1997

MARS SURVEYOR '98 PROJECT

MISSION PLAN and DATABOOK - Introduction



August 8, 1997

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1.0 INTRODUCTION

1.1 PURPOSE, SCOPE, AND RELATION TO OTHER DOCUMENTS

The Mars Surveyor 98 Orbiter and Lander Mission Plan and Databook combines the functionality of a high-level mission summary for the Orbiter and Lander, a databook containing mission data, including those usually found in trajectory characteristics documents, and a navigation plan. It defines the baseline mission and provides the basis for development of detailed mission event sequences. This document does not levy new mission and system requirements, but is intended to show how previously defined requirements, constraints, or capabilities are combined to define the mission concept. This document includes change-controlled sections containing baseline data or processes requiring review prior to alteration. It reflects a current understanding of evolving mission capabilities; these capabilities may, in certain cases, differ from contractual or other requirements.

This document is consistent with and responsive to high level project policies, constraints, and capabilities, as described in the following documents:

Mars Surveyor '98 Project Plan [1-1001]

Mars Surveyor '98 Project Policies, Requirements, and Capabilities Document [1-1002]

Payload Interface Control Documents

It is also consistent with capabilities and constraints of the project systems as described in the following documents:

Planetary Protection Plan [3-2001]

Launch Vehicle Specifications [3-4001]

The portions of this document under change control are described in the following section.

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DOCUMENT PURPOSE, SCOPE, AND RELATION TO OTHER DOCUMENTS

- **CONTENTS:**
 - High-level summary of mission events for the Orbiter and Lander
 - Mission data, including trajectory characteristics
 - Navigation Plan
- **PURPOSE:**
 - Defines the baseline mission
 - Provides the basis for development of detailed mission event sequences
 - Demonstrates how current requirements, constraints, or capabilities combine to define the mission concept
 - It does not levy new mission and system requirements
 - Includes change-controlled sections containing baseline data or processes requiring review prior to alteration.
 - Reflects current mission capabilities [may differ from contractual or other requirements]
 - Documents design reference missions used to assess performance vs. resources
- **The Mission Plan and Databook is responsive to:**
 - **Mars Surveyor '98 Project Plan [1-1001]**
 - **Mars Surveyor '98 Project Policies, Requirements, and Capabilities Document [1-1002]**
 - **Payload Interface Control Documents**
- **The Mission Plan and Databook is consistent with:**
 - **Planetary Protection Plan [3-2001]**
 - **Launch Vehicle Specifications [3-4001]**

1.2 SECTIONS UNDER CHANGE CONTROL

The following table lists those sections of the Mission Plan and Databook which are under change control as part of the Project Documentation Tree. Changes are subject to review by the Project Manager and Project Change Board.

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SECTIONS UNDER CHANGE CONTROL

- Indicated sections are under change control as part of the Project Documentation Tree, and are subject to review by the Project Manager and Project Change Board.

- INTRODUCTION:**

Section	Description of Controlled Items
1.3	Planetary Constants
3.1	Launch Vehicle wet mass capabilities

- ORBITER MISSION PLAN and DATABOOK:**

Section	Description of Controlled Items
4.2.3	Orbiter Launch/Arrival Period
4.2.4	Orbiter Launch Period Strategy
4.2.5	Summary of Mission Events and DSN Tracking Requirements
4.2.6	Orbiter ΔV and Propellant Mass Summary
4.4.1	Orbiter Cruise Navigation
4.4.2	TCM's
4.6.3.1	TMO Maneuvers
4.7.1	Overview [Lander Support Phase]
4.8.1	Mapping Orbit
4.10	Orbiter Design Reference Missions
A.13	Orbiter Approach Targeting Data

- LANDER MISSION PLAN and DATABOOK:**

Section	Description of Controlled Items
5.2.3	Lander Launch/Arrival Period
5.2.4	Summary of Mission Events and DSN Tracking Requirements
5.2.5	Lander ΔV and Propellant Mass Summary
5.4.1	Lander Cruise Navigation
5.4.2	TCM's
5.6.2	Sol 0,1 Design Reference Mission
5.6.3	TEGA Day 1 Design Reference Mission
B.11	Lander Approach Targeting Data

1.3 TBD LIST

The following table lists TBD [to be determined] items. These include items for which no value is yet available, or for which a representative value is proposed in the Mission Plan and Databook. These items may be revised pending further review or analysis. TBD items appearing in change-controlled sections are indicated.

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TBD LIST

- ORBITER MISSION PLAN and DATABOOK:**

Section	Description of TBD Item	In a Change Controlled Section?
4.2.5	Use of BWG antenna	yes
4.2.6	Inclination trim during and after aerobraking	yes
4.4.5.1	Use of PMIRR, MARCI during HGA transmission [undeployed]	
4.4.5.1	MARCI pictures taken during Earth-Moon Calibration	
4.4.5.1	Requirement to keep sun off PMIRR scan mirror during checkout	
4.5.1.1	Confidence level for 150 km altitude limit at MOI	
4.5.1.1	Accelerometer cutoff value during MOI-1 [current estimate 65-75%]	
4.5.1.2	Time before MOI to disable Safe Mode	
4.6.1	Updating walk-in maneuver post-MOI	
4.6.2.2	When to go to reduced tracking pass duration during power end-game	
4.6.2.2	Feasibility of measures to compensate for reduced periapse prediction capability	
4.6.3.1	Time for transfer to mapping orbit [current allocation = 24 hrs]	yes
4.6.3.1	Maximum feasible maneuver after HGA deployment	yes
4.6.3.2	Need for HGA calibration after deployment	
4.7.1	Days after Lander Landing to initialize PMIRR and MARCI	yes
4.7.1	Orbiter science operations during Lander Support Phase [EMI interference]	yes
4.7.2.1	Maximum size of lander command load	
4.8.1	Acceptable range of mapping orbit inclinations	yes
4.8.3	Frequency of nav predicts during mapping	

- LANDER MISSION PLAN and DATABOOK:**

Section	Description of TBD Item	In a Change Controlled Section?
5.1.2	Operation of Lander under dust-storm conditions	
5.2.3	Confidence level for achieving $\pm 0.25^\circ$ entry angle control	yes
5.4.1	Near-simultaneous tracking for entry control	yes
5.4.4.1	2100 bps for Checkout/Calibration Campaigns using 70m station	
5.4.4.2	TEGA checkout interval, requirement for TEGA valve exercise	
5.4.4.3	D/L percentage allocation for Science during Checkout/Calibration Campaigns	
5.4.5	Schedule for updating entry state	
5.4.5	Time before Entry to disable Safe Mode	
B.5.7	Payload scenarios, transition to "nominal" Sol 1 activities.	

1.4 PLANETARY CONSTANTS

** This page under Change Control **

The following table summarizes the planetary constants to use for all mission calculations. Data are based on MGS and Pathfinder planetary constants. All other data not listed [e.g. data for Earth-relative calculations, definitions of coordinate systems, etc.] must conform to the Mars Pathfinder Project PLANETARY CONSTANTS AND MODELS (JPL D-12947), September, 1996 revision.

The "Reference Radius" of 3397.2 is used to define Mars-relative planetocentric altitudes, index altitudes, and entry interface points. Entry interface is defined to occur at a radial distance of $3397.2 + 125 = 3522.2$ km.

Mars-relative planetographic altitudes are calculated using the MarsGRAM reference triaxial ellipsoid. Calculations requiring the use of an oblate spheroid use an equatorial radius equal to the mean of the two triaxial equatorial radii.

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PLANETARY CONSTANTS

- Values are based on MGS and Pathfinder Planetary Constants. Constants not listed below must conform to the Mars Pathfinder Project PLANETARY CONSTANTS AND MODELS (JPL D-12947), September, 1996 revision.

Description	Value	Units	Application	Reference
Mars Reference Radius	3397.2	km	Planetocentric altitudes, Index altitudes, and Entry Interface.	MO Planetary Constants 7/86, MGS Mission Plan 6/95
MarsGRAM Triaxial Ellipsoid [6.1 mb surface] - Rx - Ry - Rz	3394.67 3393.21 3376.78	km km km	Planetographic altitudes, elevations.	Pathfinder Planetary Constants & Models 9/96
MarsGRAM-based Oblate Spheroid - Equatorial Radius - Polar Radius - flattening = (Equatorial Radius - Polar radius)/ (Equatorial Radius)	3393.94 3376.78 [0.00505607]	km km	Planetographic altitude calculations requiring the use of an oblate spheroid.	Equatorial radius = average of the two triaxial equatorial radii.
GM of Mars	42828.3142580671	km ³ /s ²		Pathfinder Planetary Constants & Models 9/96
Gravity Field of Mars	Mars 50c	-		Pathfinder Planetary Constants & Models 9/96

- Entry Interface Definition:** radial distance of 3397.2 + 125 = 3522.2 km.

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1.5 LIST OF ACRONYMS - DEFINITION OF TERMS

Acronym or Term	Definition
AMM	Autonomous Momentum Management
bps	bits per second
C3	Launch Energy = outgoing V_{∞}^2
CE	Cincinnati Electronics protocol
CPU	Central Processing Unit
D/L	Downlink
desat	Abbreviation for momentum wheel desaturation, using the RCS thrusters
DOD	Battery depth of discharge
DRAM	Dynamic RAM
DRM	Design Reference Mission
DSN	Deep Space Network
DTE	Direct to Earth telecomm link on the Lander
EMI	Electromagnetic Interference
HGA	High Gain Antenna
ICD	Interface Control Document
LIDAR	lidar [light detection and ranging] experiment
LMST	Local Mean Solar Time
Ls	Longitude of the sun with respect to the vernal equinox of Mars
LTST	Local True Solar Time
MARCI	Mars Color Imager
MARDI	Mars Descent Imager
MET	Meteorological Package [MVACS instrument]
MGA	Medium Gain Antenna
MGs	Mars Global Surveyor
MOI	Mars Orbit Insertion
MSP	Mars Surveyor Program

MVACS	Mars Volatiles and Climate Surveyor
OTM	Orbit Trim Maneuver, specifically during aerobraking.
PCS	Probability of Commanded Shutdown for the 2nd stage of the launch vehicle
PMIRR	Pressure Modulator Infra-Red Radiometer
PMU	Pressure Modulator Unit
RA	Robotic Arm [MVACS]
RAC	Robotic Arm Camera [MVACS instrument]
RCS	Reaction Control System
RWA	Reaction Wheel Assembly
SSI	Surface Stereo Imager [MVACS instrument]
TCM	Trajectory Correction Maneuver
TEGA	Thermal and Evolved Gas Analyzer [MVACS instrument]
TPS	Thermal protection system
U/L	Uplink
V_{∞}	"V-infinity" - planet relative hyperbolic excess velocity on outgoing or incoming asymptote

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2.0 ORBITER AND LANDER MISSIONS OVERVIEW

2.1 ORBITER MISSION

The MSP98 Orbiter launches on a Delta II 7425 in December 1998, arriving at Mars in September 1999. After a propulsive capture, aerobraking is used to circularize the orbit. The mapping orbit is a near sun-synchronous, near circular frozen orbit with a descending node at approximately 4 PM. It is planned to have the Orbiter in place to support MSP98 Lander data relay and commanding prior to Lander arrival in December, 1999. The nadir-pointed instruments perform imaging and systematic daily global sounding of the Mars atmosphere for a minimum of one Mars year [687 Earth days]. The science payload consists of a Pressure Modulator Infrared Radiometer (PMIRR) identical to that flown on Mars Observer, and the Mars Color Imager (MARCI). The MSP98 Orbiter serves as a communications relay asset for landed vehicles for up to 5 years from insertion into the mapping orbit.

2.2 LANDER MISSION

The MSP98 Lander launches on a separate Delta II 7425 in January 1999 and arrives in December 1999, a period in late southern spring when the seasonal CO₂ polar cap has disappeared at the prime landing site [75 - 78S]. The Lander is slowed during entry by a Mars Pathfinder-heritage aeroshell and parachute, and effects a controlled propulsive landing. The first landed day's activities include solar panel and instrument deployments, spacecraft and payload functional checkouts, establishment of communication with the Orbiter and Earth, and time critical science activities. Science investigations continue for the remainder of the 2-3 month landed surface mission. The Lander has a UHF telecomm system which supports data relay via the MSP98 Orbiter and/or MGS, and commanding via the MSP98 Orbiter. A direct Earth link is also available for backup commanding and telemetry relay.

The Lander carries the Mars Volatiles and Climate Surveyor (MVACS) instrument suite, a LIDAR instrument supplied by the Russian Space Agency, and the Mars Descent Imager (MARDI). At the targeted landing site on the polar layered terrain, the lander's goals include a search for near-surface ice, analysis of possible surficial records of cyclic climate change, and characterization of physical processes key to understanding the seasonal cycles of water, carbon dioxide and dust on Mars.

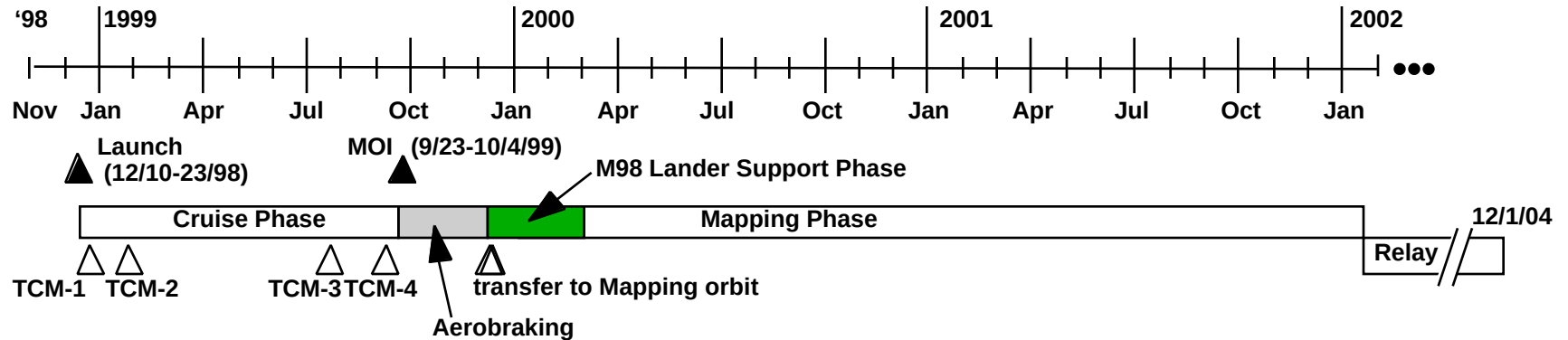
2.3 MARS MISSIONS TIMELINES

The following timeline illustrates the primary activities of the MSP98 Orbiter, Lander, and the MGS spacecraft during their respective operational life cycles.

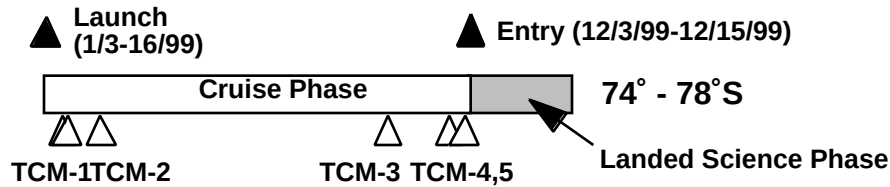
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MARS MISSIONS TIMELINES

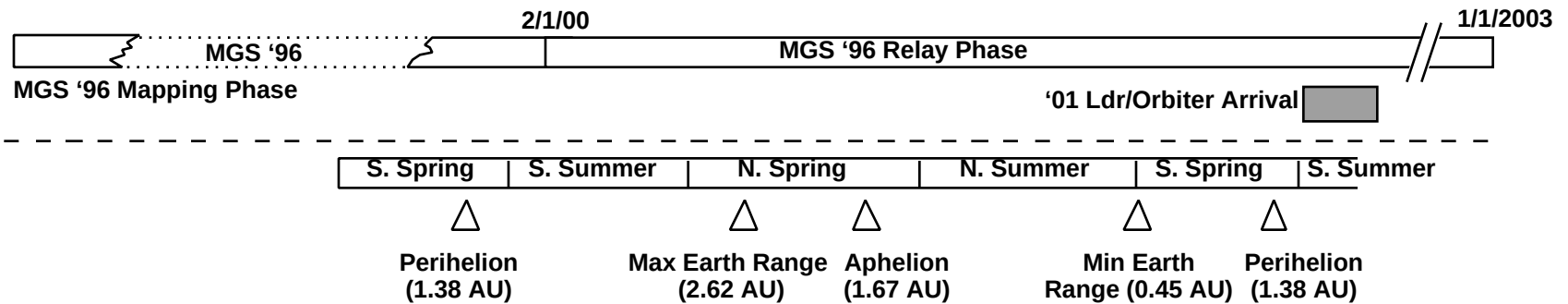
MSP '98 ORBITER



MSP '98 LANDER



MGS ORBITER, '01 LANDER/ORBITER



3.0 LAUNCH VEHICLE

3.1 LAUNCH VEHICLE DESCRIPTION

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The Mars98 Orbiter and Lander are each separately launched on McDonnell Douglas Delta II 7425 launch vehicles, procured via the MedLight Launch Vehicle contract. Each launch vehicle is equipped with 4 thrust augmentation solids and use the 9.5 ft. fairing. The upper stage in each case consists of a spin stabilized Star 48 with a Nutation Control System and a yo-yo despin device. For both vehicles, a single, near instantaneous launch window is baselined for each day in the launch period, using a 95° flight azimuth and short coast ascent trajectories.

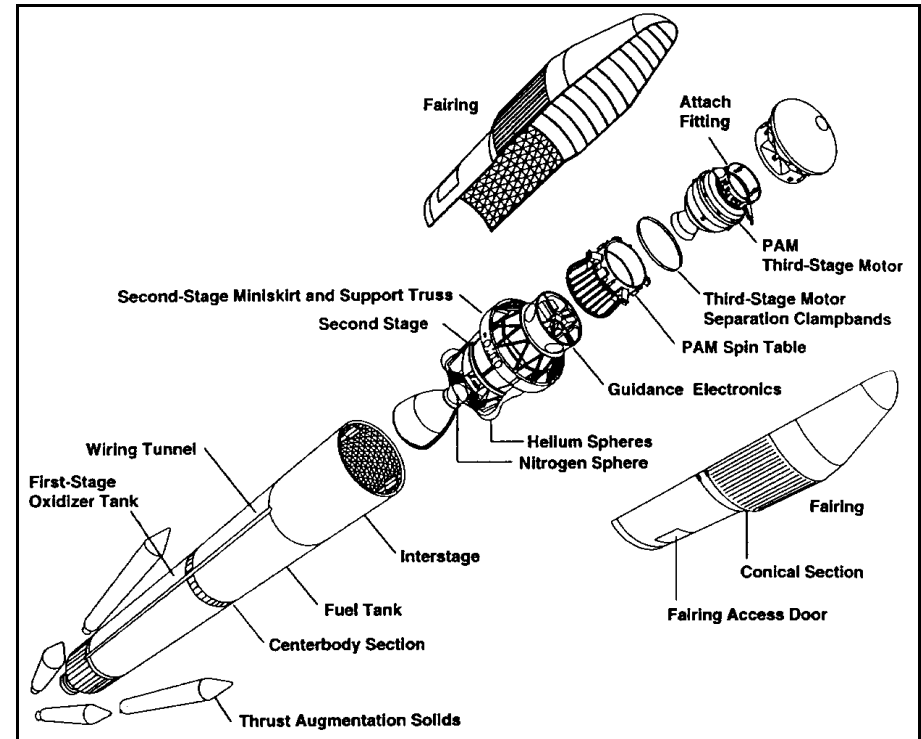
A minimum probability of second stage commanded shutdown [PCS] of 95% is required by the Project. The Delta II 7425 capability for the Orbiter is 643 kg wet mass at a C3 of $11.263 \text{ km}^2/\text{s}^2$ and 95% PCS. [The current estimated maximum C3 is $11.19 \text{ km}^2/\text{s}^2$ at the start of the launch period.] The Lander wet mass at launch must not exceed 615 kg, a figure dictated by the maximum mass allowed at atmospheric entry and landing, and the need to carry the New Millenium Microprobes. The performance of the Delta II 7425 accommodates this requirement with PCS greater than 99.7% across the entire launch period.

Launch vehicle operational constraints limit the time between Orbiter and Lander launch to be no less than 9 days, assuming the use of two launch pads. This has been accommodated by separating the end of the Orbiter launch period and the start of the Lander launch period by 9 days.

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LAUNCH VEHICLE DESCRIPTION

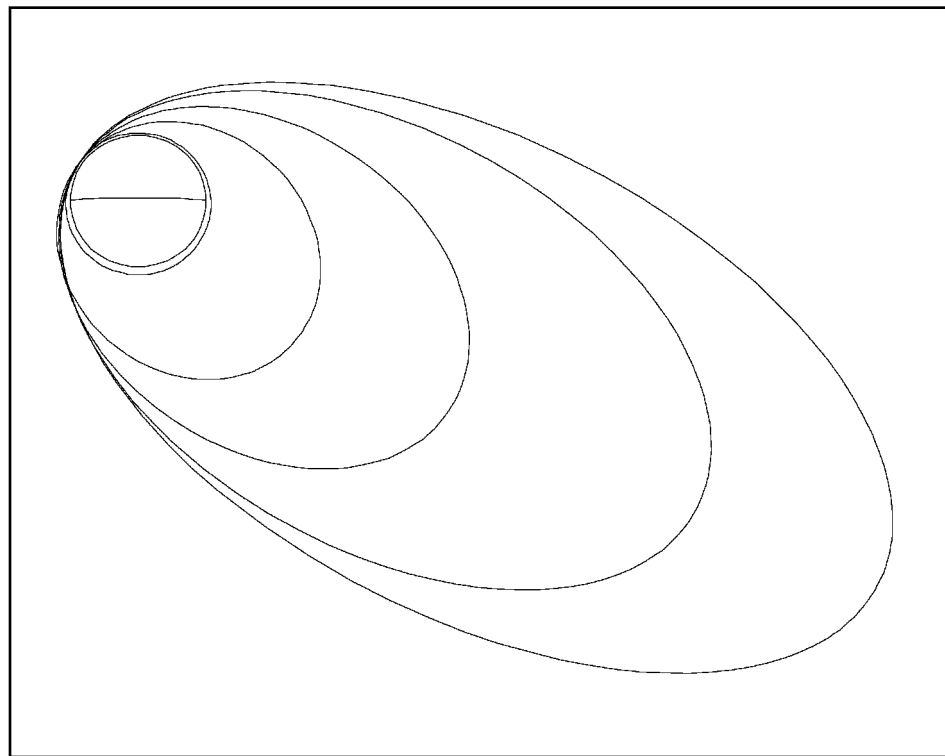
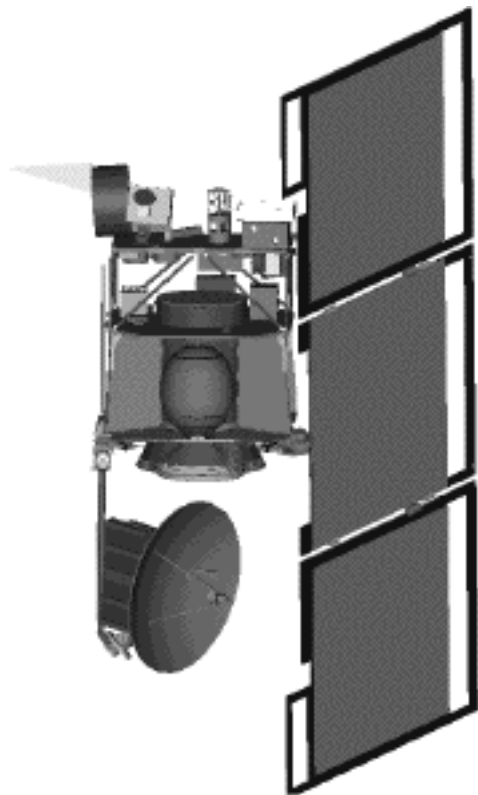
- **Orbiter and Lander each separately launched on McDonnell Douglas Delta II 7425.**
 - Procured via MedLite Launch Vehicle contract
 - 4 solid [GEM] version of Delta II
 - 9.5 ft fairing
 - Spin stabilized Star 48 upper stage
 - » Nutation Control System
 - » Yo-yo despin device
- **Daily Launch Opportunities across each launch period.**
 - 95° flight azimuth
 - Near instantaneous launch windows
 - Short coast ascent trajectories
- **Capability:**
 - **Project requires 2nd Stage probability of commanded shutdown [PCS] $\geq 95\%$**
 - » Orbiter: **643 kg** wet mass capability.
 - » Lander maximum wet mass = **615 kg**, dictated by maximum entry, landed masses, and need to carry New Millenium Microprobes.
 - Launch vehicle performance exceeds this requirement with PCS $\geq 99.7\%$
- **The Orbiter and Lander launches must occur at least 9 days apart.** Two pads are needed to support this requirement.



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MARS SURVEYOR '98 PROJECT

ORBITER MISSION PLAN and DATABOOK



August 8, 1997

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APPENDIX A: ORBITER MISSION DATABOOK

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- A.10 Orbiter Data Rates, Earth Contact Durations, Daily Data Volumes**
 - A.10.1 Orbiter and Lander Communication Strategy during the Mission [Memo MSP-SE-97-0162]
 - A.10.2 Data Rates, Data Volumes during Mapping
- A.11 Orbiter Mapping Navigation**
- A.12 34m BWG Usage and Tracking Schedule Modifications**
 - A.12.1 DSN Contention Resolution**
 - A.12.2 Approach, near-Simultaneous Tracking Integrated Schedule**
- A.13 Orbiter Approach Targeting Data** **This Section under Change Control**

4.0 MARS SURVEYOR 1998 ORBITER MISSION PLAN

4.1 FLIGHT SYSTEM DESCRIPTION

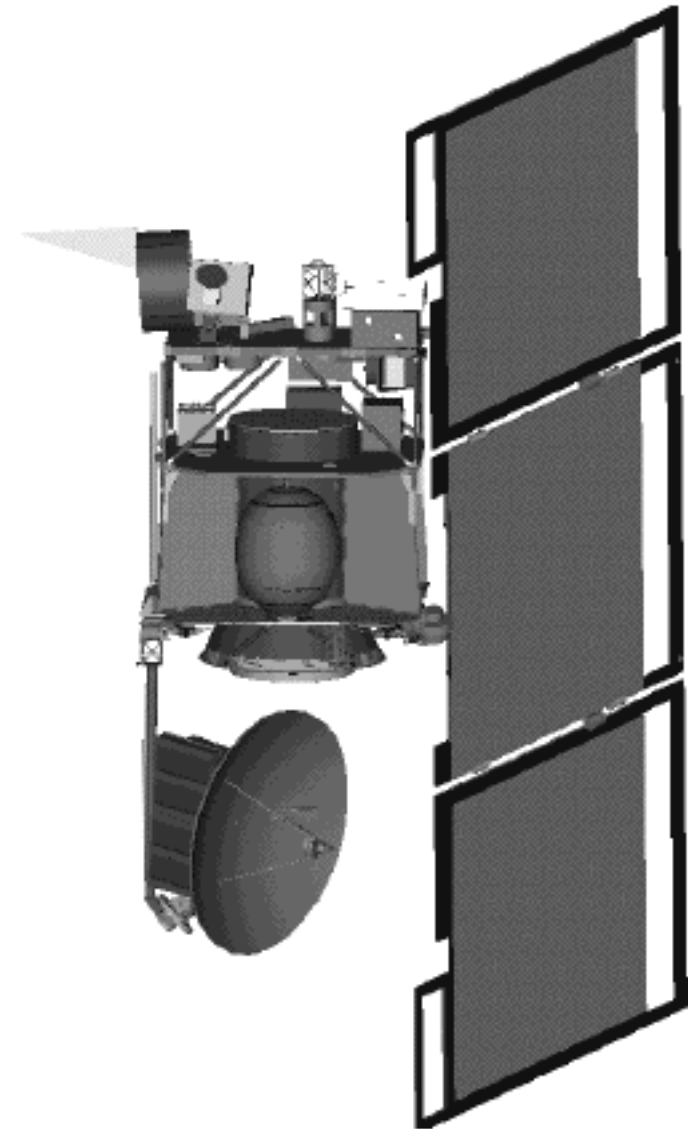
4.1.1 Orbiter Bus

The Orbiter is 3-axis stabilized in all mission phases following separation from the launch vehicle. The primary attitude determination is via star camera and an inertial measurement unit, and is backed up by analog sun sensors. Reaction wheels provide primary attitude control during most mission phases, and are desaturated via RCS thrusters. Because of IMU lifetime concerns, the IMUs will be turned off during significant portions of Cruise and Mapping, and the vehicle operated in all-stellar mode. except during maneuvers. The RCS thrusters also provide attitude control during TCM's, MOI, aerobraking drag pass, OTM's, and safe mode [until rates are damped, at which point RW control is used]. In all, four 5-lbf thrusters are used for TCM's and pitch/yaw control. Four 0.2-lbf thrusters are used for roll control. The Orbiter C&DH uses the RAD6000 processor. The X-band link with Earth employs Cassini Deep Space Transponders, 15 W RF solid state power amplifiers (SSPA's), one 1.3 m transmit/receive high gain antenna (HGA), one transmit-only medium gain antenna (MGA), and one receive-only low gain antenna. A 10 Watt RF UHF system supports the 2-way link with the Lander. The 3-panel, single wing solar array (SA) uses GaAs/Ge solar cells and also functions as the primary drag brake during aerobraking. The batteries are NiH₂ CPV batteries, while the electrical power electronics are based on the SSTI spacecraft electronics. The thermal control subsystem is passive, with louvers to control the temperature of the batteries and SSPA's and combinations of MLI, Kapton, paints, and dedicated radiators for certain other components. Both thermostatically controlled and computer controlled heater circuits are used. The Orbiter equipment module (EM) is a composite truss structure with titanium end fittings and two Aluminum honeycomb panels with composite face sheets. The solar array and HGA track the Sun and Earth, respectively, with 2-axis gimbals. The propulsion subsystem is dual mode, employing a bipropellant main engine for Mars Orbit Insertion (MOI) and TCM (hydrazine) thrusters for all other propulsive events. Most subsystem components are redundant, with critical items cross strapped.

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FLIGHT SYSTEM DESCRIPTION: ORBITER BUS

- **AACS:**
 - 3 axis stabilized
 - Reaction wheels desaturated via RCS thrusters
 - IMUs turned off during significant portions of Cruise, Mapping [all-stellar mode] except during maneuvers
 - » IMU lifetime concerns.
 - Star camera + IMU, backed up by analog sun sensors
 - 4 5-lbf TCM thrusters also used for Pitch & Yaw
 - 4 0.2-lbf thrusters for Roll control
- **C&DH: RAD6000 processor**
- **Telecom:**
 - Cassini Deep Space Transponders
 - 15W RF SSPA's
 - One 1.3m Tx/Rx HGA, 1 Tx-only MGA, 1 Rx-only LGA
 - UHF 10 Watt RF system for 2-way communication with Lander
- **Power:**
 - Single, 3 panel GaAs/Ge solar array, 2 axis gimbaled
 - NiH2 CPV batteries
- **Thermal Control:**
 - Passive: louvers, MLI, Kapton, paints, dedicated radiators
 - Thermostatically controlled and computer controlled heater circuits
- **Propulsion:**
 - Biprop system for MOI only
 - Hydrazine TCM thrusters [4 5-lbf thrusters] for all other maneuvers
- **Structure: Composite facesheets on Aluminum honeycomb.**



4.1.2 Orbiter Payload

Pressure Modulator Infrared Radiometer (PMIRR)

PMIRR is a nine-channel limb and nadir scanning atmospheric sounder designed to vertically profile atmospheric temperature, dust, water vapor and condensate clouds and to quantify surface radiative balance. PMIRR observes in a broadband visible channel, calibrated by observations of a solar target mounted on the instrument, and in eight spectral intervals between 6 and 50 μm in the thermal infrared. High spectral discrimination in the 6.7 μm water vapor band and in two parts of the 15 μm carbon dioxide bands is achieved by employing pressure (density) modulation cells in front of selected spectral detectors. Adequate signal-to-noise in these channels is ensured through the placement of their detectors on a cold focal plane assembly cooled to 80 K by a passive radiative cooler. The PMIRR Principal Investigator is Dr. Daniel McCleese (JPL/ Caltech); Vasily Moroz (IKI/ Russia) is Joint Principal Investigator.

PMIRR science observations will commence only after the PMIRR radiator door is fully opened. Once PMIRR is deployed in the mapping orbit, vertical profiles of atmospheric properties are constructed from observations in three fields-of-view (FOV) stepped across the limb and onto the planet using a two-axis scan mirror in front of the primary telescope. Nominally, PMIRR views the aft limb, referenced to the spacecraft, except for the polar regions where it routinely views in and out of the plane of the spacecraft track to quantify the polar surface albedo by observing much of the bi-direction reflectance distribution function. PMIRR can also view to the side limb, acquiring observations characterized by different local times. PMIRR's vertical resolution is 5 km.

Mars Color Imager (MARCI)

MARCI combines Wide Angle (WA) and Medium Angle (MA) cameras with individual optics but identical focal plane assemblies, data acquisition system electronics, and power supplies. Each camera is small in size ($\approx 6 \times 6 \times 12$ cm, including baffle) and mass (combined mass ≤ 2 kg). Both cameras operate in a "pushframe" mode, with their CCD detectors overlaid with spectral ("color") filter strips. The cameras are electronically shuttered at intervals timed so that the spacecraft motion spatially overlaps each filter strip view, thereby providing a "color" composite. The MARCI Principal Investigator is Dr. Michael Malin (Malin Space Science Systems, San Diego).

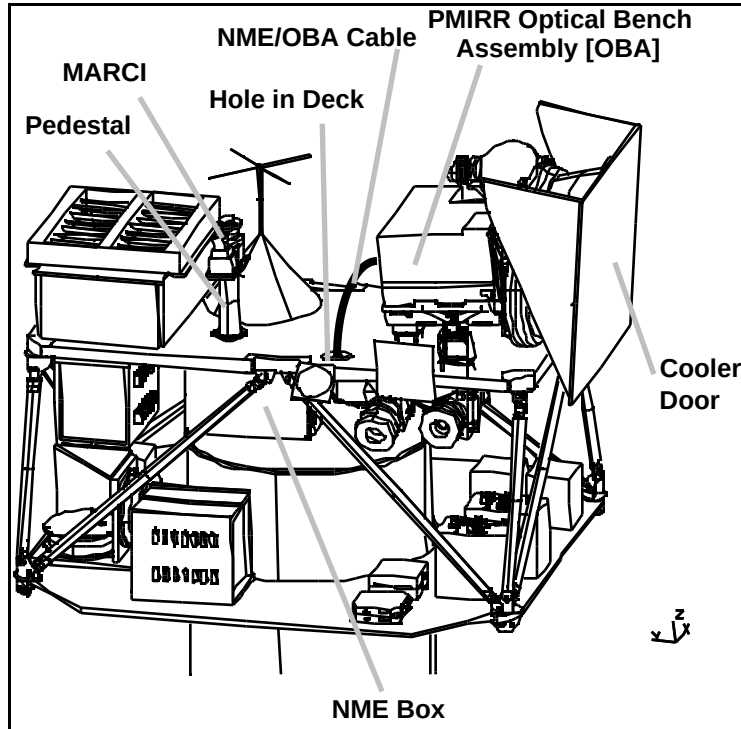
Near the end of the Orbiter's cruise phase, MARCI acquires approach images of Mars. Once in the mapping orbit, MARCI provides daily global images of the Mars atmosphere (and surface) with the WA camera and monitors surface changes with the MA camera during mission periods with high data rates.

The WA camera has seven spectral bands [5 visible, 2 UV] and has spatial resolutions on the planet better than 7.2 km/pixel, for nominal orbital altitude and downlink data rates. Kilometer-scale resolutions are possible, when data rates permit. Limb observations detail the atmospheric structure of clouds and hazes at ≈ 4 km resolution. The MA camera has a 6° FOV covering 40 km at 40 m/pixel (nadir) and accessing all positions of the planet (except the rotational poles due to the slight inclination of the spacecraft orbit). Ten spectral channels from 425 to 1000 nm provide the ability to discriminate both atmospheric and surface features on the basis of composition.

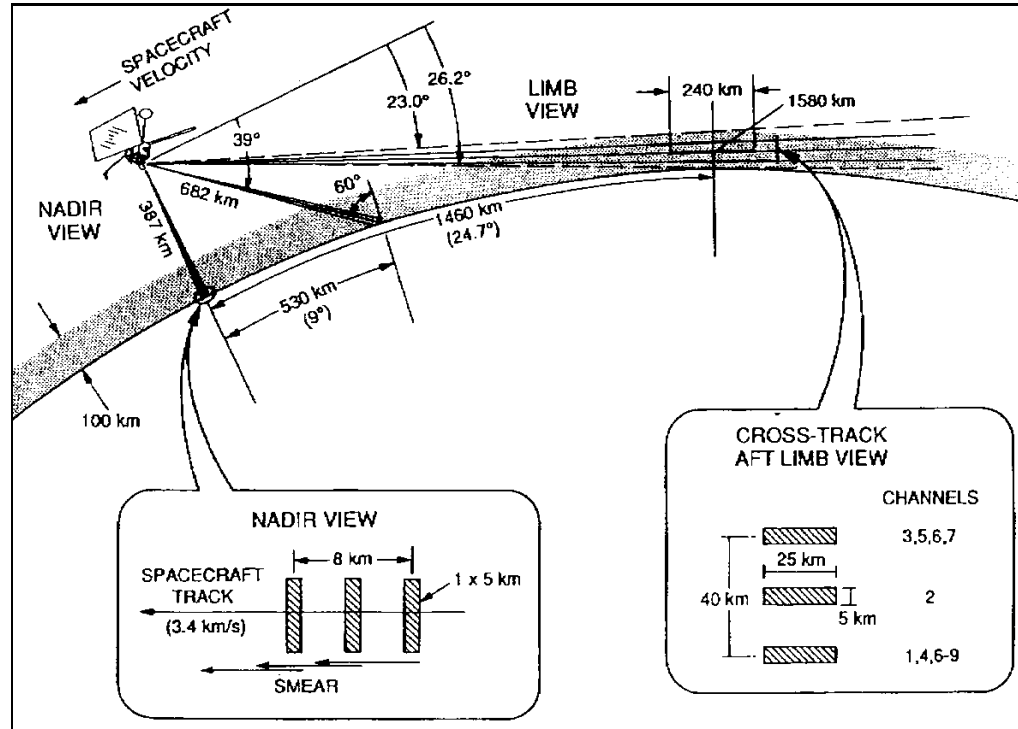
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ORBITER PAYLOAD

Orbiter Science and Equipment Decks



PMIRR Fields of View



- **Pressure Modulator Infrared Radiometer [PMIRR]**

- Multispectral limb and nadir scanning atmospheric sounder
 - » Provides vertical profiles of atmos. temp, dust, water vapor & clouds, quantifies surface radiative balance
- Radiator door deployed upon achieving mapping orbit
- Nominal FOV includes aft limb. Can also view out of s/c orbit plane.
- Vertical resolution = 5 km

- **Mars Color Imager (MARCI)**

- Combined nadir pointed pushframe Wide Angle [WA] and Medium Angle [MA] cameras, totaling 2 kg
- WA camera: FOV = 140°, 7 spectral bands [5 visible, 2 UV]; MA camera: FOV = 6°, 10 spectral channels
- Imaging: Approach imaging, daily global Mars images with WA, monitoring of surface changes with MA during intervals with high data rates.

4.2 ORBITER MISSION OVERVIEW

4.2.1 Overall Mission Description

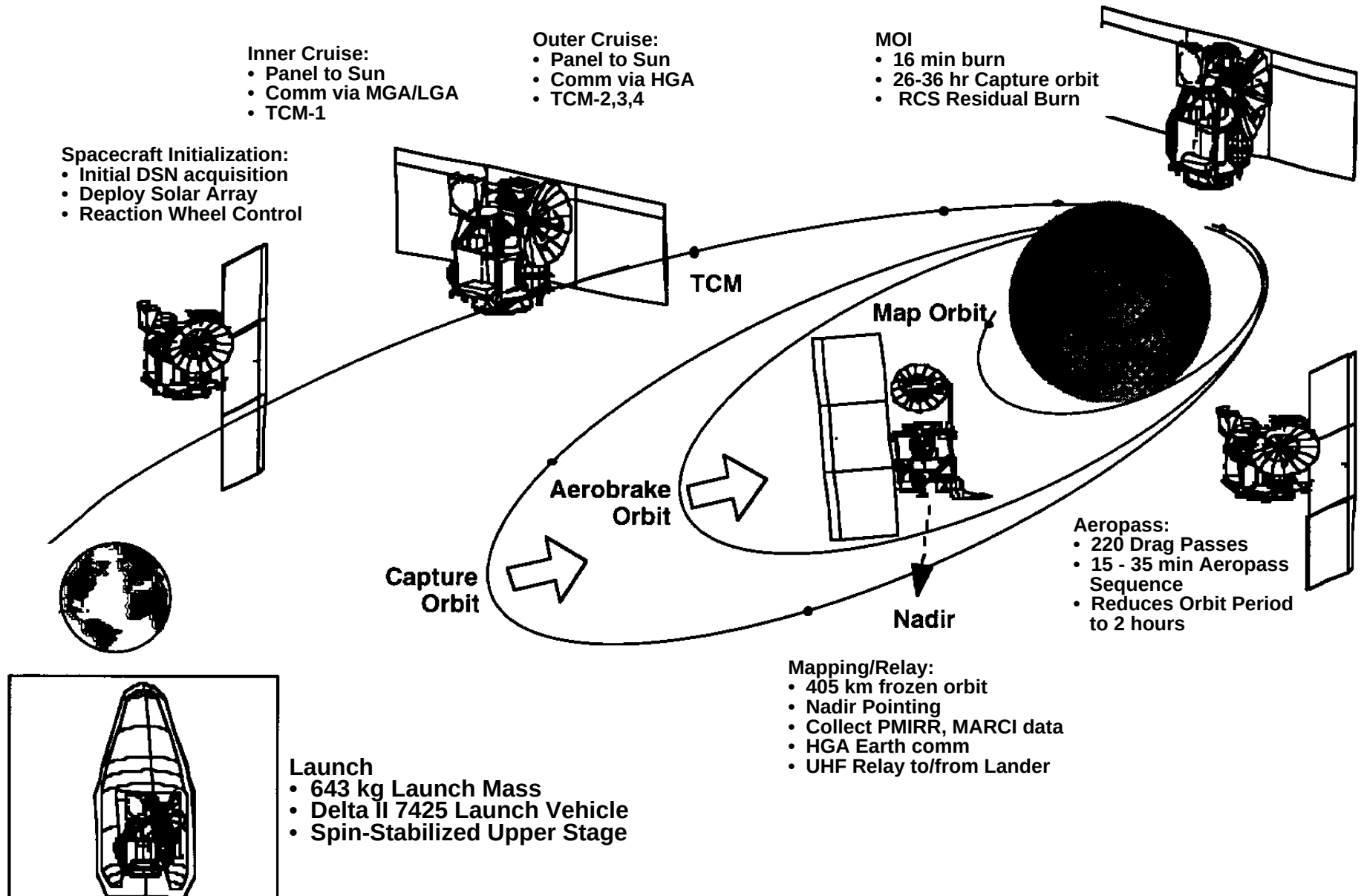
The MSP 98 Orbiter launches aboard a Delta 7425 in December 1998, and arrives at Mars in September 1999. Burnout of the 3rd stage is followed by yo-yo despin of the entire stack, followed by spacecraft separation. At this point both the spacecraft and upper stage have been injected onto a Type 2 trajectory whose aimpoint is biased away from the nominal MOI aimpoint, to assure that the upper stage has less than a $1\text{E-}4$ probability of impacting Mars, as required by Planetary Protection regulations. After separation, the solar panels are deployed and pointed to the sun, and initial acquisition achieved by the DSN. During inner cruise, the solar panel is sun pointed, and contact maintained via the Low Gain and Medium Gain Antennae. Approximately 15 days after launch, the largest Trajectory Correction Maneuver [TCM-1] is executed. This maneuver removes launch vehicle injection errors and the spacecraft's injection aimpoint bias. Provisions have been made to execute up to 3 additional small TCM's during the remainder of cruise, as needed, to shape the orbit and direct the spacecraft to the proper aimpoint for Mars Orbit Insertion. All TCM's are performed with the monoprop Hydrazine thrusters. As the heliocentric distance increases during cruise, communications moves to the High Gain Antenna.

At Mars arrival, the Orbiter biprop engine is used to propulsively insert the spacecraft into an elliptical capture orbit. The biprop engine burns for approximately 16 minutes, until all the loaded oxidizer is exhausted. The oxidizer tank is isolated via pyro firings prior to the end of the biprop burn. One minute later, an additional maneuver is executed by the Hydrazine thrusters, if needed, to reduce the orbit period further. Depending on launch date during the Primary and Secondary launch periods and propellant mass consumed during cruise, the resultant orbit period lies between approximately 26 and 36 hrs, with a nominal periapse altitude of 160 km. A maneuver to lower periapse in preparation for aerobraking occurs at the first apoapse of the final capture orbit. Over the next two months, the energy of the orbit is reduced via successive passes through the atmosphere of Mars, controlled by small Orbit Trim Maneuvers near apoapse. At aerobrake termination, two maneuvers transfer the Orbiter to its final, near-circular, frozen, near sun-synchronous mapping orbit, at a descending node of approximately 4 PM. This occurs some time prior to the MSP98 Lander arrival in December, 1999. During the Lander's surface lifetime, the Orbiter provides command and data relay support, and also engages in a limited amount of orbital science. In its mapping phase, the Orbiter performs systematic daily global sounding and imaging of the Mars atmosphere for approximately one Mars year [687 days]. The nadir-mounted science payload consists of a Pressure Modulator Infrared Radiometer (PMIRR), and the Mars Color Imager (MARCI).

Once its mapping mission is complete, the Orbiter will be available as a communication relay for future Mars landers for up to 3 additional years. Upon completion of its relay mission, the Orbiter may perform a maneuver or be placed in a low-drag attitude to satisfy Planetary Protection regulations.

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OVERALL MISSION DESCRIPTION



4.2.2 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 initial DSN acquisition to preparation for the Mars Orbit Insertion (MOI) maneuver. It includes initial checkout of the spacecraft, instrument calibrations, and trajectory correction maneuvers (TCMs).

Orbit Insertion Phase: The orbit insertion phase extends from MOI preparation through completion of MOI-2.

Aerobraking Phase: The Aerobraking phase starts at completion of MOI and extends through aerobraking termination and transfer to the map orbit.

MSP98 Lander Support Phase: The MSP98 Lander support phase starts at insertion into the mapping orbit, and continues through the end of the Lander's nominal lifetime [2/29/00]. Events during this Phase include Lander relay and commanding support, a reduced level of Orbiter science, and an interval for overlapping observations between the Lander, Orbiter, and MGS.

Mapping Phase: The Mapping Phase starts at the end of the Lander Support Phase and continues for 687 Earth days [one Martian year]. This is the primary science mission phase for the Orbiter instruments.

Relay Phase: The Relay Phase starts at termination of mapping operations, and concludes 5 Earth years after transfer to the Mapping orbit. [Total phase duration is approximately 2.9 Earth years.] This interval shall include needed relay operations from landed surface stations, and, if required, an end-of-mission maneuver and/or reconfiguration to accommodate Planetary Protection.

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MISSION PHASES

- **Launch and Boost and S/C Initialization Phases:**
 - **Launch:** Liftoff - 20 hours to liftoff.
 - **Boost and s/c Initialization:** Liftoff until initial DSN contact.
- **Cruise Phase:**
 - From initial DSN acquisition through preparation for MOI
 - Includes initial checkout of the spacecraft, TCMs and instrument calibrations
- **Orbit Insertion Phase:**
 - From MOI preparation through MOI-2
- **Aerobraking Phase:**
 - From completion of MOI through Aerobraking termination and transfer to the map orbit.
- **MSP98 Lander Support Phase:**
 - From insertion into mapping orbit through end of Lander's nominal lifetime [2/29/00]
 - Include Lander relay & commanding support, reduced level of Orbiter science
 - » Includes period of overlapping observations between Lander, Orbiter, and MGS
- **Mapping Phase:**
 - Starts at end of the Lander Support Phase and continues for 687 Earth days [one Martian year].
 - Primary science mission phase for the Orbiter instruments
- **Relay Phase:**
 - Starts at termination of mapping operations, concludes 5 Earth years after transfer to the Mapping orbit [Duration = 2.9 Earth years]
 - Support future landers
 - End of mission maneuver and/or turn to low drag attitude, if needed, for Planetary Protection

4.2.3 Orbiter Launch/Arrival Period

** This page under Change Control **

Integrated trajectories with minimum total deterministic ΔV [comprising injection, deep space deterministic maneuvers, and MOI ΔV] have been developed for launches from December 1, 1998 through January 3, 1999. These trajectories included the effects of solar radiation pressure and perturbations from other solar system bodies and were generated using the CATO [Computer Algorithm for Trajectory Optimization] program. In all cases, the minimum ΔV trajectories during this interval were of Type 2 [transfer angle at least 180°] and did not require the use of a deterministic deep space maneuver.

The results of various trade studies examining the optimal placement of the Orbiter launch period to maximize delivered dry mass, while keeping at least 9 days between the end of the Orbiter launch period and the start of the Lander launch period, led to the selection of the Orbiter launch period: December 10, 1998 - December 23, 1998.

The following figure illustrates the Orbiter interplanetary trajectory projected on the plane of the ecliptic, for the open of the Orbiter launch period. Also shown is a table indicating launch and arrival dates, flight times, launch energy [C3, the square of the hyperbolic excess velocity on the outgoing asymptote], arrival V-infinity [excess hyperbolic velocity on the Mars approach asymptote], and local mean solar time of the descending node. [This table includes the results of a detailed trajectory analysis performed for the first day in the Orbiter launch period, which incorporates the effects of the the biased TCM-1 aimpoint on arrival conditions. See Appendix A.8.] The maximum C3 of $11.19 \text{ km}^2/\text{s}^2$ occurs at the start of the launch period, and the maximum V-infinity of 3.41 km/s occurs at the close of the launch period.

Additional state information for the Orbiter Launch/ Arrival period can be found in Appendix A.1, the Orbiter Mission Database.

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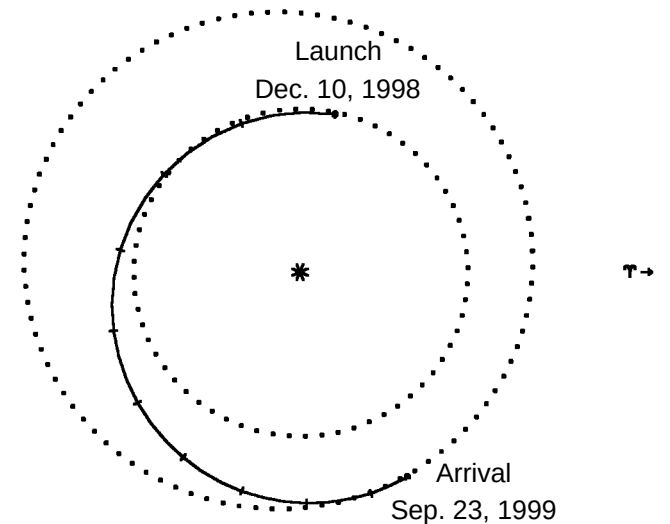
ORBITER LAUNCH/ARRIVAL PERIOD

	Day in Launch Period	Injection Date	Arrival Date	Flight Time [days]	Depart C3 [km ² /s ²]	Arrival Vinf [km/s]	Local Mean Solar Time Desc. Node
P r i m a r y	1	12/10/98	9/23/99*	286	11.189	3.344	6:15 PM
	2	12/11/98	9/25/99	288	11.101	3.341	6:08 PM
	3	12/12/98	9/25/99	288	10.941	3.343	6:07 PM
	4	12/13/98	9/26/99	287	10.781	3.345	6:06 PM
	5	12/14/98	9/27/99	287	10.636	3.348	6:05 PM
	6	12/15/98	9/27/99	287	10.508	3.352	6:04 PM
	7	12/16/98	9/28/99	287	10.393	3.356	6:03 PM
	8	12/17/98	9/29/99	285	10.287	3.365	6:05 PM
S e c o n d	9	12/18/98	9/30/99	286	10.193	3.367	6:01 PM
	10	12/19/98	10/1/99	286	10.109	3.374	5:59 PM
	11	12/20/98	10/2/99	286	10.036	3.382	5:57 PM
	12	12/21/98	10/2/99	286	9.974	3.391	5:56 PM
	13	12/22/98	10/3/99	286	9.924	3.400	5:54 PM
	14	12/23/98	10/4/99	286	9.885	3.411	5:52 PM

* Includes effects of TCM-1 aimpoint biasing

Open of Primary Launch Period

30 Day Tics on s/c Trajectory



** This page under Change Control **

4.2.4 Orbiter Launch Period Strategy

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The MSP98 Orbiter launch period is divided into an 8 day Primary launch period [12/10/98 - 12/17/98] followed by a 6 day Secondary launch period [12/18/98 - 12/23/98]. These two intervals are characterized by different mission requirements associated with the ability of the Orbiter to finish aerobraking prior to Lander arrival.

Primary Launch Period: For launch during the Primary launch period, the mission and spacecraft design shall support a 95% or greater probability that the Orbiter will complete aerobraking by the time the Lander arrives. Specifically, the Orbiter propellant load must support establishment of a capture orbit with a period low enough to allow aerobraking to circularize the orbit prior to Lander arrival. The maximum C_3 of $11.19 \text{ km}^2/\text{s}^2$ occurs on the first day of this Primary launch period, and dictates the maximum launch mass the launch vehicle can support over the launch period. The Delta II 7425 capability at this C_3 is 643 kg [total wet mass of Orbiter]. 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.

Secondary Launch Period: If launch is delayed past the end of the Primary interval, a lower probability that the Orbiter will complete aerobraking by Lander arrival is allowed. The maximum V-infinity [hyperbolic excess velocity at Mars arrival] of 3.41 km/s occurs for launch on the last day of this secondary interval. Due to the higher values of V-infinity encountered during this time, the Orbiter will be placed into capture orbits higher than those encountered during the Primary interval. If aerobraking is not expected to be completed before Lander arrival, Mars Global Surveyor or the Lander's direct to Earth [DTE] link will support Lander data relay until the MSP98 Orbiter is available. During such an interval, the DTE link would be the only command path for the Lander.

If launch is delayed beyond the end of the secondary period, launch of the Orbiter remains possible, since the C_3 continues to decrease for some interval past 12/23/98. However, because the approach velocity increases during this interval, the period of the capture orbit would also increase.

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ORBITER LAUNCH PERIOD STRATEGY

- **14 Day Launch Period: 12/10/98 - 12/23/98**
 - **Primary Launch Period: 8 days: 12/10/98 - 12/17/98**
 - During this period, assure high probability [$\geq 95\%$] that Orbiter will complete aerobraking by Lander arrival.
 - 98% Launch Probability
 - Max $C3 = 11.19 \text{ km}^2/\text{s}^2$ occurs on first day
 - **Secondary Launch Period: 6 days: 12/18/98 - 12/23/98**
 - Accept lower probability that Orbiter will complete aerobraking in time.
 - Use MGS or direct link to support lander until MSP98 Orbiter is available.
 - Max $V_\infty = 3.41 \text{ km/s}$ occurs on last day
- **Launch and Mars capture into higher orbits remain possible beyond the 14 day launch period**

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4.2.5 Summary of Mission Events and DSN Tracking Requirements

** This page under Change Control **

Shown on the following 3 pages is a summary of the timing of major mission events and associated DSN support requests. Data are provided for the open and close of the Primary Launch Period, and the end of the Secondary Launch Period.

34m Coverage: Baseline coverage is via the 34m subnet for the majority of the mission, and use of the 34m HEF antennae has been maximized during this time. TBD: 34m BWG support will be necessary for limited intervals, however, to accommodate DSN usage conflicts and maximize tracking of the Orbiter during the last 30 days of Lander approach [interval of near-simultaneous tracking]. 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 A.12.

70m Coverage: 70m coverage for MOI and conjunction is currently baselined. In addition, 70m coverage during the Lander Support Phase and the two MARCI Science Campaigns will be requested. The 70m subnet is not scheduled to have X-band uplink capability until late 2001. As a result, with the exception of the second MARCI science campaign, 34m support will be required in addition to 70m coverage, to support uplink.

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Orbiter Open Primary Launch Period

DSN REQUIREMENTS

				Start Date	Start DOM	End Date	End DOM	# Days	Hrs/ Pass	Passes/ Day	Passes/ Week	Total Hrs	Note
Phase	Sub-Phase	Event											
Launch				12/10/98	0								
Cruise		Launch to Launch + 7	Launch + 7 d	12/10/98	0	12/17/98	7	7	8	3	21	168	A
Cruise		Cruise		12/17/98	7	12/22/98	12	5	4	1	7	20	
Cruise		TCM1, entry		12/22/98	12	12/25/98	15	3	4	1	7	12	
Cruise		TCM1, maneuver	TCM1 @ Launch + 15 d	12/25/98	15	12/26/98	16	1	4	1	7	4	
Cruise		TCM1, exit		12/26/98	16	12/29/98	19	3	4	1	7	12	
Cruise		Cruise		12/29/98	19	1/21/99	42	23	4	1	7	92	
Cruise		TCM2, entry		1/21/99	42	1/24/99	45	3	4	1	7	12	
Cruise		TCM2, maneuver	TCM2 @ Launch + 45 d	1/24/99	45	1/25/99	46	1	4	1	7	4	
Cruise		TCM2, exit		1/25/99	46	1/28/99	49	3	4	1	7	12	
Cruise		Cruise		1/28/99	49	7/22/99	224	175	4	1	7	701	
Cruise		TCM3, entry		7/22/99	224	7/25/99	227	3	4	1	7	12	
Cruise		TCM3, maneuver	TCM3 @ Arrival - 60 d	7/25/99	227	7/26/99	228	1	4	1	7	4	
Cruise		TCM3, exit		7/26/99	228	7/29/99	231	3	4	1	7	12	
Cruise		Cruise to Arrival - 45 d	Ends at Arrival - 45 d	7/29/99	231	8/9/99	242	11	4	1	7	44	
Cruise	Approach	Arrival - 45d to TCM4		8/9/99	242	9/10/99	274	32	4	3	21	384	A
Cruise	Approach	TCM4, entry		9/10/99	274	9/13/99	277	3	4	3	21	36	A
Cruise	Approach	TCM4, maneuver	TCM4 @ Arrival - 10 d	9/13/99	277	9/14/99	278	1	4	3	21	12	A
Cruise	Approach	TCM4, exit		9/14/99	278	9/17/99	281	3	4	3	21	36	A
Cruise	Approach	Cruise		9/17/99	281	9/18/99	282	1	4	3	21	12	A
Cruise	Approach	Cruise [34m + 70m coverage]	Starts at MOI - 5 d	9/18/99	282	9/21/99	285	3	4	3	21	36	A,B
Cruise	Approach	Start continuous coverage [34m + 70m]	Starts at MOI - 2 d	9/21/99	285	9/23/99	287	2	8	3	21	48	A,B
Orbit Insertion	Mars Capture	MOI [34m + 70m]		9/23/99	287	9/23/99	288	1	8	3	21	12	A,B
Orbit Insertion	Aerobraking	Walk-in [34m + 70m]	Starts at MOI + 0.5 d	9/23/99	288	9/25/99	290	2	8	3	21	48	A,B
Orbit Insertion	Aerobraking	Walk-in [End 70m & cont. coverage]	MOI + 2 d	9/25/99	290	9/25/99	290	0	8	3	21	0	A,B
Orbit Insertion	Aerobraking	Walk-in		9/25/99	290	9/27/99	291	2	4	3	21	19	A
Orbit Insertion	Aerobraking	Main	Starts at MOI + 4.1 d	9/27/99	291	11/3/99	328	37	4	3	21	439	A
Orbit Insertion	Aerobraking	Main, start near-simul tracking		11/3/99	328	11/22/99	347	19	4	3	21	233	A,D
Orbit Insertion	Aerobraking	Walk-out	Starts at MOI + 60 d	11/22/99	347	12/1/99	356	9	4	3	21	103	A,D
Orbit Insertion	TMO	Transfer to Map Orbit	Duration = 1 d	12/1/99	356	12/2/99	357	1	4	3	21	12	A,D
Orbit Insertion	Transition	Support of Approaching Lander		12/2/99	357	12/3/99	359	2	4	3	21	22	A,D
Lander Support	Lander Support	Lander Support Phase [34m + 70m]		12/3/99	359	3/1/00	447	88	10	1	7	881	B,C
Mapping	Mapping	Mapping ops	Total Duration = 687 d	3/1/00	447	3/26/00	472	25	10	1	7	250	
Mapping	MARCI SC #1	MARCI Sci. Campaign #1 [34m + 70m]	10 d	3/26/00	472	4/4/00	482	10	10	1	7	100	B
Mapping	Mapping	Mapping ops		4/4/00	482	6/21/00	559	77	10	1	7	770	
Mapping	Mapping	Conjunction support [34m + 70m]	20 d	6/21/00	559	7/11/00	579	20	10	1	7	200	B
Mapping	Mapping	Mapping ops		7/11/00	579	12/18/01	1104	525	10	1	7	5250	
Mapping	MARCI SC #2	MARCI Sci. Campaign #2 [70m only]	30 d	12/18/01	1104	1/16/02	1134	30	10	1	7	300	E
Relay	Relay	Relay only	ends 5 Earth yrs > TMO	1/16/02	1134	12/1/04	2183	1049	10	1	7	10493	
EOM				12/1/04				2183	Grand Total 20806				

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 Lander daily contacts TBD. [See Lander req.]

D: Near-simultaneous tracking. Orbiter tracked on each rev: HEF tracks coordinated w/ Lander, remaining tracks on BWG

E: 70m U/L and D/L support. No 34m support required.

** This page under Change Control **

Orbiter End Primary Launch Period

DSN REQUIREMENTS

				Start Date	Start DOM	End Date	End DOM	# Days	Hrs/ Pass	Passes/ Day	Passes/ Week	Total Hrs	Note
Phase	Sub-Phase	Event											
Launch				12/17/98	0								
Cruise		Launch to Launch + 7	Launch + 7 d	12/17/98	7	12/24/98	14	7	8	3	21	168	A
Cruise		Cruise		12/24/98	14	12/29/98	19	5	4	1	7	20	
Cruise		TCM1, entry		12/29/98	19	1/1/99	22	3	4	1	7	12	
Cruise		TCM1, maneuver	TCM1 @ Launch + 15 d	1/1/99	22	1/2/99	23	1	4	1	7	4	
Cruise		TCM1, exit		1/2/99	23	1/5/99	26	3	4	1	7	12	
Cruise		Cruise		1/5/99	26	1/28/99	49	23	4	1	7	92	
Cruise		TCM2, entry		1/28/99	49	1/31/99	52	3	4	1	7	12	
Cruise		TCM2, maneuver	TCM2 @ Launch + 45 d	1/31/99	52	2/1/99	53	1	4	1	7	4	
Cruise		TCM2, exit		2/1/99	53	2/4/99	56	3	4	1	7	12	
Cruise		Cruise		2/4/99	56	7/28/99	230	174	4	1	7	696	
Cruise		TCM3, entry		7/28/99	230	7/31/99	233	3	4	1	7	12	
Cruise		TCM3, maneuver	TCM3 @ Arrival - 60 d	7/31/99	233	8/1/99	234	1	4	1	7	4	
Cruise		TCM3, exit		8/1/99	234	8/4/99	237	3	4	1	7	12	
Cruise		Cruise to Arrival - 45 d	Ends at Arrival - 45 d	8/4/99	237	8/15/99	248	11	4	1	7	44	
Cruise	Approach	Arrival - 45d to TCM4		8/15/99	248	9/16/99	280	32	4	3	21	384	A
Cruise	Approach	TCM4, entry		9/16/99	280	9/19/99	283	3	4	3	21	36	A
Cruise	Approach	TCM4, maneuver	TCM4 @ Arrival - 10 d	9/19/99	283	9/20/99	284	1	4	3	21	12	A
Cruise	Approach	TCM4, exit		9/20/99	284	9/23/99	287	3	4	3	21	36	A
Cruise	Approach	Cruise		9/23/99	287	9/24/99	288	1	4	3	21	12	A
Cruise	Approach	Cruise [34m + 70m coverage]	Starts at MOI - 5 d	9/24/99	288	9/27/99	291	3	4	3	21	36	A,B
Cruise	Approach	Start continuous coverage [34m + 70m]	Starts at MOI - 2 d	9/27/99	291	9/29/99	293	2	8	3	21	48	A,B,E
Orbit Insertion	Mars Capture	MOI [34m + 70m]		9/29/99	293	9/29/99	294	1	8	3	21	12	A,B,E
Orbit Insertion	Aerobraking	Walk-in [34m + 70m]	Starts at MOI + 0.5 d	9/29/99	294	10/1/99	296	2	8	3	21	48	A,B,E
Orbit Insertion	Aerobraking	Walk-in [End 70m & cont. coverage]	MOI + 2 d	10/1/99	296	10/1/99	296	0	8	3	21	0	A,B,E
Orbit Insertion	Aerobraking	Walk-in		10/1/99	296	10/3/99	297	2	4	3	21	19	A
Orbit Insertion	Aerobraking	Main	Starts at MOI + 4.1 d	10/3/99	297	11/3/99	328	31	4	3	21	370	A
Orbit Insertion	Aerobraking	Main, start near-simul tracking		11/3/99	328	11/28/99	353	25	4	3	21	302	A,D
Orbit Insertion	Aerobraking	Walk-out	Starts at MOI + 60 d	11/28/99	353	12/3/99	359	6	4	3	21	68	A,D
Orbit Insertion	TMO	Transfer to Map Orbit	Duration = 1 d	12/3/99	359	12/4/99	360	1	4	3	21	12	A,D
Lander Support	Lander Support	Lander Support Phase [34m + 70m]		12/4/99	360	3/1/00	447	87	10	1	7	872	B,C
Mapping	Mapping	Mapping ops	Total Duration = 687 d	3/1/00	447	3/26/00	472	25	10	1	7	250	
Mapping	MARCI SC #1	MARCI Sci. Campaign #1 [34m + 70m]	10 d	3/26/00	472	4/4/00	482	10	10	1	7	100	B
Mapping	Mapping	Mapping ops		4/4/00	482	6/21/00	559	77	10	1	7	770	
Mapping	Mapping	Conjunction support [34m + 70m]	20 d	6/21/00	559	7/11/00	579	20	10	1	7	200	B
Mapping	Mapping	Mapping ops		7/11/00	579	12/18/01	1104	525	10	1	7	5250	
Mapping	MARCI SC #2	MARCI Sci. Campaign #2 [70m only]	30 d	12/18/01	1104	1/16/02	1134	30	10	1	7	300	E
Relay	Relay	Relay only	ends 5 Earth yrs > TMO	1/16/02	1134	12/4/04	2186	1052	10	1	7	10521	
EOM				12/4/04				2186	Grand Total 20762				

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 Lander daily contacts TBD. [See Lander req.]

D: Near-simultaneous tracking. Orbiter tracked on each rev: HEF tracks coordinated w/ Lander, remaining tracks on BWG

E: 70m U/L and D/L support. No 34m support required.

** This page under Change Control **

Orbiter End Secondary Launch Period

				DSN REQUIREMENTS									
Phase	Sub-Phase	Event		Start Date	Start DOM	End Date	End DOM	# Days	Hrs/Pass	Passes/Day	Passes/Week	Total Hrs	Notes
Launch				12/23/98	0								
Cruise		Launch to Launch + 7	Launch + 7 d	12/23/98	13	12/30/98	20	7	8	3	21	168	A
Cruise		Cruise		12/30/98	20	1/4/99	25	5	4	1	7	20	
Cruise		TCM1, entry		1/4/99	25	1/7/99	28	3	4	1	7	12	
Cruise		TCM1, maneuver	TCM1 @ Launch + 15 d	1/7/99	28	1/8/99	29	1	4	1	7	4	
Cruise		TCM1, exit		1/8/99	29	1/11/99	32	3	4	1	7	12	
Cruise		Cruise		1/11/99	32	2/3/99	55	23	4	1	3	92	
Cruise		TCM2, entry		2/3/99	55	2/6/99	58	3	4	1	7	12	
Cruise		TCM2, maneuver	TCM2 @ Launch + 45 d	2/6/99	58	2/7/99	59	1	4	1	7	4	
Cruise		TCM2, exit		2/7/99	59	2/10/99	62	3	4	1	7	12	
Cruise		Cruise		2/10/99	62	8/2/99	235	173	4	1	3	692	
Cruise		TCM3, entry		8/2/99	235	8/5/99	238	3	4	1	7	12	
Cruise		TCM3, maneuver	TCM3 @ Arrival - 60 d	8/5/99	238	8/6/99	239	1	4	1	7	4	
Cruise		TCM3, exit		8/6/99	239	8/9/99	242	3	4	1	7	12	
Cruise		Cruise to Arrival - 45 d	Ends at Arrival - 45 d	8/9/99	242	8/20/99	253	11	4	1	3	44	
Cruise	Approach	Arrival - 45d to TCM4		8/20/99	253	9/21/99	285	32	4	3	21	384	A
Cruise	Approach	TCM4, entry		9/21/99	285	9/24/99	288	3	4	3	21	36	A
Cruise	Approach	TCM4, maneuver	TCM4 @ Arrival - 10 d	9/24/99	288	9/25/99	289	1	4	3	21	12	A
Cruise	Approach	TCM4, exit		9/25/99	289	9/28/99	292	3	4	3	21	36	A
Cruise	Approach	Cruise		9/28/99	292	9/29/99	293	1	4	3	21	12	A
Cruise	Approach	Cruise [34m + 70m coverage]	Starts at MOI - 5 d	9/29/99	293	10/2/99	296	3	4	3	21	36	A,B
Cruise	Approach	Start continuous coverage [34m + 70m]	Starts at MOI - 2 d	10/2/99	296	10/4/99	298	2	8	3	21	48	B,E
Orbit Insertion	Mars Capture	MOI [34m + 70m]		10/4/99	298	10/4/99	299	1	8	3	21	12	B,E
Orbit Insertion	Aerobraking	Walk-in [34m + 70m]	Starts at MOI + 0.5 d	10/4/99	299	10/6/99	301	2	8	3	21	48	B,E
Orbit Insertion	Aerobraking	Walk-in [End 70m & cont. coverage]	MOI + 2 d	10/6/99	301	10/6/99	301	0	8	3	21	0	B,E
Orbit Insertion	Aerobraking	Walk-in		10/6/99	301	10/8/99	302	2	4	3	21	19	A
Orbit Insertion	Aerobraking	Main	Starts at MOI + 4.1 d	10/8/99	302	11/3/99	328	26	4	3	21	311	A
Orbit Insertion	Aerobraking	Main, start near-simul tracking	Ends at Landing	11/3/99	328	12/3/99	358	30	4	3	21	360	A,D
Orbit Insertion	Aerobraking	Main		12/3/99	358	12/17/99	372	14	4	3	21	169	A
Orbit Insertion	Aerobraking	Walk-out	Starts at MOI + 74 d	12/17/99	372	12/23/99	378	6	4	3	21	72	A
Orbit Insertion	TMO	Transfer to Map Orbit	Duration = 1 d	12/23/99	378	12/24/99	379	1	4	3	21	12	A,D
Lander Support	Lander Support	Lander Support Phase [34m + 70m]		12/24/99	379	3/1/00	447	68	10	1	7	679	B,C
Mapping	Mapping	Mapping ops	Total Duration = 687 d	3/1/00	447	3/26/00	472	25	10	1	7	250	
Mapping	MARCI SC #1	MARCI Sci. Campaign #1 [34m + 70m]	10 d	3/26/00	472	4/4/00	482	10	10	1	7	100	B
Mapping	Mapping	Mapping ops		4/4/00	482	6/21/00	559	77	10	1	7	770	
Mapping	Mapping	Conjunction support [34m + 70m]	20 d	6/21/00	559	7/11/00	579	20	10	1	7	200	B
Mapping	Mapping	Mapping ops		7/11/00	579	12/18/01	1104	525	10	1	7	5250	
Mapping	MARCI SC #2	MARCI Sci. Campaign #2 [70m only]	30 d	12/18/01	1104	1/16/02	1134	30	10	1	7	300	E
Relay	Relay	Relay only	ends 5 Earth yrs > TMO	1/16/02	1134	12/23/04	2205	1071	10	1	7	10714	
EOM				12/23/04	2205								
										Grand Total		20930	

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 Lander daily contacts TBD. [See Lander req.]
 D: Near-simultaneous tracking. Orbiter tracked on each rev: HEF tracks coordinated w/ Lander, remaining tracks on BWG
 E: 70m U/L and D/L support. No 34m support required.

** This page under Change Control **

4.2.6 Orbiter ΔV and Propellant Mass Summary

** This page under Change Control **

Propellant required by the Orbiter during its mission life has been calculated using an end-to-end Monte Carlo simulation. The assumptions and approach used in this analysis are summarized in Appendix A.9. The driving requirement is that the Orbiter, if launched within its primary launch period, achieve a minimum 95% probability of completing aerobraking by Lander arrival. Assuming Orbiter launch at the end of its primary period [launch 12/17/98, arrival 9/29/99] and arrival of the Lander during its primary period [arrival 12/3/99], the maximum allowable capture orbit period is approximately 29 hrs. For the Primary launch period, this yields a 99% probability of completing aerobraking by Lander arrival. This is the most stressful case within the Orbiter's primary launch period because it allows the least time for aerobraking, and also has the highest arrival V-infinity value. For this analysis, a maximum wet mass capability of 643 kg was assumed, consistent with the performance of the Delta II 7425 launched at the start of the Orbiter's primary period, where the required launch energy is highest.

The following table summarizes the ΔV or ACS mass drops expected for each mission event. These events include all 4 interplanetary TCM's, attitude control during cruise, MOI [rotational and translational], aerobraking [including walk-in, rotational and translational corridor control, an emergency exit/re-entry maneuver, and end game], inclination trims during aerobraking [TBD] to correct for MOI and aerobraking dispersions, transfer to the mapping orbit, ACS usage during mapping, and ACS contingency. It does not currently include an allocation for inclination trims which may be required during or after aerobraking termination or during the transfer to map orbit [TBD]. Ranges are shown in those cases where statistical models of the events [e.g. TCM's] were included as part of the Monte Carlo simulation. Fixed parameter values are reported in the "mean" column only. The succeeding table summarizes propellant load required to accommodate 95% of the simulated cases.

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ORBITER ΔV AND PROPELLANT MASS SUMMARY

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- **REQUIREMENT:** $\geq 95\%$ probability of Orbiter completing aerobraking by Lander arrival
 - Loading based on Orbiter launch at end of its primary and Lander arrival during its primary launch period
 - » 29 hr initial capture orbit [yields 99% probability of aerobraking completion by Lander arrival, for Primary]
 - **643 kg** wet mass capability

ORBITER ΔV AND MASS DROPS

Event	Type	95% Low	Mean	95% High
TCM-1	Translational ΔV	12.4	34.0	68.1
TCM-2	Translational ΔV	0.07	0.29	0.69
TCM-3	Translational ΔV	0.03	0.19	0.51
TCM 4	Translational ΔV	0.01	0.04	0.08
Cruise RCS	Mass Drop [kg]	-	2.0	-
MOI - biprop	Translational ΔV	1221.1	1248.2	1279.8
MOI - hydrazine	Translational ΔV	0.0	25.8	53.1
MOI - ACS	Mass Drop [kg]	-	0.9	-
Walk-in	Translational ΔV	2.5	3.5	4.5
Corridor Control - Trans	Translational ΔV	-	12.0	-
Corridor Control - ACS	Rotational ΔV	-	15.2	-
Inclination Trim #1	Translational ΔV	0.0	0.4	1.0
Inclination Trim #2	Translational ΔV	0.1	1.6	3.1
Aerobraking exit/re-entry	Translational ΔV	-	17.0	-
Aerobraking End Game	Translational ΔV	-	1.5	-
Transfer to map	Translational ΔV	84.3	87.2	90.1
Map/Relay ACS	Rotational ΔV	-	22.6	-
ACS Contingency*	Rotational ΔV	-	16.0	-

* includes RCS uncertainty, failed reaction wheel, other contingency, project mgr reserve

DRY MASS CAPABILITY AND REQUIRED PROPELLANT

Maximum Dry Mass	359.0 kg
Oxidizer Load	95.0 kg
Hydrazine Load	188.1 kg
Pressurant	0.9 kg
Total Wet Mass	643.0 kg

4.3 ORBITER LAUNCH AND BOOST & S/C INITIALIZATION PHASES

4.3.1 Orbiter Pre-launch Countdown

The following timeline shows the Orbiter Pre-launch Countdown.

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ORBITER PRE-LAUNCH COUNTDOWN

Time	Operation
Launch - 8 days	• Final Orbiter Functional Test
Launch - 6 days	• F-6 Launch Vehicle Test Ascent Sequence
Launch - 20:00:00	• Orbiter Power up • Orbiter Closeout • Install Battery Enable Plug
Launch - 12:00:00	• Start MST Rollback for Launch
Launch - 06:00:00	• MST Rollback Complete
Launch - 03:00:00 (T - 150 min)	• Terminal Count Initiation and Briefing
Launch - 02:40:00 (T - 130)	• Orbiter Go for LV LOX Fueling
Launch - 00:20:00 (T - 4)	• Provide MSP Go for Launch
Launch - 00:04:00 (T - 4)	• Transfer to Battery Power
LAUNCH	Primary Window: 12/10 - 12/17, 1998 Secondary Window: 12/18 - 12/23, 1998



4.3.2 Launch Events Summary

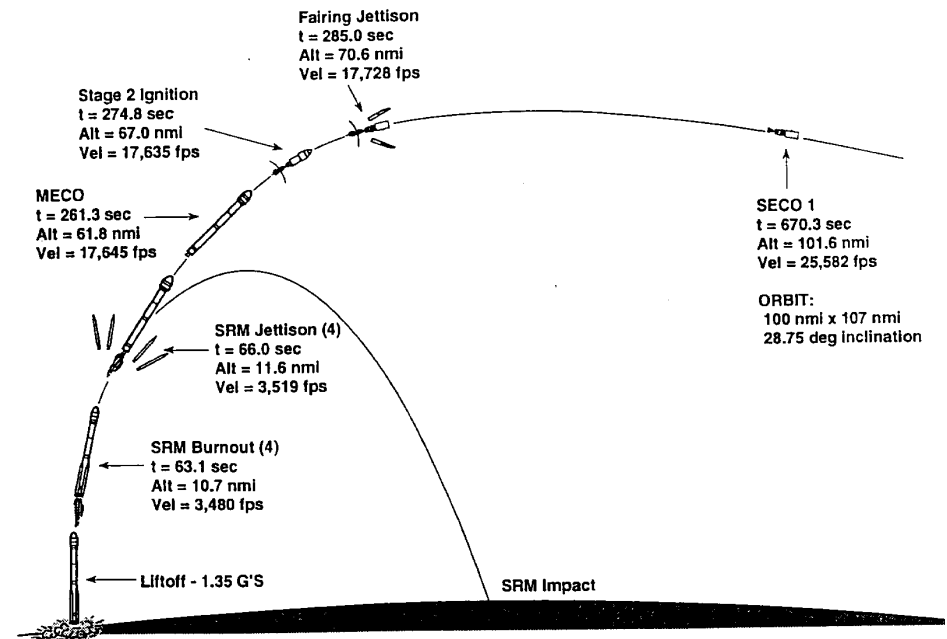
Shown below is a representative launch events timeline for the Launch Vehicle.

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LAUNCH EVENTS SUMMARY

Launch 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)	670.3
Restart Stage II	2219.7
Second Cutoff-Stage II (SECO 2)	2245
Start Stage III Ignition Time Delay Relay	2295
Fire Spin Rockets	2295
Jettison Stage II	2298
Stage III Ignition	2335
Stage III NCS Enable	2335
Stage III Burnout (TECO)	2422.1
NCS Disable/Yo-Yo Despin Initiation	2705
Spacecraft Separation	2710

Note: Assumes a "short-coast" trajectory for launch on 10 December 1998.



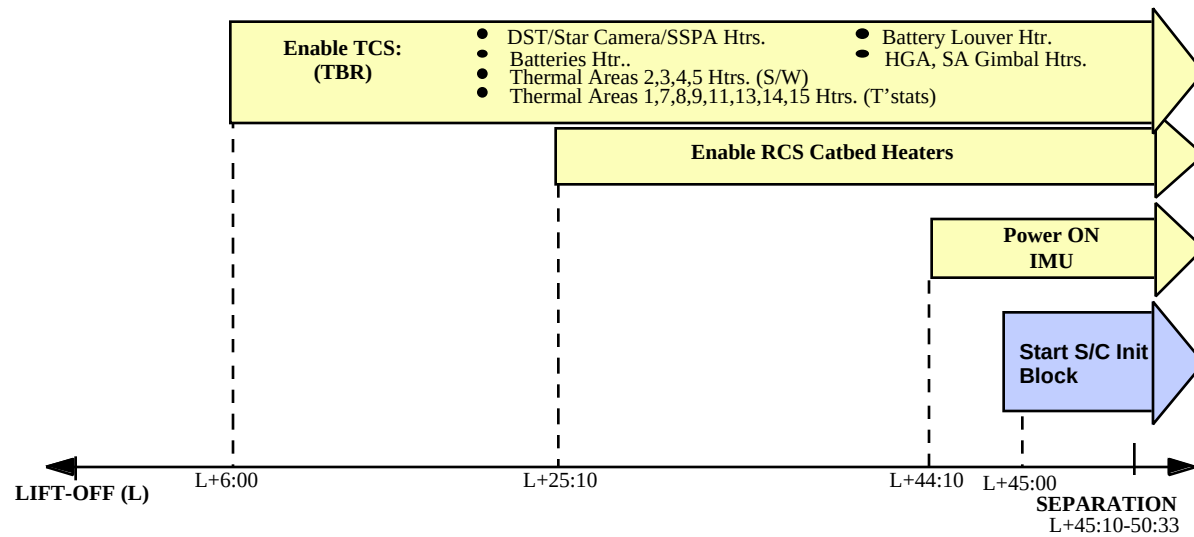
4.3.3 Orbiter Ascent and Spacecraft Initialization Timelines

The following timelines illustrate events during boost and spacecraft initialization after separation [CDR 1/22/97]. Following separation, the primary objective is to acquire the Sun. See Appendix A.2 for initial DSN and Air Force Tracking Station acquisition geometry data.

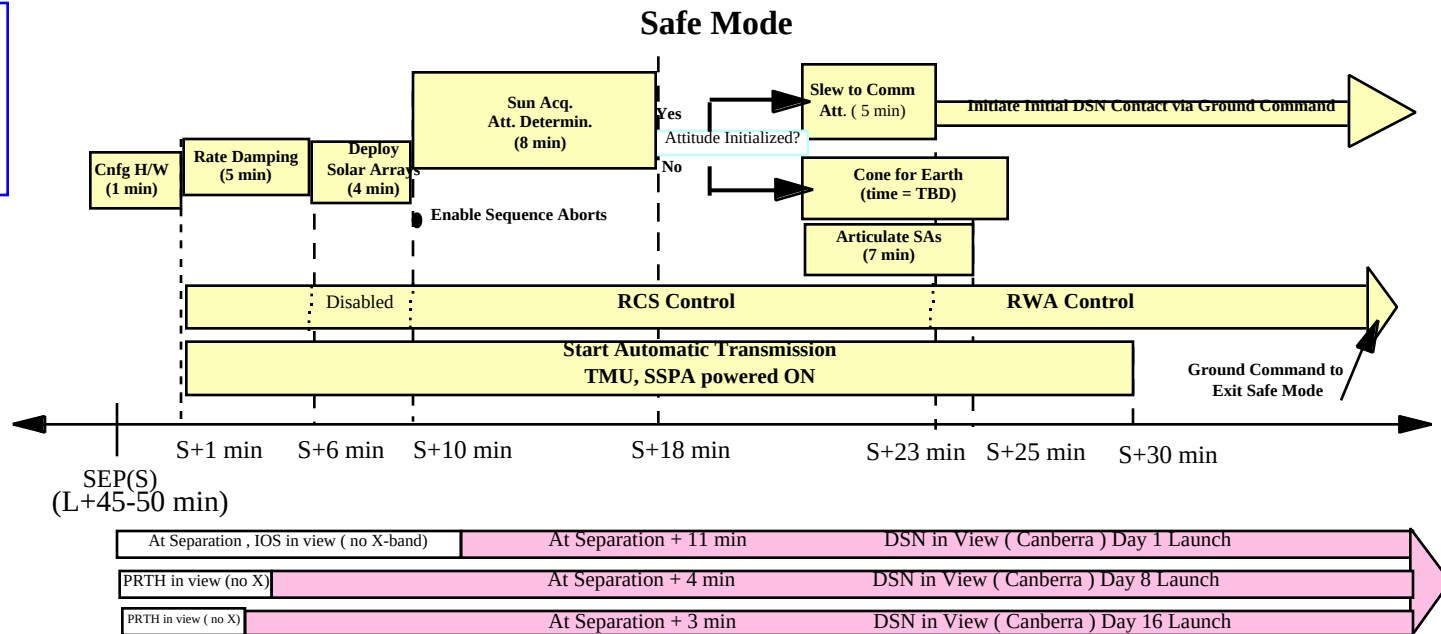
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ORBITER ASCENT AND SPACECRAFT INITIALIZATION TIMELINES

ASCENT TIMELINE



S/C INITIALIZATION TIMELINE



4.4 ORBITER CRUISE PHASE

4.4.1 Orbiter 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 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 occurring 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 A.8 assumed 3 4-hr passes per day during the 24 hours centered on each TCM. Analyses performed for the Lander indicate that a single 4-hr pass is sufficient.] Additional tracking is required for the 45 days prior to MOI; during this time, three 4 hour passes per day are required for the higher precision navigation needed prior to MOI. These numbers reflect minimum navigation requirements. Additional tracking is being requested for the purpose of daily s/c monitoring.

4.4.2 TCM's

** This page under Change Control **

Although the Orbiter trajectory does not require any deterministic deep space maneuvers to reach Mars, Trajectory Correction Maneuvers [TCM's] are required to shape the cruise trajectory. Four TCM's are planned to occur at Launch + 15 days, Launch + 45 days, MOI - 60 days, and MOI - 10 days. Provision has also been made for executing a contingency maneuver as late as MOI - 2 days, if needed. At injection, the trajectory is aimed at a point in the arrival B Plane such that the probability of impact of the upper stage is less than $1E-4^*$, as required by Planetary Protection regulations. The primary purpose for TCM-1 is to correct injection errors and remove the Planetary Protection injection aimpoint bias. TCM-1 constitutes more than 97% of the total TCM ΔV required during a mission.

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. [Note: these values are higher than those listed in Appendix A.8, due to analysis of PCS effects subsequent to the issuing of that memo.] Propellant loading is based on an end-to-end Monte Carlo analysis of Orbiter propellant usage, including the effects of maneuver execution errors and orbit determination errors.

* MGS Planetary Protection Plan

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ORBITER CRUISE NAVIGATION

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- Navigation Cruise Tracking Requirements:**

Mission Event	Estimated Nav Tracking 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
TCM (1,2,3) entry [TCM-3.5 days to TCM]	1 4-hr pass/day	<- Must be visible from single DSN station
TCM (1,2,3) [24 hrs centered on TCM]	1 4-hr pass/day	
TCM (1,2,3) exit [TCM to TCM + 3.5 days]	1 4-hr pass/day	
Approach [MOI-45 days to MOI]	3 4-hr passes/day	

- Navigation Data Types:** Two-way Coherent Doppler and Ranging
- Trajectory Correction Maneuvers:**
 - Nominally 4 maneuvers, with 5th contingency maneuver [if needed] not later than MOI - 2 days
 - Probability(Mars impact) of upper stage < 1E-4 [Planetary Protection] used to bias injection aimpoint
 - TCM placement and magnitudes for Open of Primary Launch Period:

TCM #	Placement	95% Low ΔV	Mean ΔV	95% High ΔV	Modeling includes maneuver execution and OD errors MACDAC Injection covariance dated 9/5/96, including effects of 95% PCS.
1	Launch + 15 days	12.36	33.98	68.11	
2	Launch + 45 days	0.07	0.29	0.69	
3	MOI - 60 days	0.03	0.19	0.51	
4	MOI - 10 days	0.01	0.04	0.08	
Totals		12.66	34.51	68.81	

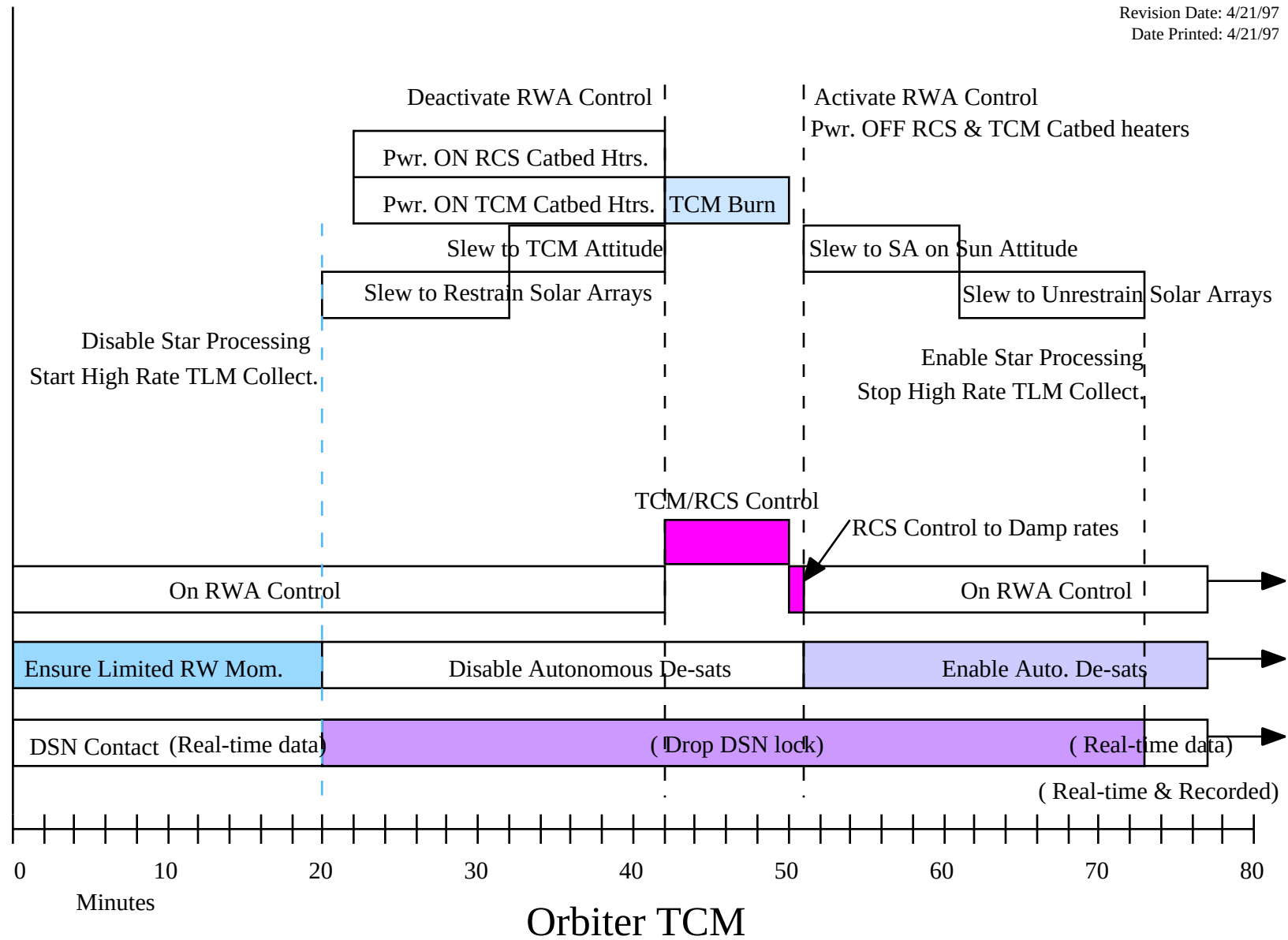
4.4.3 TCM Sequence of Events

The following timeline illustrates the TCM maneuver implementation. In general, DSN lock will be lost upon slewing to the TCM burn attitude.

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TCM SEQUENCE OF EVENTS

Revision Date: 4/21/97
Date Printed: 4/21/97



4.4.5 Orbiter Science Payload Cruise Checkout, Characterization and Calibration

4.4.5.1 Overview

CPU speed: during cruise, in the all-stellar mode, the CPU speed is 10 Mhz.

CONSTRAINTS: Cruise calibrations of PMIRR and MARCI must be de-conflicted with Orbiter and Lander mission-critical events. No science checkouts, calibrations, or playback of data will be performed within 3 days of an Orbiter TCM, 15 days of MOI or 15 days of Orbiter launch. [The exception is the MARCI Earth-Moon calibration, described below.] PMIRR and MARCI operation during periods of HGA transmissions is TBD during cruise, due to potential EM interference from the undeployed HGA. PMIRR cruise calibrations should not occur when the PMIRR X-Z plane is within 5° of the sun.

MARCI EARTH-MOON CALIBRATION [Launch + 4 days]: This consists of a slew to a certain point, a scan across Earth-Moon system with a single slew, and a slew back to cruise attitude. During the scanning slew, MARCI takes TBD pictures with the Medium Angle Camera and TBD pictures with the Wide Angle Camera. Data volumes are: 1 Megabyte=8 Mbits (uncompressed) per MAC picture, 0.1 Megabyte=0.8 Mbits (uncompressed) per WAC picture. This activity requires an interruption to normal cruise operations.

If the post-launch s/c condition is nominal, this activity is performed at Launch + 4 days, with complete playback of data by Launch + 7 days, to avoid interference with TCM-1 at Launch + 15 days. Thus, the data volume must be sized to be returned in 3 days of D/L at 2100 bps [see section 4.4.5.2 for data volume estimates]. Data taken in excess of this allocation would be returned after TCM-1 on a best-efforts basis. One issue to be resolved is the impact on required ΔV of a 2 week - 30 day delay in TCM-1, should the s/c go into safe mode as a result of the slew.

PMIRR [Launch + 7 days]: The nominal plan is to move the PMIRR radiator door to the vent position at Launch + 7 days. [It is desired that this occur no later than Launch + 2 weeks.]

ORBITER PAYLOAD CRUISE CHECKOUT, CHARACTERIZATION AND CALIBRATION CAMPAIGN [Launch + 80 days]: This week-long activity consists of PMIRR checkout and the MARCI star calibration. The duration of the PMIRR checkout is 4 hours, starting one hour before a DSN contact. The purpose of this sequence is to perform internal checkouts of PMIRR and exercise the PMU's [Pressure Modulator Units]. Backup commands for shutting off the PMC's will be available to be uplinked during the DSN contact. The Sun should be kept off the scan mirror during this activity [TBD]. The MARCI star calibration occurs after the PMIRR checkout [contingency is to perform it later], and consists of a slew to a certain point, a scan across a specific star cluster [e.g. Pleiades] with a single slew, and a slew back to cruise attitude. MARCI star calibration data volume will be sized to be returned in 3 days of D/L at 2100 bps [see section 4.4.5.2 for data volume estimates].

MARCI MARS IMAGES [MOI - 18 days]: This sequence is nominally performed at MOI - 18 days, with complete playback of data by MOI - 15 days. The data volume is therefore sized to be returned in 3 days of D/L at 2100 bps [see section 4.4.5.2 for data volume estimates].

IMPLEMENTATION: Under nominal conditions, the baseline is a single attempt for each activity. Retries on a best-efforts basis are at the discretion of the MSOP Flight Operations Manager. These sequences are initiated by ground command. Selected portions of these sequences [blocks] can be re-run via ground command as well.

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ORBITER PAYLOAD CRUISE CHECKOUT, CHARACTERIZATION AND CALIBRATION - Overview

- **CPU speed** = 10 Mhz during cruise [all-stellar mode]
- **Constraints:**
 - Checkouts, Calibrations of PMIRR and MARCI must be de-conflicted with Orbiter & Lander mission-critical events.
 - No calibrations, checkouts or playback of data within 3 days of an Orbiter TCM, 15 days of MOI, or 15 days of Orbiter Launch.
 - Exception is MARCI Earth-Moon Calibrations
 - PMIRR and MARCI operation during HGA transmissions is TBD during cruise [undeployed HGA]
 - PMIRR calibrations should not occur when the PMIRR X-Z plane is within 5° of the sun.
- **MARCI EARTH-MOON CALIBRATION [Launch + 4 days]**
 - Slew to a certain point, scan across Earth-Moon system with a single slew, slew back to cruise attitude.
 - » During the scanning slew, MARCI takes TBD pictures with the Medium Angle Camera and TBD pictures with the Wide Angle Camera. 1 Megabyte=8 Mbits (uncompressed) per MAC picture, 0.1 Megabyte=0.8 Mbits (uncompressed) per WAC picture.
 - » Requires an interruption to normal cruise operations.
 - If s/c condition is nominal, perform at Launch + 4 days. Complete playback of data by Launch + 7 days
 - » Data volume sized to be returned in 3 days of D/L at 2100 bps [see section 4.4.5.2 for data volumes]
 - » Data beyond this allocation would be returned after TCM-1 on best efforts basis
 - Issue: ΔV impact of a 2 week - 30 day delay in TCM-1, should the s/c go into safe mode as a result of the slew.
- **PMIRR RADIATOR DOOR moved to the vent position [Launch + 7 days]**
- **ORBITER PAYLOAD CRUISE CHECKOUT, CHARACTERIZATION AND CALIBRATION CAMPAIGN [Launch + 80 days]:**
 - Total duration = 7 days
 - **PMIRR Checkout:**
 - » Duration=4 hrs, starting 1 hour before a DSN contact
 - » Purpose: perform internal checkouts and exercise the PMU's [Pressure Modulator Units].
 - » Backup commands for shutting off the PMU's will be available to be uplinked during the DSN contact.
 - » Sun should be kept off the scan mirror during the checkout [TBD]
 - **MARCI Star Calibration:**
 - » Done once, after PMIRR checkout. [Contingency: perform later in cruise].
 - » Slew to a certain point, scan across a specific star cluster [e.g. Pleiades] with a single slew, slew back to cruise attitude.
 - » Data volume sized to be returned in 3 days of D/L at 2100 bps [see section 4.4.5.2 for data volumes]
- **MARCI MARS IMAGES [MOI - 18 days]:**
 - Perform at MOI - 18 days. Complete playback of data by MOI - 15 day
 - » Data volume scoped to be returned in 3 days of D/L at 2100 bps [see section 4.4.5.2 for data volumes]
- **Implementation:** Under nominal conditions, baseline is a single attempt for each activity. Retries on a best-efforts basis are at the discretion of the MSOP Flight Operations Manager. These sequences are initiated by ground command. Selected portions of these sequences [blocks] can be re-run via ground command as well.

4.4.5.2 Orbiter Cruise Data Playback Strategy:

Downlink Priority and 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 Intervals, Science receives 50% of the available downlink.

Cruise Phase Science Data Volume: Science data volume returned during the cruise phase, after Launch + 7 days and prior to Approach, is calculated assuming one 4 hour DSN contact per day, a data rate of 2100 bps, 50% usage percentage, and 15% overhead. Thus, daily data volume = $2100 \text{ bits/sec} * 3.92 \text{ hours / day (interleaved portion of one DSN pass, assuming 5 minutes telemetry lockup time)} * 3600 \text{ sec/hr} * 0.5 * [1-0.15] = 12.58 \text{ Mbits per day}$.

Post-launch and Approach Science Data Volume: During post-launch tracking [Launch to Launch+ 7 days] and Approach [MOI - 45 days to MOI] tracking levels are at 4 hours on/5 hours off. Thus, during these intervals, the daily data volume = $2100 \text{ bits/sec} * 3600 \text{ sec/hr} * 10.4 \text{ hours/day} * 0.5 * [1-0.15] = 33.56 \text{ Mbits/day}$.

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ORBITER CRUISE DATA PLAYBACK STRATEGY

- APID tables control the priority of data return.
- **Downlink Allocations:**
 - **Nominal cruise: Engineering receives 100% of available downlink**
 - **Checkout/Calibration Intervals: Science receives 50% of available downlink**
 - » **Cruise Phase Science Data Volume:**
 - One 4 hour DSN contact per day
 - Data rate of 2100 bps, 50% usage percentage, and 15% overhead.
 - Daily data volume = $2100 \text{ bits/sec} * 3.92 \text{ hours /day (interleaved portion of one DSN pass, assuming 5 minutes for telemetry lockup)} * 3600 \text{ sec/hr} * 0.5 * [1-0.15] = \mathbf{12.58 \text{ Mbits per day.}}$
 - » **Post-launch [L to L+7 days] and Approach [MOI-45 days to MOI] Science Data Volume:**
 - Tracking at 4 hrs on / 5 hrs off
 - Daily data volume = $2100 \text{ bits/sec.} * 3600 \text{ sec/hr} * 10.44 \text{ hours/day} * 0.5 * [1-0.15] = \mathbf{33.56 \text{ Mbits/day.}}$

4.5 ORBIT INSERTION PHASE

4.5.1 Mars Orbit Insertion

4.5.1.1 MOI Strategy

Approach: Approximately 9.4 months after launch, the Orbiter arrives in the vicinity of Mars. The Orbiter is targeted for closest approach over the Northern hemisphere, with an initial inclination biased approximately 0.1° higher than the mapping orbit inclination, to account for the expected mean variation in this parameter during aerobraking. Also, in order to prevent unacceptable heating, the periapse altitude must be kept above approximately 150 km. This is accomplished by choosing the final aimpoint to keep the altitude above 150 km at a TBD confidence level, given the dispersion of the approach trajectory.

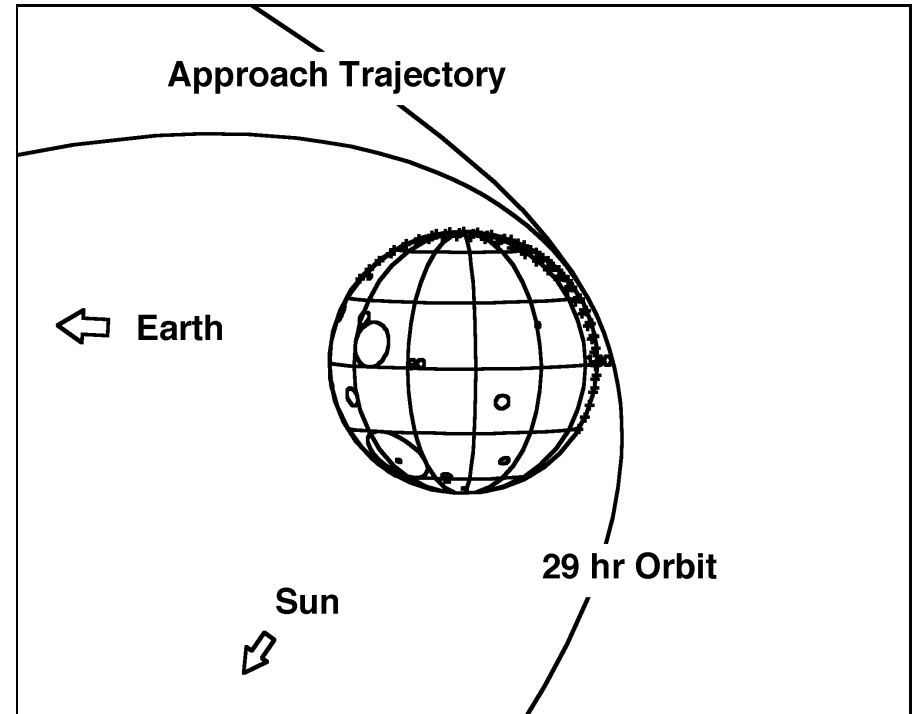
MOI biprop and Hydrazine Burns: For launch at the end of the Primary launch period, it is required that the capture orbit have a period of 29 hrs or less after MOI [Mars Orbit Insertion], so that aerobraking can be completed prior to lander arrival. MOI starts with MOI-1, the biprop burn, which lasts approximately 16 - 17 minutes. Main engine cutoff occurs at an accelerometer reading of 65% - 75% thrust [TBD], backed up by a timer cutoff. This maneuver exhausts the supply of oxidizer. The biprop system is isolated prior to cutoff. The ΔV imparted to the spacecraft from this maneuver depends on the approach mass of the Orbiter, which in turn depends on TCM and other propellant usage during cruise. After a one minute coast, the hydrazine system must, in most cases, provide a supplemental maneuver [designated MOI-2] to trim the orbit period to the needed value of 29 hrs. The supplemental burn, which may last as long as 7 minutes, occurs as soon after the biprop burn as possible, to minimize gravity loss. By placing the hydrazine burn soon after the biprop burn, the hydrazine maneuver is less efficient than if it were placed at periapse, but time is saved because walk-in can occur at the apoapse of the capture orbit, approximately 14 hours after MOI. Cutoff for MOI-2 is determined by an accelerometer detection of the total ΔV required, backed up by a timer cutoff.

Capture Orbit Periods: For launch at the end of the primary interval, the biprop burn yields orbit periods between 27 and 44 hrs [95% range]. For launch at this time, there is a probability of approximately 88% that a hydrazine burn will be required to trim the orbit to the required 29 hrs. The final range of capture orbit periods after the hydrazine makeup burn is approximately 27 - 29 hours [95% range], depending on TCM usage during cruise. These results vary slightly across the primary launch period. As one moves further and further into the Secondary interval, the final capture periods get larger and larger. At the end of the Secondary period, the orbit period is 37 hours after the hydrazine burn. In this case, an additional ~2 weeks of aerobraking are required before mapping orbit can be established.

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MARS ORBIT INSERTION STRATEGY

- **Northern Approach**
 - Initial inclination targeted 0.1° high to accommodate inclination perturbations during aerobraking.
 - Aimpoint chosen to keep periaipse altitude > 150 km during MOI [heating constraint].
- **MOI-1: biprop burn**
 - Burn Oxidizer to depletion [16 minute burn]
 - Main engine cutoff at accelerometer reading of 65% - 75% thrust [TBD], with timer backup.
 - » Biprop system is isolated prior to cutoff
 - Imparted ΔV depends on approach mass, and performance of biprop system
- **MOI-2: Hydrazine makeup burn:**
 - Supplemental Hydrazine burn follows 60 sec. later, as needed, to yield desired orbit period.
 - For launch at end of primary, makeup burn is required 88% of the time.
 - Allows earlier walk-in maneuver than a next-rev burn
 - Cutoff determined by accelerometer detection of total ΔV required, with timer backup.
- **Target is 29 hr maximum orbit period for launch at end of Primary**
 - 99% probability of aerobraking completion by Lander arrival
 - Orbit period ~ 26 hrs at start of Primary, ~ 36 hrs at end of Secondary



4.5.1.2 Mars Orbit Insertion SOE

The following chart illustrates the Mars Orbit Insertion sequence of events, which begins with a 4 hour DSN contact starting approximately 18h45m before the MOI biprop burn. Safe Mode is disabled some time during this DSN contact [time TBD]. Additional DSN contacts are planned: a 4 hour contact starting 9h45m before the burn, and a 23 minute contact starting 45 minutes before the burn. As part of a stored sequence, less than 1 hour before MOI, the Autonomous Momentum Management [AMM] deadbands are decreased, compelling the system to dump momentum prior to MOI if needed; the AMM software is then disabled until after MOI, to prevent further autonomous momentum wheel desaturation during MOI. Starting approximately 22.5 minutes before MOI, the Catbed and Main Engine Valve/Flange Heaters are enabled. The solar arrays are then restrained, and the main engine lines are evacuated. The slew to the MOI attitude is performed on the reaction wheels. Configuration of the biprop system continues with hard fill of the engines beginning about 5 minute before MOI, and filling of the Helium pressurant tanks.

The MOI biprop burn itself lasts approximately 16 minutes, and is terminated when oxidizer depletion is sensed by the accelerometers. A minimum timer enables the accelerometer cutoff, and a maximum timer prevents excessive Hydrazine usage. Another timer is used to fire the pyros which isolate the biprop system. This occurs before the end of the biprop burn. The remainder of the burn is performed in blowdown mode. Attitude control, including the constant pitch rate turn during the biprop burn, is maintained via the TCM and RCS thrusters. After the biprop burn, the RCS thrusters fire for approximately 1 minute to damp out the spacecraft rates. The supplemental hydrazine burn, if needed, is then executed using the 5 lbf TCM thrusters. Typically, this burn lasts less than 7 minutes, and is terminated when the accelerometers detect that the needed additional ΔV has been supplied, backed up by min and max timers. Upon completion of the supplemental burn, safe mode is re-enabled, the spacecraft is slewed via reaction wheels to an attitude permitting post-MOI DSN contact, and the Catbed and main engine heaters are disabled. The solar arrays are unstowed and sun-pointed. DSN contact is re-established at the earliest opportunity after exit from occultation.

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MARS ORBIT INSERTION SOE

MOI_BP_BURN - 18:45:00	DSN Contact 1 • Disable System Safe Mode Response • Disable Sequence Abort Response • Set Comm Loss Times to Exceed MOI • Mission Phase Bits to MOI • Set up MOI Global Variables		
MOI_BP_BURN - 14:45:00			
MOI_BP_BURN - 09:45:00	DSN Contact 2 • Downlink Health and Status		
MOI_BP_BURN - 05:45:00			
MOI_BP_BURN - 00:45:00	DSN Contact 3 • Enable RCS Catbed Heaters • Enable TCM Catbed Heaters • Config AMM • Enable ME valve, Flange, line heaters • Restrain solar arrays		
MOI_BP_BURN - 00:22:20.9	• Processor to 20 MHz		
MOI_BP_BURN - 00:11:05	• Open/Close ME valves OV1, FV1 • Slew to MOI Burn Attitude • Fill Oxidizer and fuel lines • Pressurize Oxidizer and Fuel tanks		
MOI_BP_BURN - 00:00:00.1			
MOI Burns	• Bi-Prop Burn • Mono-Prop Burn		
MOI_END + 00:00:00.1	• Enable AMM • Disable TCM, RCS catbed heaters • Disable ME heaters • Enable Safe Mode • Enable Sequence Aborts • Set Comm Loss Times for A/B • Unrestrain SA/Gimbal to Sun • Slew to DSN Attitude/Initiate Contact • Processor to 5 MHz		

4.6 AEROBRAKING PHASE

4.6.1 Post-MOI Activity

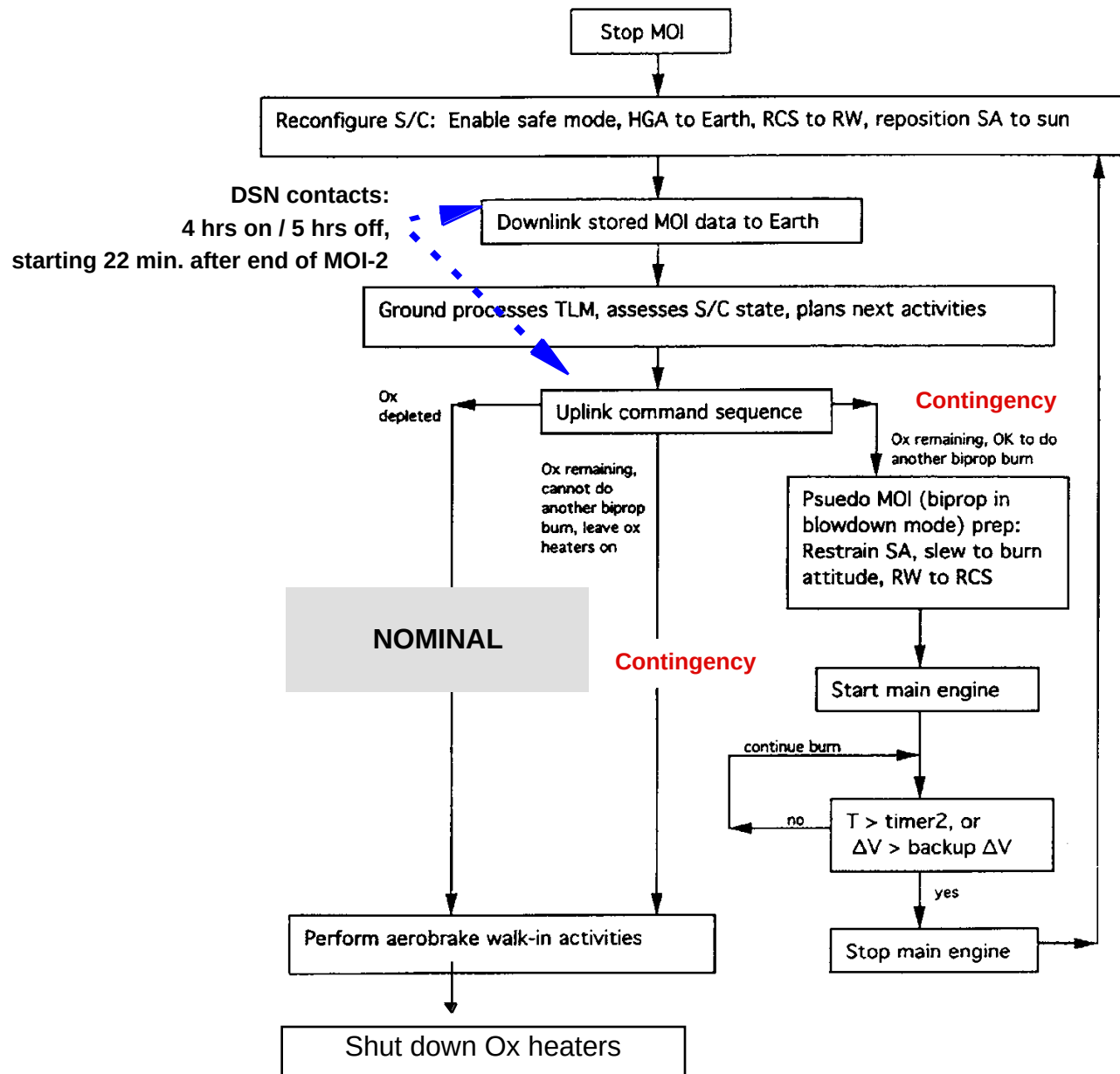
Nominal Operation: The following graphic illustrates the flow of activities after termination of MOI-2. Approximately 22 minutes after the completion of the MOI burns, the spacecraft will have been turned to its communications attitude. DSN contacts then occur on a schedule of 4 hours on / 5 hours off, allowing opportunities for downlinking telemetry data, obtaining tracking data, and sending commands. Once the stored MOI data are downlinked to Earth, the result of the MOI burns must be quickly evaluated, along with the state of the spacecraft itself. If telemetry shows that MOI-1 and MOI-2 have executed nominally, preparations are made for walk-in at the first apoapse of the capture orbit. A default walk-in maneuver will have been uplinked prior to execution of the MOI sequence. TBD: This maneuver will be updated, if required, using the post-MOI DSN contacts. Execution of the walk-in burn is enabled by ground command.

Contingency Operation: If post-MOI telemetry or tracking indicate an anomalous condition of the spacecraft or capture orbit, the aerobraking walk-in maneuver would be delayed until the anomalies are identified and resolved. For example, anomalous performance of the biprop engine may result in MOI-1 being terminated via the MOI-1 backup timer, in which case oxidizer may remain in the tank. Regardless of whether MOI-1 is terminated normally or via a timer cutoff, the biprop system is always isolated via pyro firings. Similarly, MOI-2 may be terminated via its backup timer, signalling an anomalous burn. If sufficient oxidizer remains, a second biprop burn in blowdown mode may be commanded. This would occur at periapse of a subsequent orbit. In this case the solar array would be restrained, the spacecraft slewed to the burn attitude, and thruster control enabled. The burn cuts off upon achieving the requisite ΔV , backed up by a timer. The spacecraft then re-establishes contact with Earth and downlinks data from the burn.

Oxidizer Heater Operation: The nominal plan is to keep the oxidizer heaters operating until it is determined that it is safe to turn them off. This may occur well after the aerobraking walk-in maneuver.

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POST MOI ACTIVITY



4.6.2 Aerobraking

4.6.2.1 Aerobraking Strategy

After MOI, an aerobraking schedule is planned which allows the Orbiter to complete aerobraking and place it in an orbit from which it can support Lander data relay and commanding, prior to Lander arrival. The current mission design can support this only if the Orbiter is launched within its Primary launch period [12/10 - 12/17/99] during which the resultant capture orbit periods are sufficiently short. If launch occurs during the Secondary launch period, the capture orbit periods will likely be too long to allow completion of aerobraking before Lander arrival.

For the Primary launch period, the most stressful aerobraking case occurs at the end, since this affords the least time for aerobraking prior to Lander arrival. The first walk-in maneuver occurs at apoapse of the final capture orbit [approx 0.6 days after MOI]. The Walk-in phase, during which the periapse altitude is cautiously lowered, occurs over approximately 3 orbits [3.6 days]. The Main phase of aerobraking lasts 52.6 days, and the End Game or Walk-out interval lasts 8.6 days. Aerobraking is terminated with a periapse raise maneuver as part of the transfer to map orbit. See section 4.2.5 for phase durations and mission events for other launch dates.

The following plots illustrate the evolution of the orbit during aerobraking. As the orbit period decreases, the argument of periapse, initially at 28°N, moves Northward. At the end of aerobraking, periapse is located approximately at the North pole of Mars. The sun-relative node is also changing during this interval, due primarily to the motion of Mars about the Sun. During the majority of Aerobraking, the orbit is so elliptical that the node orientation changes very little inertially, while Mars continues to move at an average rate of 0.524° per day with respect to the Sun. As a result, the node moves to earlier and earlier local mean solar times.

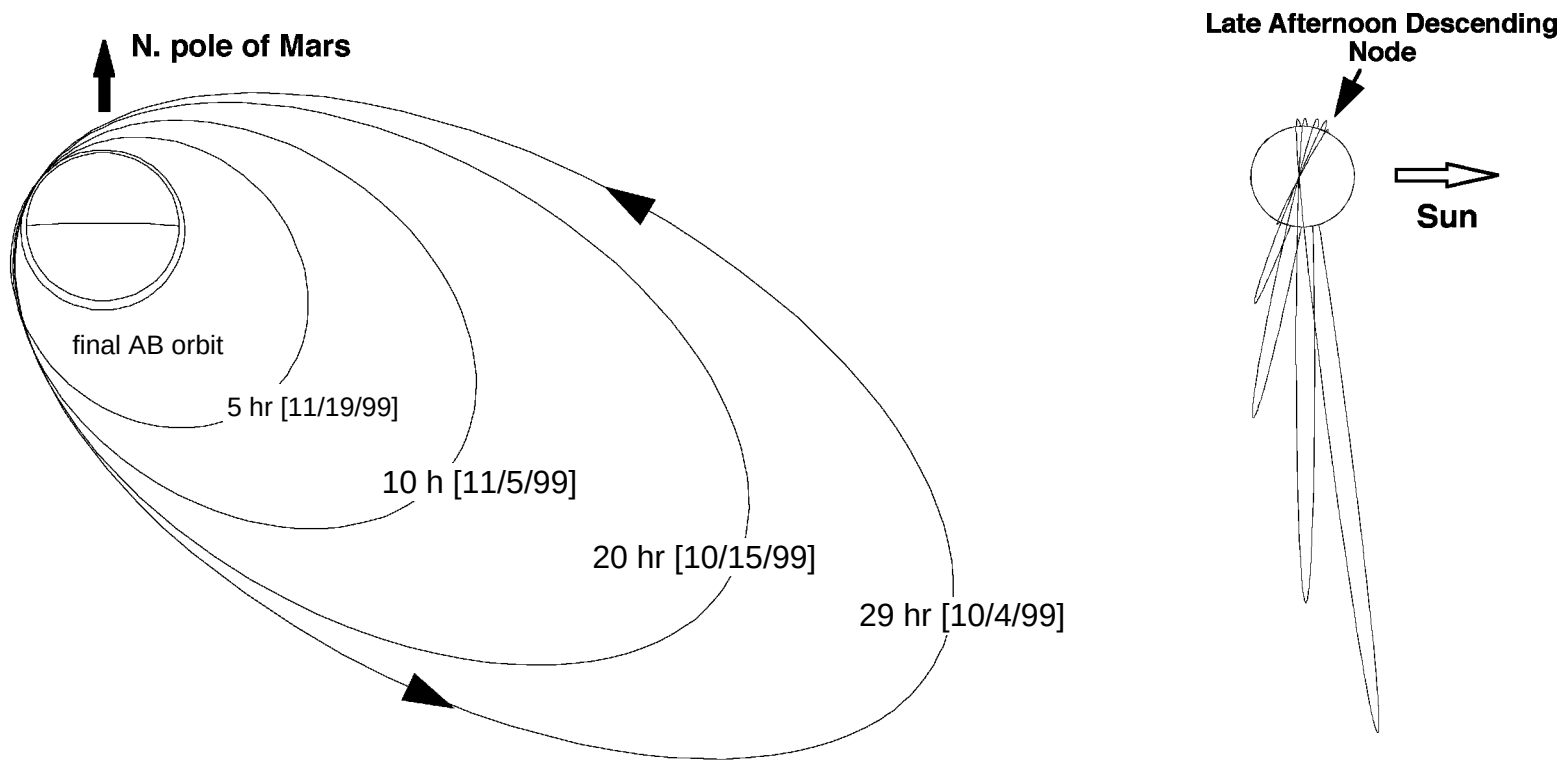
Appendix A.5, the Aerobraking Database, contains states as a function of time during the aerobraking phase, for open and close of the primary launch period.

Inclination Trims: The dispersion of the incoming trajectories, coupled with pointing errors during MOI and the effects of aerobraking, result in a perturbation of as much as $\pm 0.3^\circ$ away from the desired inclination. In order to maintain the desired degree of sun synchrony for the final mapping orbit, the majority of this dispersion is corrected during the aerobraking phase, when the orbit is still highly elliptical. Two inclination trims are planned: one when the orbit period is approximately 20 hrs [assuming a nominal capture period of 29 hrs] and the other at 10 hrs. The optimal placement for these maneuvers is at a true anomaly of approximately 190°, and results in a combined change in the inclination and the node. An inclination change of 0.2° is bookkept in the propellant calculations. A final inclination trim after aerobraking may also be required, and may be combined with the first Transfer to Map Orbit burn.

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AEROBRAKING STRATEGY

- The chosen aerobraking strategy, along with sufficiently low initial orbit periods, allows the Orbiter, if launched within its **Primary Launch Period**, to complete aerobraking by the earliest Lander arrival date.
- **Timeline for End of Primary:**
 - Start walk-in 0.5 revs [approx 0.6 days] after MOI. Walk-in lasts 3 revs [3.6 days].
 - Main phase lasts 52.6 days
 - End game [Walk-out] lasts 8.6 days
 - Aerobraking is terminated with TMO-1, the first Transfer to Map Orbit maneuver
- **Inclination trim ΔV 's** planned at orbit periods of 20 hrs and 10 hrs during aerobraking.
 - Corrects $\pm 0.2^\circ$ of the expected $\pm 0.3^\circ$ of dispersions in inclination.



4.6.2.2 Aerobraking Navigation

The driving navigation requirement for aerobraking is accurate prediction of both the timing and radius of periapse passage. The requirement currently assumed for the Orbiter is derived from the MGS requirement that the time of periapse passage be predicted to an accuracy of 225 sec [2σ], and the periapse radius predicted to 1.5 km [3σ]. The periapse passage timing requirement can be violated on occasion, but must be satisfied in general to prevent high propellant usage in stabilizing s/c attitude after each aeropass. The MGS requirement was derived based on 70% orbit-to-orbit density variation, plus 20% nav uncertainty. Unlike MGS, whose transmitter can support near continuous tracking, the MSP98 Orbiter has thermal and power constraints severely limiting its transmitter cycle. The transmitter cycle being assumed is: 4 hrs on/5 hrs off during outer cruise and early aerobraking, an on/off ratio of 0.8 in lower orbits, and a minimum of 30 minutes per orbit for the final TBD days of aerobraking. The nominal tracking schedule starts with a tracking pass as soon after the aeropass as possible. Appendix A.5 includes strawman tracking schedules for Open and Close of Primary.

Preliminary analyses using worst-case conditions during aerobraking [orbit periods ~2 hrs] indicate that periapse prediction to the desired accuracy may only be possible 2 or 3 orbits ahead, for the last part of aerobraking. As a result, during a limited interval, one or more of the following measures may be required [feasibility TBD]: more frequent nav predicts than were required for MGS, reduction of nav turnaround time on the ground compared with MGS, collection and analysis of accelerometer data taken during the aeropasses, and accepting longer intervals during which the prediction requirement is not met. It is assumed that improved gravity field modeling provided by MGS will reduce the nav uncertainty MSP98 must account for, to 10%.

4.6.2.3 Support of Lander Approach Navigation - Near Simultaneous Tracking

In order to support precision approach navigation for the MSP98 Lander, a program of near-simultaneous tracking of the Lander and the MSP98 Orbiter is required, starting 30 days from Lander arrival. [At this point, the Orbiter period is 9-11 hours.] This requires that a track of the Lander be immediately followed or preceded by an Orbiter pass, and that both passes be supported from the same HEF antenna. Analyses of these data can be used to reduce 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. Close coordination of Orbiter tracking passes and Lander passes are required during this interval. In general, because the MSP98 Orbiter is engaged in aerobraking at this time, there is little flexibility in timing the Orbiter passes, which will be scheduled in accordance with aeropass times and transmitter on/off cycles. The Lander passes must be timed to fit in with the Orbiter tracking schedule, as well as DSN pre- and post-calibration times.

If the MSP98 Orbiter is not available for support of near-simultaneous tracking with the Lander, the MGS spacecraft will be used as a backup.

AEROBRAKING NAVIGATION

- **Driving Requirement**

- Periapse Prediction accuracy: 225 sec [2σ], 1.5 km [3σ]
 - » MGS requirement to prevent high propellant usage for stabilizing attitude after aeropass.
 - » Based on 70% orbit-to-orbit density variation, 20% nav uncertainty.
 - » Must be satisfied in general. Occasional violations are acceptable.

- **S/C Constraints and Tracking Assumptions**

- Continuous tracking [assumed for MGS] not feasible due to thermal and power constraints to transmitter on times. Current design capability:
 - » 4 hrs on / 5 hrs off during outer cruise and early aerobraking
 - » 80% on:off duty cycle in lower period orbits
 - » minimum of 30 minutes per orbit during final TBD days.
- Perform first tracking pass as soon after aeropass as possible

- **Preliminary Results - Nav Capability**

- Periapse prediction to desired level may be possible only 2-3 orbits ahead when orbit period ~ 2 hrs.
 - » May require one or all of the following during a limited interval [feasibility TBD]:
 - More frequent nav predicts than needed for MGS
 - Reduction of nav turnaround time on ground
 - Collection and analysis of accelerometer data during aeropasses
 - Longer intervals during which prediction requirement is violated.
- Assumption is made that MGS will reduce nav uncertainty to 10% due to improved gravity field model

- **Orbiter/Lander Near Simultaneous Tracking**

- Lander precision approach nav requires Lander tracks to be immediately preceded or followed by an Orbiter pass from the same HEF antenna, to reduce effects of error sources common to the Lander & Orbiter [station-dependant biases, Earth orientation errors, media & solar plasma modelling errors].
- Starts at Entry - 30 days - The M98 Orbiter is in aerobraking [period = 9-11 hrs]
 - » Orbiter passes are fixed, determined by timing of aeropasses and transmitter on/off cycles.
 - » Lander must schedule its tracks to fit in with Orbiter tracks, and DSN pre- and post-cal
- If M98 Orbiter not available, MGS is backup

4.6.2.4 Aerobraking Maneuvers

Transition to Aerobraking: Walk-in Maneuver

Nominally, Aerobraking is initiated at the first apoapse of the final capture orbit, with the walk-in maneuver. Prior to MOI, a default walk-in maneuver will be present on-board. TBD: Post-MOI DSN tracking data will be used to perform orbit determination and update the default maneuver, as needed. For the first walk-in maneuver, the Autonomous Momentum Management deadbands are tightened, followed by temporarily disabling the AMM software architecture. RCS and TCM Catbed heaters are enabled. Star camera processing is disabled, the spacecraft is slewed on wheels to the burn attitude, and the solar array passively restrained. RCS thrusters are used to control attitude during the burn, which lasts approximately 20 seconds. Immediately following the burn, AACS control is restored to the reaction wheels, which effect a slew to the DSN contact attitude. Star camera processing and AMM is re-enabled, and the solar arrays are unrestrained and gimballed to sun-point. Subsequent walk-in maneuvers are smaller, and do not require restraining the solar array.

Orbital Trim Maneuvers

Approximately 14 OTM's [Orbit Trim Maneuvers] are expected to be required during this phase. Two types of OTM's can be implemented: small maneuvers ≤ 6 seconds which do not require the solar arrays to be stowed, and maneuvers > 6 seconds which require the solar array to be passively restrained.

Unrestrained Maneuvers. Unrestrained maneuver durations are based on required ΔV , with a simple back-up timer set to the maximum time allowed for unrestrained burns [i.e. 6 seconds]. These OTM maneuvers are "canned", pretested maneuvers. At any given time, a minimum of 6 maneuvers will be available on-board [3 raise periapse, and 3 lower periapse], defined by 3 burn durations and two inertial burn directions [quaternions]. The set of maneuvers is updated periodically during aerobraking.

Restrained Maneuvers. Restrained maneuvers are also cut off based on ΔV delivered, i.e. AACS commands the TCM thrusters until the specified ΔV is delivered. The back-up timer in this case is based on the 3-sigma long burn time. Prior to the burn, the solar array is restrained, using the same protocol as elsewhere in the mission.

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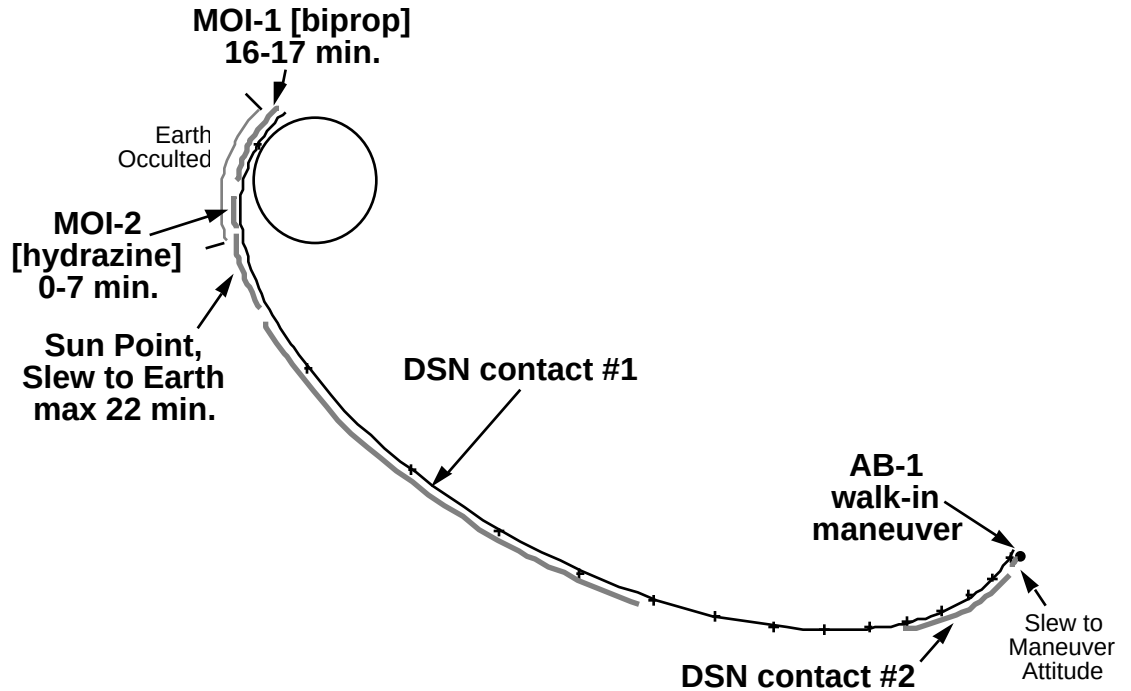
AEROBRAKING MANEUVERS

- **Transition to Aerobraking: Walk-in Maneuvers**

- Walk-in starts at first apoapse of final capture orbit
 - » Default maneuver on-board prior to MOI. TBD: Updated using post-MOI DSN passes
 - » First walk-in maneuver requires solar array to be restrained.
- Subsequent walk-in maneuvers done without restraining solar array.

- **Orbital Trim Maneuvers:**

- Approx 14 expected during aerobraking phase
- **Unrestrained OTM's:**
 - » Maneuvers ≤ 6 sec which do not require solar array to be restrained
 - » These maneuvers may be "canned"
 - Minimum of 6 maneuvers available on-board [3 periapse raise, 3 periapse lower], defined by 3 burn durations and two inertial burn directions
 - Maneuver set updated periodically throughout aerobraking phase.
 - » Cutoff based on attainment of desired ΔV . Backup timer set to max time allowed for unrestrained burns [i.e. 6 seconds]
- **Restrained OTM's:**
 - » Maneuvers > 6 sec requiring solar array to be restrained
 - » Cutoff based on attainment of desired ΔV . Backup timer based on 3σ -long burn time.



4.6.2.5 Aeropass Sequence of Events

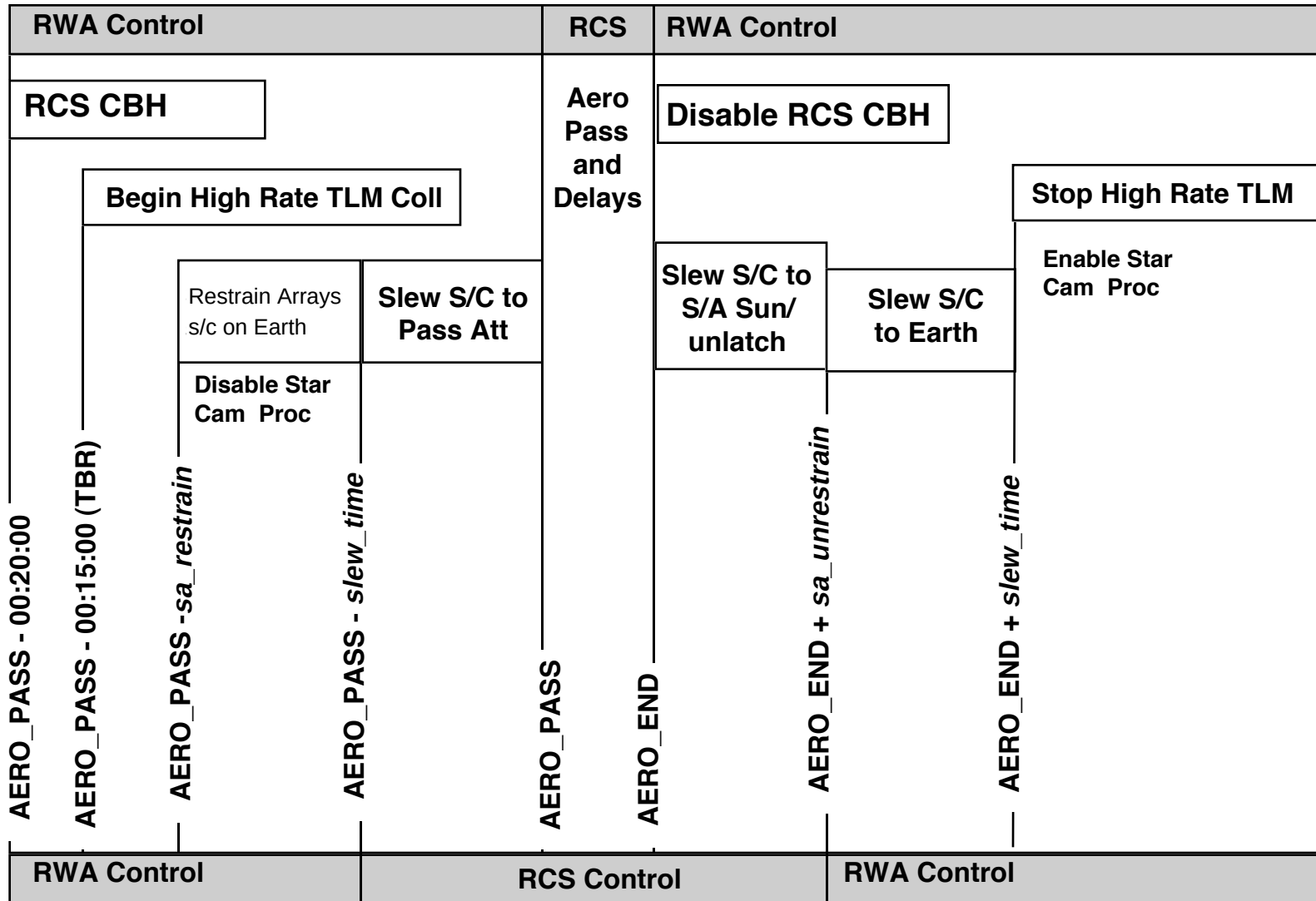
During active aerobraking, an aeropass is defined as the passage of the Orbiter through periapse, during which atmospheric drag reduces the orbit period. Approximately 220 aeropasses are expected during the Aerobraking phase. Preparation for this activity starts with tightening the AMM deadbands, at a pre-determined point prior to the aeropass, followed by temporarily disabling the AMM software. RCS Catbed heaters are enabled, Star Camera processing is disabled, and the slew to the aeropass attitude starts. During Main Phase, the slew to and from aeropass attitude is on the reaction wheels. During the last 10 orbits of the End Game, thrusters are used for these slews, to minimize the time off-sun. Solar arrays are restrained shortly before the pass. During the aeropass itself, attitude is controlled via the RCS system. After the aeropass is over, RCS Catbed heaters are disabled, and the spacecraft is slewed to the Aerobraking DSN contact attitude. Star camera processing and AMM are re-enabled, and the arrays are unrestrained.

Aeropass durations tend to increase during the Aerobraking phase, as the orbit period shrinks. Drag pass durations [including 5 minute uncertainty bands at the start and end of the aeropasses] are summarized for the end of the Primary period, in Appendix A.5 - the Aerobraking Database. Also included in this appendix is the total amount of time the spacecraft is in sun, i.e. the orbit period less the drag pass duration and time the panels are off-sun. As indicated, the solar eclipse times also increase during aerobraking, as the node moves to earlier and earlier sun times and the apoapse altitudes decrease.

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AEROPASS SOE

Main Phase



End Game

OA - 6

4.6.2.6 Aerobraking Communications Strategy

DSN contacts during aerobraking change as the orbit period and orbit plane geometry varies. In early aerobraking, the 4 hours on / 5 hours off transmitter duty cycle is maintained, with the first contact occurring as soon after aeropass exit as possible. As the orbit period decreases, a 4:5 on:off ratio is maintained in accordance with the power and thermal limitations of the transmitter. The receiver is on all the time. During walk-out, as eclipse and occultation durations increase, transmit intervals are severely limited to accommodate needed battery recharge time. DSN contacts may be as short as 30 minutes per orbit during walk-out or during OTM orbits towards the end of aerobraking. The downlink data rate at this point is 2.1-9.9 kbps.

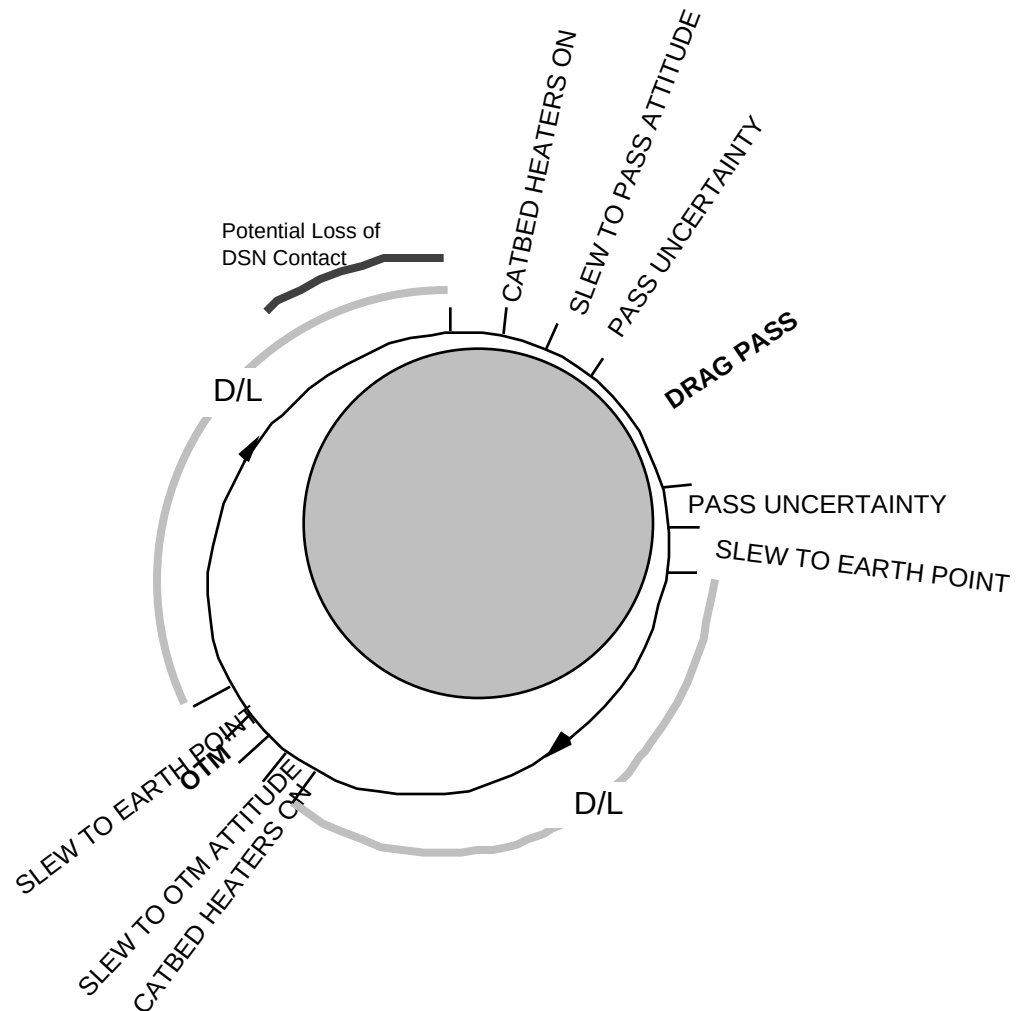
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AEROBRAKING COMMUNICATIONS STRATEGY

- **Transmitter:**

- Downlink Transmit at 2.1-9.9 kbps
- On/off cycle changes as period and orbit plane geometry evolves:
 - » Early Aerobraking: 4 hrs on/5 hrs off
 - » Intermediate Orbit Periods: 4:5 on:off ratio maintained
 - » End Game: 30 minutes per orbit
 - Constrained by energy balance as eclipse and occultation durations increase

- **Receiver** always on



4.6.3 Transfer to Map Orbit

4.6.3.1 TMO Maneuvers

** This page under Change Control **

Overview: At the end of aerobraking walk-out, periapse is very close to the North pole. A maneuver at or near apoapse of this orbit [near the South pole of Mars] raises periapse out of the atmosphere to terminate Aerobraking. This maneuver, called TMO-1 [Transfer to Map Orbit #1] also places apoapse near the North pole. The magnitude of TMO-1 is 80-82 m/s. The transition orbit the spacecraft occupies at this point has an apoapse of approximately 437 km [frozen orbit apoapse] and a periapse equal to the apoapse of the final aerobraking orbit [405±15 km]. TMO-2 is a smaller maneuver [4-10 m/s] occurring at the transition orbit's apoapse, which trims the periapse altitude to 373 km and places the spacecraft in its final frozen mapping orbit. By thus propulsively rotating the line of apsides, it is possible to enter the frozen orbit without a drift interval.

The total time for transfer to the mapping orbit is TBD but must be sufficient for tracking data to be taken, the TMO-2 maneuver to be designed, uplinked and executed, and any additional trim maneuvers to be implemented. A maximum of 24 hours is currently allocated between the final aeropass and start of mapping operations.

Post-Aerobraking Final Inclination Trim [TBD]: The current ΔV budget includes propellant sufficient to perform two inclination trims during aerobraking, at orbit periods of 20 hours and 10 hours. This leaves approximately $\pm 0.05^\circ$ of remaining inclination uncertainty at aerobraking termination, which, along with the ± 20 minutes uncertainty in final node location, must either be tolerated [impacting science and energy balance] or trimmed up [impacting the ΔV budget]. By placing the TMO-1 maneuver a few degrees away from the South pole, and introducing an out-of-plane component, this maneuver may be used to perform a final inclination trim to ameliorate the effects of uncertainties in aerobraking end state [both node and inclination], and thus prevent either very late solar times [bad for science] or very early solar times [bad for energy balance]. Appendix A.6 [Post-Arrival Trajectory Characteristics] illustrates the effect on solar time and eclipse durations of no inclination trim, a maximum trim magnitude of 0.05° , and a maximum trim magnitude of 0.1° , for the full range of possible aerobraking end nodes. Performing a post-Aerobraking inclination trim of 0.05° requires 5-7 m/s if included as part of TMO-1, or about 3 m/s if done as a separate maneuver at the node. Changing inclination by 0.1° as a part of TMO-1 would require a prohibitive 23 m/s; in this case the maneuver would have to be done at the node, for a cost of 6 m/s. If schedule pressures dictate, a final inclination trim at the node could be delayed until after Lander arrival. This would probably require a burn after the HGA has been deployed. The feasibility and/or maximum size of a maneuver after HGA deployment is TBD.

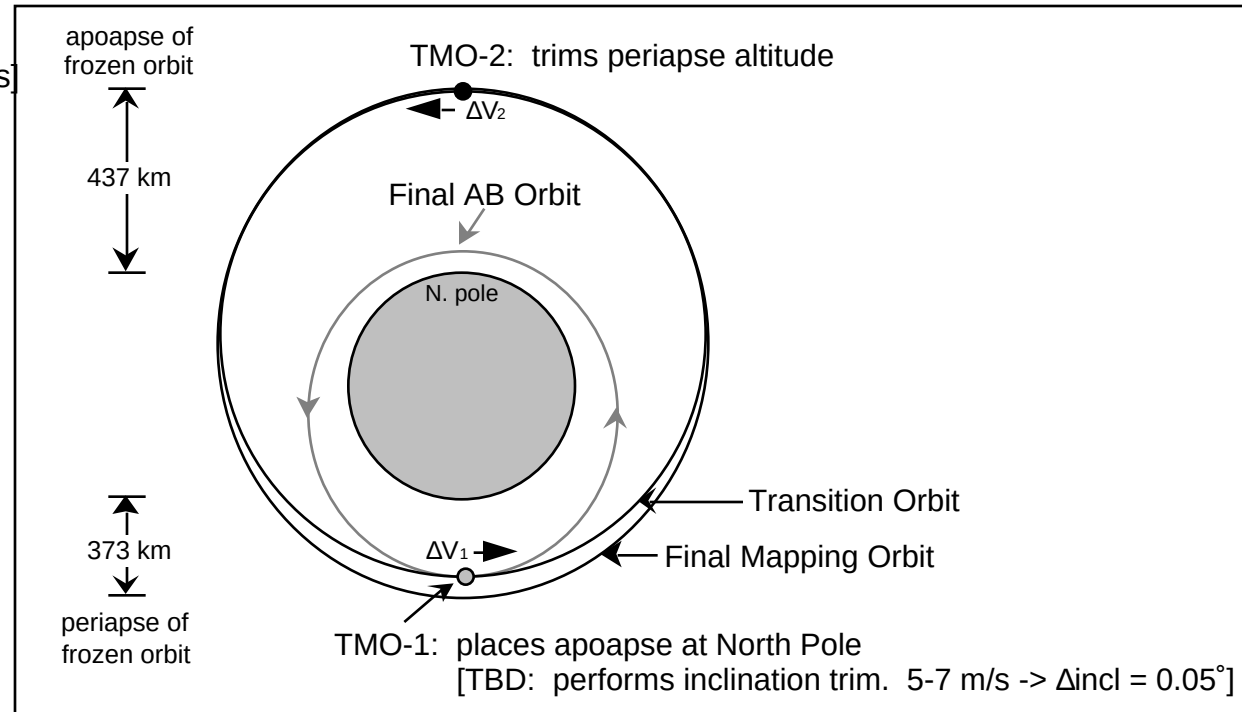
ΔV Magnitudes: Maneuver ΔV magnitudes have been estimated for the open and close of the Primary Launch Period, using as starting points the end state peripases listed in Appendix A.5 - Aerobraking Database, and an assumed final apoapse of 405 km $\pm$ 15 km. The following table summarizes the range of ΔV required, without inclination trim.

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TRANSFER TO MAP ORBIT - TMO Maneuvers * This page under Change Control *

- **Transfer to Mapping Orbit:**

- Direct propulsive insertion into the frozen Mapping orbit [2 maneuvers]
- Time between TMO-1 and TMO-2 is TBD. 24 hrs allocated between final aeropass & start of mapping.
 - » Includes trim maneuvers, if required.



- **Final Inclination Trim [TBD]:**

- Previous inclination trims during aerobraking [at orbit periods of 20 hrs, 10 hrs] leave 0.05° uncertainty in inclination.
- See Appendix A.6 for effects on solar time & eclipse durations of no inclination trim, 0.05° trim, and 0.1° trim, for full range of Aerobraking end nodes [± 20 minutes]
- **Inclination trim of 0.05° :** costs 5-7 m/s if included as part of TMO-1, or 3 m/s if a separate maneuver at the node
- **Inclination trim of 0.1° :** too costly to include as part of TMO-1, requires 6 m/s separate maneuver at the node
- Final inclination trim could be delayed until after Lander arrival [feasibility &/or max size of maneuver after HGA deploy TBD]

- **ΔV Magnitudes [without inclination trims]:**

	Aerobrake End State [periapse alt x apoapse alt (km)]	ΔV_1 [m/s]	ΔV_2 [m/s]	Total ΔV [m/s]
Open Primary	85 x 390	81.7	3.8	85.4
Open Primary	85 x 420	81.5	10.4	91.9
Close Primary	91 x 390	80.2	3.8	84.0
Close Primary	91 x 420	80.0	10.4	90.4

4.6.3.2 Mapping Initialization Activities

After transfer to the map orbit is complete, spacecraft initialization for relay operations is undertaken in anticipation of Sol 0 Lander support.

HGA Deployment and Calibration: Some time after transfer to the map orbit, the High Gain Antenna [HGA], which is restrained during Cruise, MOI, and Aerobraking, is deployed. The boom heater is first turned on to warm up the one-time release mechanism. Once it is deployed the HGA cannot be stowed again. All attitude control is disabled during the deployment. After the HGA is deployed the gimbals must be initialized. The HGA may need to be calibrated after deployment [TBD]. This would occur as soon as feasible during a DSN contact after deployment, by moving the HGA in a pre-defined pattern and analyzing the received signal power. Maneuvers larger than TBD m/s cannot be performed after HGA deployment.

Additional Bus Activities: The Mission Phase Bits, which govern how the spacecraft recovers from anomalies during Safe Mode, are set to MAPPING. New momentum limit deadbands for mapping are set for the autonomous momentum wheel desaturations. During mapping/relay operations the nominal processor speed is 20 MHz.

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MAPPING INITIALIZATION ACTIVITIES

- Orbiter initialization occurs after transfer to map orbit, in preparation for relay operations prior to Lander Sol 0:
 - » **HGA Deployment and Calibration:**
 - HGA [restrained during Cruise, MOI, and Aerobraking] is deployed.
 - Boom heater activated to warm up the one-time release mechanism.
 - Attitude control disabled during deployment.
 - Gimbals initialized.
 - TBD: HGA may need calibration after deployment.
 - Occurs as soon as feasible during a first DSN contact after deployment
 - HGA moves in a pre-defined pattern, and received signal power is analyzed.
 - Maneuvers larger than TBD m/s cannot be performed after HGA deployment.
 - » **Additional Bus Activities:**
 - Mission Phase Bits [govern how s/c recovers from anomalies during Safe Mode] set to MAPPING.
 - New momentum limit deadbands for mapping are set for the autonomous momentum wheel desaturations.
 - Processor speed 20 MHz.

4.7 LANDER SUPPORT PHASE

4.7.1 Overview

** This page under Change Control **

The Lander Support Phase occurs after transfer to the map orbit and mapping/relay initialization, and prior to the full-up mapping mission. Its duration is equal to the nominal landed science lifetime [12/3/99 - 2/29/00]. The use of 34m DSN antennae is baselined throughout. [Use of 70m support is under review; it can substantially improve orbiter data return and reduce ops complexity by eliminating the need for Lander relay support by MGS during the 3rd month of the Lander's mission.] It is also assumed that MGS is available for relay starting 2/1/00, and that the MSP98 Orbiter transitions to its lowest data rate [5.7 kbps] on or near 2/1/00. MSP98 Orbiter commanding support of the Lander is assumed throughout this phase. Note: electromagnetic interference with the Orbiter payload due to UHF transmissions is TBD, rendering Orbiter payload operations during this phase TBD as well.

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 activating onboard instrument software. For PMIRR, this also involves opening the radiator door, and allowing the instrument to cool down. PMIRR must be in its operating mode [main power on], and all significant maneuvers must have been executed by the Orbiter prior to opening the radiator door fully. 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.

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.

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LANDER SUPPORT PHASE - OVERVIEW

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- **Duration: Nominal Landed Science Lifetime: 12/3/99 - 2/29/00**
 - Assumptions:
 - 34m DSN antennae baselined
 - Use of 70m under review - can significantly improve Orbiter data return, reduce ops complexity [no reliance on MGS in 3rd month of Lander mission]
 - 2/1/00: MGS available for Relay. M98 Orbiter transition to lower data rate occurs.
 - M98 Orbiter **commanding** support of Lander throughout
 - Orbiter payload operations and EMI caused by UHF system TBD
 - » **Subphase 1: 12/3/99 - 1/2/00 [Dedicated Lander Relay Support]**
 - M98 Orbiter D/L at 9.9 kbps. M98 Orbiter supports Lander telemetry relay
 - 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.
 - Main power turned on & onboard instrument software activated
 - PMIRR also requires radiator door to be opened, cool-down interval
 - » PMIRR must be in operating mode [main power on], maneuvers must be finished, before fully opening radiator door
 - M98 Orbiter receives whatever remains in terms of D/L data volume [<10 Mbits/day], ops resources
 - Orbiter housekeeping, instrument aliveness
 - Payload operations [TBD]: Use remaining D/L for MARCI imaging
 - » **Subphase 2: 1/3/00 - 1/31/00 [Overlapping Observations]**
 - Coordinated science campaign with Orbiter, Lander, MGS
 - M98 Orbiter D/L at 9.9 kbps. M98 Orbiter supports Lander telemetry relay
 - Lander receives 110 Mbits of the 160 Mbits science D/L per day
 - M98 Orbiter payload operates at reduced level - approx 40-50Mb/day
 - PMIRR begins observations at standard data rate (~250 bps)
 - MARCI begins global mosaics & targeted MA imaging
 - » **Subphase 3: 2/1/00 - 2/29/00 [Overlapping Observations]**
 - M98 Orbiter D/L drops to 5.7 kbps
 - MGS supports Lander telemetry 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]
 - Request MGS delay PP maneuver until 3/1 [avoids interruption in Lander support]

4.7.2 Data Relay Operations

Overview: There are four cases for relay operations from the Orbiter. They are Lander Telemetry (Lander to Orbiter), Lander Telemetry (Orbiter to Earth), Lander Commands (Earth to Orbiter), and Lander Commands (Orbiter to Lander). The Lander Telemetry case sends science data back to the Earth through the UHF link. The Command case sends a command load to the Lander which goes through the Orbiter, instead of directly to the Lander via the DTE X-band link.

4.7.2.1 Lander Commanding

During each day of the Lander science mission, 8-10 Orbiter passes occur over the landing site, averaging 6 minutes per contact. Of these, 5-7 occur at solar elevations greater than 20 deg. Currently, four UHF passes are assumed to be supportable by Lander power and thermal limitations at the beginning of the Lander's surface mission, and 3 are assumed to be supportable at the end of the Lander's lifetime. Each UHF pass is a "hybrid" command/telemetry pass. The Lander is always configured to receive commands from the Orbiter at the start of each pass. Once the commands [if any are present] are sent to the Lander, the Lander is autonomously switched to transmit mode for the remainder of the pass duration.

Lander Commands (Earth to Orbiter): The command load for the Lander is double wrapped on the ground before it is sent to the Orbiter. When it arrives at the Orbiter, the Orbiter strips off the CCSDS wrapper with the Orbiter Header on it. It sees the VC 6 (virtual channel indicating it is a Lander command load) and it immediately sends it to a buffer for transmission to the Lander. Nominally, Lander commands will be sent from Earth to the Orbiter twice. The maximum size of a Lander command load x 2 is estimated to be TBD Mbits, requiring TBD minutes to uplink to the Orbiter at 125 bps.

Lander Commands (Orbiter to Lander): The command load for the Lander waits in the buffer on the Orbiter until the ground schedules a command UHF pass with the Lander. At this time the buffer is downlinked to the Lander. The downlink of the buffer is controlled by sequence. The Orbiter powers on the UHF system, sets the UHF system to transmit, and command to the CE protocol. The Reed-Solomon encoding is bypassed and the downlink data mode is set to fill. Then the downlink data mode is set to command relay. After a pre-set delay the command buffer should be empty and the downlink data mode is set to none. The length of transmission time must be set to empty the entire buffer or the buffer will be cleared. It is estimated that the maximum time required for sending a command load from the Orbiter to the Lander at 8 kbps is TBD minutes. Once the commands are sent to the Lander, the UHF mode is switched to receive Lander telemetry. The UHF system is turned off after the pass is finished.

Note: The Orbiter can only send either X-band or UHF. If the Orbiter is in the middle of a DSN contact pass, and an attempt is made to send commands to the Lander from the Orbiter [e.g. a hybrid pass occurs] the X-band link is broken. This must be accounted for in the X-band communications strategy, including potential impact to DSN SOE generation, reacquisition times, etc.

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DATA RELAY OPERATIONS - LANDER COMMANDING

- **Orbiter Passes over MSP98 Lander Site**
 - 8-10 passes, averaging 6 minutes per pass, each day [5-7 in daytime]
 - » Of these, 4 can be supported as UHF passes by Lander thermal/power constraints at start of Landed surface mission, 3 at the end of the mission.
- **Commanding Scenarios**
 - **Orbiter commanding**
 - » Each Lander UHF pass is a hybrid command/telemetry pass
 - **Hybrid:** Commands can be sent to the Lander at the start of any pass
Autonomous switching to data relay mode, followed by data relay from Lander to Orbiter
- **Lander Commands [Earth to Orbiter]**
 - Command load for Lander double wrapped on ground
 - Upon receipt at Orbiter, commands are identified as Lander commands & sent to buffer for transmission to Lander
 - Nominally, Lander commands sent twice from Earth to the Orbiter. Maximum Lander command load x 2 = TBD Mbits, requiring TBD minutes to send to Orbiter at 125 bps.
- **Lander Commands [Orbiter to Lander]**
 - Buffer containing Lander commands waits on Orbiter until the ground schedules a command UHF pass
 - » Commanding Sequence of Events:
 - UHF system set to transmit, Reed-Solomon encoding bypassed
 - Downlink data mode set to fill, then set to command relay
 - After pre-set delay sized to empty the command buffer, the downlink data mode is set to none and UHF switched to receive Lander telemetry.
 - UHF system turned off after Lander telemetry is received.
 - Time to send the maximum command load at 8 kbps = TBD minutes
 - **Note: Orbiter cannot send data simultaneously via X-band and UHF.** Attempts to send commands to the Lander from the Orbiter during an Orbiter DSN pass will cause the Orbiter's X-band link to be broken, with potential impacts on DSN SOE generation, and usable D/L durations.

4.7.2.2 Lander Data Relay Operations

Lander Telemetry (Lander to Orbiter): The Lander telemetry sequence is straightforward. The Orbiter UHF system is powered up, and set to Receive, using the Cincinnati Electronics (CE) protocol. Once the Lander begins transmitting, the link is established automatically. Once the data are on the Orbiter it is sent off to the FIFO [first in first out] buffer where it is stored for later downlink to Earth. The Lander telemetry has previously been RS [Reed Solomon] encoded on the Lander.

Lander Telemetry (Orbiter to Earth): Once the data are in the buffer, the Orbiter must send it to the Earth. This will be done during the nominal 10-hour DSN contact. Unlike the rest of the Orbiter data, the UHF buffer is not included in any APID table and thus is not automatically sent down with the other spacecraft data. It must be specially commanded to be sent. [Note: onboard the Lander, data can be ordered in its buffer using the Lander's APID tables.] A predetermined time after the beginning of the Orbiter's DSN contact, realtime Orbiter data are sent, until the DSN locks up on the Orbiter's telemetry signal. Interleaved [realtime and stored] Orbiter data are sent next, followed by Lander relay data.

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LANDER DATA RELAY OPERATIONS

- **Lander Telemetry [Lander to Orbiter]:**

- Lander telemetry has been Reed Solomon encoded on the Lander
- Sequence of Events:
 - » Orbiter powers up UHF system, setting system to receive
 - » CE protocol selected
 - » Link established automatically once Lander starts transmission
 - » Data received on Orbiter stored in FIFO [first in first out] buffer for later downlink to Earth.

- **Lander Telemetry [Orbiter to Earth]:**

- Lander data stored in buffer are sent to Earth during nominal 10 hour DSN contact
- Downlink of Lander data must be commanded by the ground. It is not automatically sent with the other Orbiter data.
 - » UHF buffer on Orbiter is not included in an APID table.
 - » Data onboard the Lander can be ordered in its buffer using the Lander APID tables.
- Sequence of Events:
 - » Pre-determined time after start of DSN contact, Orbiter realtime data are sent until DSN locks up on the Orbiter's telemetry signal.
 - » Orbiter interleaved [realtime and stored] data sent next
 - » Lander data sent next

4.8 MAPPING PHASE

4.8.1 Mapping/Relay Orbit

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Index Altitude and Semimajor Axis: Index altitude = 405 km. Semimajor axis = 3802.2 km.

Eccentricity is small but non-zero [mean $e = 0.0083$], and remains bounded.

Inclination: The inclination of the mapping orbit is chosen for a given value of semimajor axis, to maintain approximate synchrony with respect to the fictitious mean sun. For the chosen semimajor axis of 3802.2 km, the sun synchronous inclination is 92.931° . The final range of acceptable inclinations is TBD; it will depend on the range of sun and earth angles required by the flight system and science payload during the Orbiter science mission, the ΔV required to place the spacecraft in the required range of inclinations, and the sun-relative node location after Aerobraking.

Node: The initial location of the descending node at the end of aerobraking is: 4:14 AM $\pm$ 20 minutes [Open of Primary Launch Period] to 4:08 PM, $\pm$ 20 minutes [Close of Primary Launch Period], with respect to the mean sun. The evolution of the local mean solar time during the mission will depend on the chosen range of inclinations.

Argument of Periapse: Since the mapping orbit is initially frozen, the argument of periapse starts out at the South pole, and remains within a few degrees of this location over an extended period of time.

Mean Orbit Elements: The following table shows the mean orbit elements chosen for the frozen mapping orbit. Because the node of the mapping orbit at start of mapping operations is uncertain to within ± 20 minutes [5 degrees], and because the duration of Aerobraking is also uncertain, the node and epoch chosen for the representative orbit elements is equal to those of the final aerobraking states in the Aerobraking Timeline, Appendix A.5.

Appendix A.6 includes plots of solar and earth geometry for an inclination of 92.93° , and a plot of altitude variation in the frozen orbit.

Orbit Maintenance: No orbit maintenance maneuvers are planned once the mapping orbit is established.

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MAPPING/RELAY ORBIT

- **Semimajor Axis:** 405 km index altitude [3802.2 km semimajor axis]
- **Frozen Orbit - Mean Elements** (Mars Mean Equator and Node of Epoch [IAU]):

	Open of Primary	Close of Primary	Comments
Epoch [ET]	12/1/1999 08:44:41	12/4/1999 17:52:34	Final aerobraking periapse epoch
Semimajor Axis	3802.2 km	3802.2 km	405 km index altitude
Eccentricity	0.0083	0.0083	Planetocentric Periapse Altitude = 373.4 km Planetocentric Apoapse Altitude = 436.56 km
Inclination	92.93°	92.93°	Acceptable range TBD
Long. of Asc. Node	1.17°	1.07°	Final aerobraking node [DN LMST = 4:14 PM for Open, 4:08 for Close] Uncertainty = ±20 minutes
Argument of Periapse	270°	270°	
Mean Anomaly	0°	0°	

- **Orbit Maintenance:** no orbit maintenance maneuvers are planned once the mapping orbit is established.

** This page under Change Control **

4.8.2 Mapping Sequence of Events

Nominal mapping activities consist of two types of orbits: Non-Communication Orbits and Communication Orbits. Orbiter science data and Lander science data are collected during either orbit, but are downloaded to Earth, along with Orbiter engineering telemetry and Lander data, only during the Communication Orbits.

Orbiter Payload Activities: PMIRR data taking proceeds continuously over each orbit, including intervals of eclipse and Earth occultation. MARCI images are taken predominantly over the daylit portion of the planet. The night side may be used for MARCI data management.

Communication Orbits: Each day, five consecutive orbits during a contiguous 10 hour interval are planned for downlink of data to Earth. In order to support Lander commanding, it will in general be necessary for this 10 hour interval to be correlated with the Lander's operational "day". Because the rotation periods of Mars and Earth differ by 40 minutes, this produces a secular drift in the Earth-relative times of the 10 hour DSN contact period, during the Lander Support Phase. The 10 hour interval is not tied to Mars rotation after the end of the Lander Support Phase. A portion of the contact period is used for Orbiter commanding and radiometric tracking to support position predicts. All communications during this time are two-way coherent. Earth contact durations during each orbit are limited by Earth occultations, HGA gimbal limits, obscuration of the HGA by the spacecraft body itself, and the Orbiter energy balance. Orbiter data rates, Earth contact times, and daily data volumes are indicated in Appendix A.10

Autonomous momentum management is enabled throughout, for both Communication and non-Communication orbits. As the spacecraft enters sunlight, the solar array tracks the Sun and the HGA tracks Earth to maintain DSN contact. As the spacecraft enters eclipse, the solar array motion is stopped. During eclipse the array is rewound in preparation for re-emergence into the sunlight. The HGA continues to track the position of the Earth even during eclipse and occultation.

The sequence repeats as the spacecraft moves again into sunlight.

Transition to Non-Communication Orbit: At the end of the 10 hour DSN pass, the HGA is parked in a position which minimizes principal axis misalignment, thus reducing RCS fuel usage during mapping and relay.

Non-Communication Orbits: Seven of the twelve orbits the Orbiter experiences every day are non-communication orbits. As the spacecraft moves into sunlight, the solar array tracks the sun until eclipse, or until it enters a hardware keepout zone, at which point the solar array movement is stopped. The solar array is then unwound in preparation for exiting eclipse, at which point the sequence repeats.

Transition to Communication Orbit: At the end of the 14 hour interval of the non-communication orbits, the HGA is moved to the DSN contact attitude.

The Orbiter CPU is set to 20 Mhz throughout.

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MAPPING SEQUENCE OF EVENTS

- **Orbiter Payload Activities:**
 - **PMIRR** data taking proceeds continuously over each orbit, including intervals of eclipse and Earth occultation
 - **MARCI** images taken predominantly over the daylight portion of the planet. [Night side may be used for MARCI data management]
- **Communication Orbits:**
 - Each day, 5 consecutive orbits during a contiguous 10 hour interval are planned for downlink of data to Earth
 - To support Lander commanding this 10 hour interval must in general be correlated with the Lander's operational "day" during the Lander Support Phase.
 - » Different rotation periods of Earth and Mars leads to 40 minutes/day secular drift in 10 hour DSN contact period.
 - All communications are two-way coherent.
 - Earth contact durations during each orbit are limited by Earth occultations, HGA gimbal limits, obscuration of the HGA by the spacecraft body, Orbiter energy balance.
 - Orbiter data rates, Earth contact times, and daily data volumes are indicated in Appendix A.10
 - Autonomous momentum management enabled [Comm and non-Comm orbits]
 - **As s/c moves into sunlight:** solar array tracks the Sun, HGA tracks Earth to maintain DSN contact.
 - **As s/c enters eclipse:** solar array motion is stopped
 - **During eclipse:** solar array is rewound. HGA continues to track the position of the Earth even during eclipse and occultation.
 - The sequence repeats as the spacecraft moves again into sunlight.
- **Transition to Non-Communication Orbit:** At the end of the 10 hour DSN pass, the HGA is parked in a position which minimizes principal axis misalignment, reducing RCS fuel usage during mapping and relay.
- **Non-Communication Orbits:**
 - 7 orbits per day are non-communication orbits.
 - **As s/c moves into sunlight:** solar array tracks the sun
 - **As s/c enters eclipse:** solar array movement is stopped [also if it encounters a hardware keepout zone]
 - **During eclipse:** solar array is unwound in preparation for exiting eclipse, at which point the sequence repeats.
- **Transition to Communication Orbit:** At the end of the 14 hour interval of the non-communication orbits, the HGA is moved to DSN contact attitude.
- **CPU setting:** 20 Mhz throughout.

4.8.3 Mapping Orbit Navigation

Mapping Orbit Prediction Capabilities: Preliminary estimates of orbit prediction capabilities during Mapping are summarized in Appendix A.11. The dominant influence on the accuracy of downtrack orbit prediction is atmospheric density uncertainty at orbital altitudes. Because the Lander Support Phase and the start of Mapping occur at a time in the solar cycle of high flux, and near Mars perihelion, density at the mapping altitude is at its highest during this time, yielding the worst prediction capabilities for the mission. Position prediction requirements during the Lander Support Phase are those needed for adequate prediction of UHF passes. Position prediction accuracies required by the Orbiter science payload will be accommodated on a best efforts basis during the Lander Support Phase. Prediction requirements for Mapping are listed in the Project Policies, Requirements, and Capabilities Document.

Ranging may not be needed during the Mapping Phase.

Mapping Orbit Prediction Frequency Profile [TBD]: Based on preliminary estimates of prediction accuracies required to satisfy payload needs, navigation updates will be required at least weekly during the Lander Support Phase, and during the early portion of the Mapping Phase, until approximately 6/19/00. From 6/19/00 through 5/6/01 predictions every 2 weeks are required. From 5/6/01 through end of mapping, weekly or more frequent predictions will again be required as Mars nears perihelion again.

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MAPPING ORBIT NAVIGATION

- Preliminary position prediction capabilities shown in Appendix A.11
- Lander Support and start of Mapping phases occur at highest density during mission [high solar flux, perihelion]
 - Worst prediction capability during mission
- **Lander Support Phase:**
 - Prediction needs based on UHF pass support.
 - Position prediction required by Orbiter science payload accommodated on best efforts basis
- **Mapping Phase:** prediction requirements listed in PPRDC
- **Position Prediction Frequency Profile [TBD]:**
 - At least weekly during the Lander Support Phase and until 6/19/00 during Mapping.
 - Every 2 weeks from 6/19/00 through 5/6/01.
 - Weekly from 5/6/01 through end of Mapping.
- Ranging may not be needed during the mapping phase.

4.8.4 MARCI Science Campaigns

Two MARCI science campaigns are planned to occur when the True Solar Time at the descending node is at its earliest, enabling the best multispectral imaging during the mission. During these intervals, 70m support is requested to increase data return.

MARCI Science Campaign #1: The first MARCI Science Campaign occurs in March/April 2000. At this point, the True Solar Time is approximately 3:25 PM and the data rate using the 70m antenna is 9.9 kbps [5.7 kbps on the 34m]. Earth range is approximately 2.3 AU. 70m support during this campaign accommodates downlink only. Uplink support still requires use of the 34m antennae. Duration of this campaign is approximately 10 days, from 3/26/99 - 4/4/99.

MARCI Science Campaign #2: The second MARCI Science Campaign occurs in December/January 2002, at the very end of the MSP98 Orbiter mapping mission, during another period of low True Solar Time. The Earth is closer to Mars [1.4-1.6 AU] than it is during the first science campaign, yielding a 33.2 kbps data rate on the 70m [9.9 kbps on 34m]. Also, by this time, uplink capability is scheduled to be available on the 70m subnet, eliminating the need for dual 34m/70m coverage to support both uplink and downlink. This science campaign occupies the final 30 days of the Mapping mission, from 12/18/01 - 1/16/02. True solar time varies between 3:28 and 3:39 PM for launch at the open of the Primary launch period.

The following graphic illustrates the relationship between data rate, local true solar time of the descending node [LTST], and earth range during the mapping mission.

[Go to TOC](#)

MARCI SCIENCE CAMPAIGNS

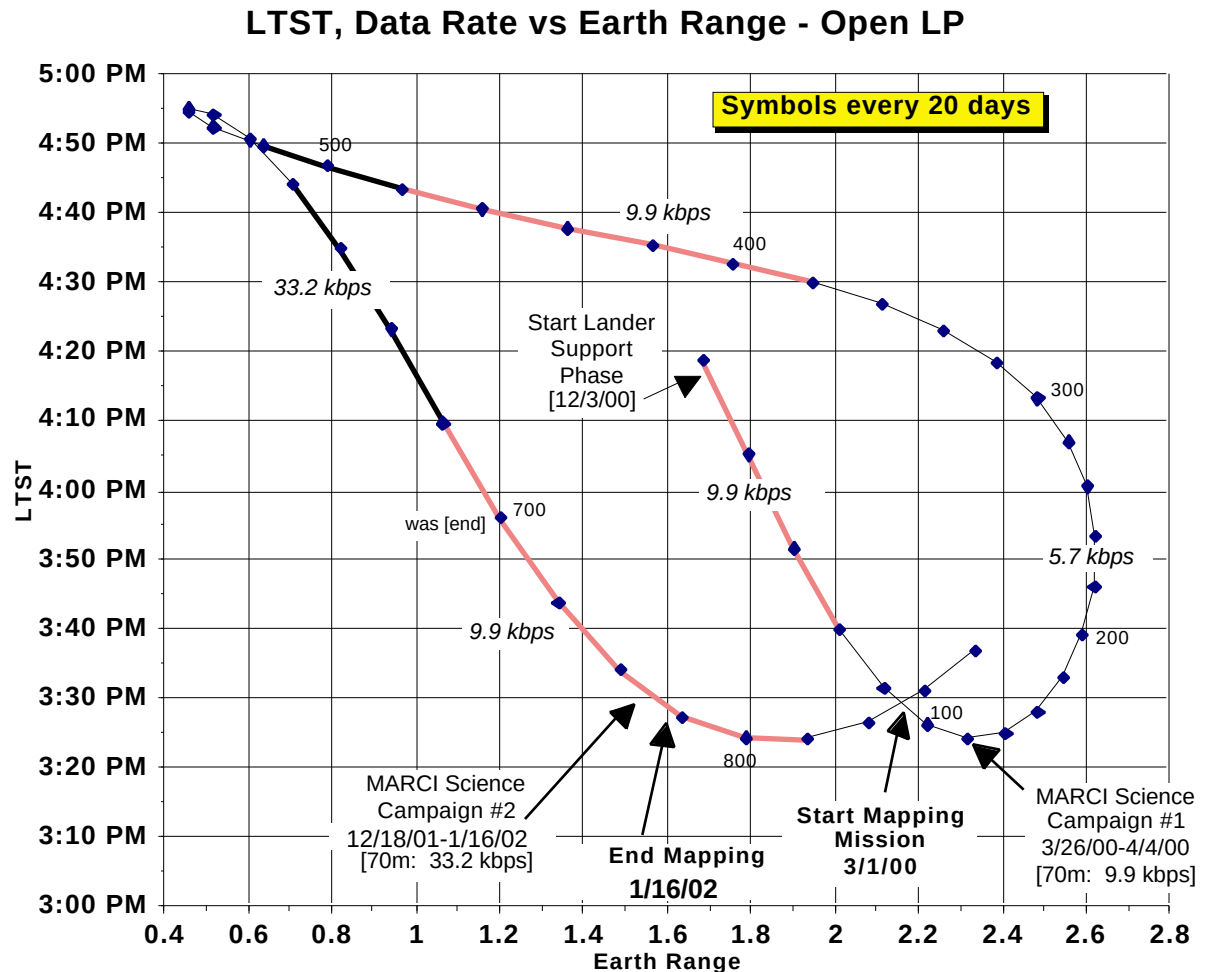
- Planned for lowest True Solar Time at descending node [better multispectral imaging]
- 70m support requested [increased data return.

- MARCI Science Campaign #1:**
3/26/99 - 4/4/99 [10 days]

- True Solar Time = 3:25 PM
- Earth range = 2.3 AU
- **70m data rate = 9.9 kbps**
» 34m data rate = 5.7 kbps
- 70m supports D/L only.
34m required for uplink.

- MARCI Science Campaign #2:**
12/18/01 - 1/16/02 [30 days]

- Final 30 days of Mapping
- True solar time = 3:28 - 3:39 PM [Open of Primary]
- Earth range = 1.4-1.6 AU
- **70m data rate = 33.2 kbps**
» 34m data rate = 9.9 kbps
- Uplink now available on 70m.



4.9 RELAY PHASE

4.9.1 Overview

The Relay phase starts with the termination of mapping operations and continues for approximately three Earth years, terminating approximately 5 Earth years after the transfer to map orbit. [Note: this is an estimate of the likely usable lifetime for the Orbiter. Propellant loading is based on contractual requirements to maintain orbit attitude control and spacecraft operability for a total of 3 Earth years from the start of Mapping.] During this interval, the Orbiter acts primarily as a command and data relay asset for other landed surface stations, as needed.

4.9.2 End-of-Mission Planetary Protection Activities

In accordance with the provisions of the Planetary Protection Plan [3-2001] and related documents, the Project must demonstrate the ability to satisfy the following impact probabilities for the Orbiter, assuming no special bioburden control is effected:

The probability of entry into the martian atmosphere shall not exceed the following levels for the specified time periods:
1% for the first 20 years from date of launch, 5% for the period of 20 to 50 years from date of launch.

The MGS Project has determined that, in order to satisfy these requirements, MGS shall be raised to an index altitude of 427 km at the end of its mapping phase. Equivalent altitudes for the MSP98 Orbiter range from approximately 396-449 km, depending on the drag factor at which the uncontrolled Orbiter would stabilize. Because the baseline index altitude of 405 km for the mapping orbit lies between these extremes, some action at the end of the Relay phase may be required to satisfy planetary protection. If sufficient propellant is available at end of mission, the spacecraft will be placed into a circular orbit at a higher altitude. [Note: this requires a maneuver of approximately 19 m/s. Feasibility and/or max size of maneuver after HGA deployment is TBD.] Approximately 3.5 kg of Hydrazine is required to place the Orbiter into a circular orbit at 449 km; the probability that this amount of propellant will be available three years after transfer to the map orbit is approximately 97%. If, however, no end-of-mission propellant remains for translational maneuvers, the Orbiter may be reconfigured and/or turned to present a smaller drag area for increasing orbit lifetime. Options include: turning to a passively stable low-drag attitude, “feathering” the solar array, and deliberately tumbling the spacecraft.

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RELAY PHASE

- **Overview**

- Begins with termination of mapping operations, terminates ~5 Earth years after start of Mapping
 - » Note: propellant loading based on 3 Earth years operability from start of Mapping
- Primary Orbiter mission is command and data relay support for Mars landers, as needed.

- **End-of-Mission Planetary Protection Activities**

- Planetary Protection Plan [3-2001] requirements: probability of entry into the martian atmosphere $\leq 1\%$ for the first 20 years from date of launch, $\leq 5\%$ for the period of 20 to 50 years from date of launch.
- MGS Planetary Protection altitude = 427 km
 - Equivalent altitudes for MSP98 Orbiter: 396 km [lowest drag area] - 449 km [highest drag area]
- **At End of Relay - Only Phase:**
 - If sufficient propellant is available, Orbiter is placed into a higher altitude orbit
 - 3.5 kg required to place Orbiter into 449 km circular orbit. The probability that this amount of propellant will be available 3 years after transfer to map orbit, is approximately 97%.
 - Requires 19 m/s w/ deployed HGA. Feasibility &/or max size of maneuver after HGA deployment TBD.
 - If no propellant available for translational maneuver, Orbiter may be reconfigured and/or turned to present a smaller drag area for increasing orbit lifetime. Options include:
 - Turn to passively stable low-drag attitude
 - "Feather" solar arrays
 - Deliberate tumbling of s/c

4.10 ORBITER DESIGN REFERENCE MISSIONS

4.10.1 Overview and Assumptions

** This page under Change Control **

Design Reference Missions have been developed for the Orbiter, to measure mission and spacecraft performance during critical or stressing situations, and assess effects of changes in the sequence of events. These scenarios are:

- DRM #1: MSP98 Lander Relay Support Phase
- DRM #2: Mars Aphelion
- DRM #3: Minimum Earth-Mars Distance

Orbit Geometry: It is assumed that Aerobraking operations place the orbit node at its nominal expected position with respect to the sun [i.e. descending node at 4:14 PM for the open of the Primary Launch Period, and 4:08 PM at the end of Primary].

Payload Operations: MARCI runs continuously at 4 Watts per camera (8 Watts total). PMIRR runs continuously at 40.4 watts plus 4.1 watts for auxiliary power at aphelion.

Communications, CPU utilization: Five comm orbits and 7 non-comm orbits are baselined per day, consistent with the 10 hours per day allocated for contact with Earth. Use of 34m HEF dishes is assumed. The spacecraft operates at 20 MHz throughout. During non-comm intervals, 3 MHz is allocated to science payload operations. Science payload CPU allocations during a DSN contact (i.e. during actual transmit times) are: 2.8 MHz at 9.9 kbps, 2.5 MHz at 33 kbps, and 1.7 MHz at 110 kbps. The remainder of the 20 MHz must accommodate all spacecraft bus operations and 25% system margin.

Bus Data Management: Maximum data transfer rate across the RS-422 is 1 Mbit/sec. The processor utilization for obtaining this rate is allocated against science; it is not in the spacecraft portion of the budget. DRAM buffer size for MARCI data is as per the MARCI ICD (330 Mbits work space, 512 Kbytes software, 24 Kbytes DSP init, etc.). DRAM buffer size for PMIRR data is as per the PMIRR ICD (small compared to MARCI).

Orbiter Data Volume estimates are contained in the file "orbitermapdatavol_revA1.97" on the MSP collaborative server in LMA Distributed/System Engineering and Integration/System Tools/. [See Also Appendix A.10]. Science data volume indicated on these files is for science data plus science packet overhead. Engineering data, RS encoding, CCSDS frame and transfer overhead have been removed from these estimates. Science packet overhead is dependent on the length of the science packets. [E.g. if each science packet is 11 bytes then the overhead is 100% since the telemetry packet overhead is 11 bytes. If the science data packets are 1000 bytes long then the overhead is 1.1%.] DSN lockup time and some margin for modeling uncertainty have also been removed. Some additional system margin has been withheld at Mars Aphelion to support potential variations to the power budget.

ORBITER DESIGN REFERENCE MISSIONS - Overview and Assumptions

- **Purpose:** Design Reference Missions measure mission and spacecraft performance during critical or stressing situations, and assess effects of changes in the sequence of events.
- **Scenarios:**
 - DRM #1: MSP98 Lander Relay Support Phase**
 - DRM #2: Mars Aphelion**
 - DRM #3: Minimum Earth-Mars Distance**
- **Orbit Geometry:** nominal post-aerobraking descending node: 4:14 PM [open Primary Launch Period], 4:08 PM [end of Primary].
- **Payload Operations:**
 - MARCI runs continuously, 4 Watts per camera (8 Watts total).
 - PMIRR runs continuously, 40.4 watts plus 4.1 watts for auxiliary power at aphelion.
- **Communications, CPU utilization, Margins:**
 - 5 Five comm orbits, 7 non-comm orbits per day, using 34m HEF antennae.
 - S/c operates at 20 MHz throughout.
 - Science CPU allocations:
 - » Non-comm intervals: 3 MHz allocated to science payload.
 - » Comm intervals [during actual transmit times]: 2.8 MHz at 9.9 kbps, 2.5 MHz at 33 kbps, and 1.7 MHz at 110 kbps. Remainder must accommodate spacecraft bus operations & 25% system margin.
- **Bus Data Management:**
 - Maximum data transfer rate across the RS-422 = 1 Mbit/sec. [Processor utilization for obtaining this rate is allocated against science; it is not in the spacecraft portion of the budget.]
 - MARCI: DRAM buffer size per MARCI ICD (330 Mbits work space, 512 Kbytes software, 24 Kbytes DSP init, etc.).
 - PMIRR: DRAM buffer size per PMIRR ICD
- **Orbiter Data Volume estimates: see Appendix A.10**
 - Science data volume is for science data plus science packet overhead.
 - » Engineering data, RS encoding, CCSDS frame and transfer overheads, DSN lockup time, & margins for modeling uncertainty have been removed.
 - » Aphelion only: additional system margin withheld to accommodate potential variations to the power budget.
 - Science packet overhead dependent on length of the science packets.

** This page under Change Control **

4.10.2 Orbiter Design Reference Mission #1 - Lander Support Phase

** This page under Change Control **

Orbiter Design Reference Mission #1 consists of 3 cases, appropriate for stressing conditions during each of the 3 major subphases of the Lander Support Phase [See Section 4.7 - Lander Support Phase].

Case 1.a [Suphase 1]: During this subphase, the majority of the science D/L capability of the Orbiter is assigned to Lander data relay. Remaining D/L capability is available for Orbiter housekeeping, instrument aliveness tests, and payload operations. The comm time per orbit is approximately 63 minutes, at 9.9 kbps. Daily data volume [not including packet overhead or X-band pass interruptions due to lander commanding via UHF] = 160 Mbits. Maximum eclipse duration during this subphase is approximately 31 minutes. It is assumed that the Orbiter supports 4 UHF passes of the Lander per Lander day.

Case 1.b [Subphase 2]: During this interval, the Lander receives approximately 110 Mbits of the total D/L volume. PMIRR and MARCI operate at a reduced level [approximately 40 Mbits/day]. The comm time per orbit is approximately 67 minutes, at 9.9 kbps. Daily data volume [not including packet overhead or X-band pass interruptions due to lander commanding via UHF] = 163 Mbits. Maximum eclipse duration during this subphase is approximately 32-33 minutes. It is assumed that the Orbiter supports 4 UHF passes of the Lander per Lander day.

Case 1.c [Subphase 3]: During this subphase, eclipse time is approximately 32 minutes per orbit for the open of the Primary launch period, and 33 minutes at the close of the Primary launch period. True solar time of the descending node is 3:28 p.m. for open of Primary, and 3:20 at the close of Primary. The communications time per orbit is approximately 65 minutes at 5.7 kbps. Total Science data volume returned by the Orbiter (not including packet overhead) is 90 Mbits per day, of which approximately 70 Mbits/day are allocated to Orbiter science. One daily UHF communication with the Lander is allocated for the MSP98 Orbiter during this time, primarily for the purpose of commanding the Lander. Although some telemetry from the Lander to the Orbiter may be sent up during this pass, the primary data relay path during this time is the MGS orbiter. There is some additional overhead on total data volume returned each day because of the interruption to the X-band pass on the Orbiter during the UHF contact with the Lander.

The CPU processor utilization for science is limited to 3 MHz for non comm periods [i.e. whenever the X-band transmitter is not powered on, approximately 57 minutes per orbit]. CPU processor utilization for science is limited to 2.8 Mhz for comm periods [63 minutes per orbit].

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ORBITER DESIGN REFERENCE MISSION #1 - LANDER SUPPORT PHASE

Timeline To Be Supplied

** This page under Change Control **

4.10.3 Orbiter Design Reference Mission #2 - Mars Aphelion

** This page under Change Control **

The Mars Aphelion Design Reference Mission examines Orbiter operations at aphelion [11/3/2000] a time of reduced power output. Eclipse time is approximately 21 minutes per orbit at open of the Primary launch period and 23 min. at close of Primary. True solar time of the descending node is 4:23 PM at the open of Primary, and 4:16 at the close of Primary. The communication time per orbit is approximately 42 minutes @ 5.7 kbps. The total Science data volume per day (not including packet overhead) is about 57 Mbits. CPU processor utilization for science is limited to 3 MHz for non comm periods and 2.8 MHz for comm periods.

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ORBITER DESIGN REFERENCE MISSION #2 - MARS APHELION

Timeline To Be Supplied

** This page under Change Control **

4.10.4 Orbiter Design Reference Mission #3 - Minimum Earth-Mars Distance

** This page under Change Control **

The Minimum Earth-Mars Distance Design Reference Mission examines Orbiter operations at 6/22/2001. It is assumed that the Orbiter operates at its maximum data rate of 110 kbps. At this point in the mission the orbiter is in constant sunlight, but the solar arrays are off-sun approximately 10 minutes per orbit while the panel unwinds. Thermal limits on the SSPA limit the communications interval to 75 minutes per orbit. True solar time of the descending node is approximately 4:54 p.m. for launch at the open of the Primary launch period, and 4:47 p.m. at close of Primary. Total Science data volume per day (not including packet overhead) is approximately 2090 Mbits. CPU processor utilization for science is limited to 3 MHz for non comm periods and 1.7 MHz for comm periods.

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ORBITER DESIGN REFERENCE MISSION #3 - MINIMUM EARTH-MARS DISTANCE

Timeline To Be Supplied

** This page under Change Control **

APPENDIX A: ORBITER MISSION DATABOOK

- A.1 Orbiter Mission Database**
- A.2 Orbiter DSN and Air Force Tracking Initial Acquisition Geometry**
- A.3 Orbiter Cruise Trajectory Characteristics**
- A.4 MOI Illustrations**
- A.5 Aerobraking Database**
 - A.5.1 Open Primary Launch Period: State Data and Strawman Tracking Schedule
 - A.5.2 Close Primary Launch Period: State Data and Strawman Tracking Schedule
- A.6 Orbiter Post-Arrival Trajectory Characteristics**
 - A.6.1 Solar Time and Eclipse Durations During Mission
 - A.6.2 Post-Arrival Planetary Geometry
 - A.6.3 Frozen Orbit Characteristics
- A.7 Orbiter Configuration Drawings**
- A.8 Orbiter Navigation Memo**
- A.9 Orbiter Monte Carlo Simulation Description**
- A.10 Orbiter Data Rates, Earth Contact Durations, Daily Data Volumes**
 - A.10.1 Orbiter and Lander Communication Strategy during the Mission [Memo MSP-SE-97-0162]
 - A.10.2 Data Rates, Data Volumes during Mapping
- A.11 Orbiter Mapping Navigation**
- A.12 34m BWG Usage and Tracking Schedule Modifications**
 - A.12.1 DSN Contention Resolution
 - A.12.2 Approach, near-Simultaneous Tracking Integrated Schedule
- A.13 Orbiter Approach Targeting Data** **This Section under Change Control**

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A.1 Orbiter Mission Database

|

Orbiter Mission Database

10/24/96

Departure Coord. System: Hyperbolic Asymptote Earth equator and equinox of J2000 WRT: Earth
 lorb = 152
 all times Ephemeris Time unless otherwise indicated

Day in Launch Period	Injection Date	Injection Time	Cartesian X [km]	Cartesian Y [km]	Cartesian Z [km]	Cartesian Xdot [km/s]	Cartesian Ydot [km/s]	Cartesian Zdot [km/s]	Depart C3 [km^2/s^2]	Depart Dec.Vinf [deg.]	Depart RA.Vinf [deg.]
1	12/10/98	20:12:07.2	1483.362	5711.844	-2908.145	-11.049	2.319	-2.213	11.189	14.404	217.881
2	12/11/98								11.101	14.141	217.727
3	12/12/98								10.941	14.849	218.044
4	12/13/98								10.781	15.550	218.249
5	12/14/98								10.636	16.161	218.421
6	12/15/98								10.508	16.754	218.641
7	12/16/98								10.393	17.377	218.880
8	12/17/98	19:11:51.4	1505.555	5624.569	-3040.162	-11.106	2.515	-1.407	10.287	18.860	219.530
9	12/18/98								10.193	18.693	219.325
10	12/19/98								10.109	19.368	219.518
11	12/20/98								10.036	20.046	219.691
12	12/21/98								9.974	20.723	219.845
13	12/22/98								9.924	21.392	219.983
14	12/23/98								9.885	22.051	220.106

Maximum 11.189

MacDAC Injection Data [from 5/31/96]

Launch Date	Launch Time [UTC]	3rd Stage Burnout [UTC]	C3 km^2/s^2	Decl Vinf [deg.]	RA Vinf [deg.]
12/10/98	19:30:44	20:11:06	11.2628	13.496	217.357
12/17/98	18:28:37	19:10:50	10.288	18.027	219.111
12/25/98	17:00:40	17:46:25	9.841	23.322	220.322

Orbiter

10/24/96

Arrival

Coord System: Hyperbolic Asymptote equator and node of epoch [IAU] WRT: Mars

lorb = -11073

all times Ephemeris Time unless otherwise indicated

Day in Launch Period	Flight Time [days]	Arrival Date	Arrival Time	Arrival Peri.Rad* [km]	Incl. [deg.]	Arrival T.wrt.Peri [sec.]	Arrival Vinf [km/s]	Arrival Dec.Vinf [deg.]	Arrival RA.Vinf [deg.]
1	286.451	9/23/99	07:01:37.9	3557.200	92.930	0.000	3.344	-29.727	173.327
2	288.065	9/25/99	01:33:22.5	3557.200	92.930	0.000	3.341	-29.817	172.451
3	287.734	9/25/99	17:36:23.0	3557.200	92.930	0.000	3.343	-30.229	172.606
4	287.445	9/26/99	10:40:08.3	3557.200	92.930	0.000	3.345	-30.652	172.734
5	287.179	9/27/99	04:18:12.1	3557.200	92.930	0.000	3.348	-31.087	172.845
6	286.921	9/27/99	22:06:50.1	3557.200	92.930	0.000	3.352	-31.530	172.949
7	286.685	9/28/99	16:26:17.5	3557.200	92.930	0.000	3.356	-31.980	173.036
8	285.242	9/29/99	01:00:03.6	3557.200	92.930	0.000	3.365	-32.870	173.728
9	286.293	9/30/99	07:01:54.1	3557.200	92.930	0.000	3.367	-32.897	173.156
10	286.139	10/1/99	03:19:39.4	3557.200	92.930	0.000	3.374	-33.362	173.188
11	286.012	10/2/99	00:17:49.6	3557.200	92.930	0.000	3.382	-33.831	173.202
12	285.914	10/2/99	21:56:26.7	3557.200	92.930	0.000	3.391	-34.301	173.198
13	285.844	10/3/99	20:15:23.6	3557.200	92.930	0.000	3.400	-34.772	173.177
14	285.802	10/4/99	19:15:12.8	3557.200	92.930	0.000	3.411	-35.241	173.138

Maximum 3.411

* does not include effects of altitude loss during MOI finite burn

Orbiter

10/24/96

Capture Orbit*

Coord System: Classical (Keplerian) equator and node of epoch [IAU]

WRT: Mars

lorb = -71

all times Ephemeris Time unless otherwise indicated

Day in Launch Period	Capture Semi-M.Ax [km]	Capture eccen.	Capture Incl [deg.]	Capture Node [deg.]	Capture Arg.Peri [deg.]	Capture Mean.An [deg.]	Local Mean Solar Time of DN [hh:mm:ss PM]	Days to Lander Arrival	Capture Period [hrs]
1	21473.888	0.83434765	92.93	-4.998	151.00	0	6:15:29 PM	71.6	26.5
2	21329.956	0.83322985	92.93	-5.868	151.12	0	6:08:17 PM	69.8	26.3
3	21420.244	0.83393279	92.93	-5.685	151.51	0	6:07:37 PM	69.1	26.4
4	21539.985	0.83485597	92.93	-5.528	151.92	0	6:06:45 PM	68.4	26.7
5	21713.530	0.83617587	92.93	-5.386	152.32	0	6:05:47 PM	67.7	27.0
6	21925.739	0.83776146	92.93	-5.252	152.73	0	6:04:45 PM	67.0	27.4
7	22185.047	0.83965777	92.93	-5.132	153.14	0	6:03:38 PM	66.2	27.9
8	22781.944	0.8438588	92.93	-4.377	153.94	0	6:05:55 PM	65.8	29.0
9	22891.985	0.84460937	92.93	-4.947	153.95	0	6:01:00 PM	64.6	29.2
10	23344.949	0.84762443	92.93	-4.881	154.34	0	5:59:30 PM	63.7	30.1
11	23895.555	0.85113549	92.93	-4.832	154.74	0	5:57:52 PM	62.9	31.2
12	24542.069	0.85505705	92.93	-4.801	155.12	0	5:56:06 PM	62.0	32.4
13	25306.845	0.85943724	92.93	-4.787	155.50	0	5:54:12 PM	61.0	34.0
14	26227.260	0.86437012	92.93	-4.790	155.86	0	5:52:11 PM	60.1	35.8

* Data are approximate, based on 29 hr orbit at end of Primary period, impulsive maneuvers.

Lander Arrival 12/3/99 20:56:51

A.2 Orbiter DSN and Air Force Tracking Initial Acquisition Geometry

ORBITER

JET PROPULSION LABORATORY

INTEROFFICE MEMORANDUM

312/96.2-2010

Aug 21, 1996

TO: Phil Knocke

FROM: Steve Williams *SW*

SUBJECT: Mars 98 Tracking Station Initial Acquisition Geometry Update

This memo provides Mars 98 Initial acquisition geometries for a 2 hour period following stage 3 burnout for the 3 DSN stations and the 12 Air Force tracking stations given below. The burnout states used here were provided by you in a personal communication. The data is arranged in seven groups:

- 1) day 1 lander trajectories launching on 3 Jan 99 (short coast)
- 2) day 8 lander trajectories launching on 10 Jan 99 (short coast)
- 3) day 16 lander trajectories launching on 16 Jan 99 (short coast)
- 4) day 25 lander trajectories launching on 27 Jan 99 (short coast)
- 5) day 1 orbiter trajectories launching on 10 Dec 98 (short coast)
- 6) day 8 orbiter trajectories launching on 17 Dec 98 (short coast)
- 7) day 16 orbiter trajectories launching on 25 Dec 98 (short coast)

As before, four parameters are plotted for each station: range, range rate, elevation angle, and aspect angle between the S/C z-axis and the vector to the station (z-axis is assumed to be the S/C velocity vector at burnout as we discussed).

Stations shown in this memo are :

GOLD : Goldstone

MAD : Madrid

CAN : Canberra

ANT : Antigua

ASC : Ascension Island

DGS : Diego Garcia

LBV : Libreville, Gabon

IOS : Indian Ocean

KWAJ : Ennylabegan

HTS : Hawaii

GTS : Guam

HBK : Hartebeesthoek, South Africa

TEL4 : Tel-4

VTs : Vandenberg

PRTH : Perth

Distribution

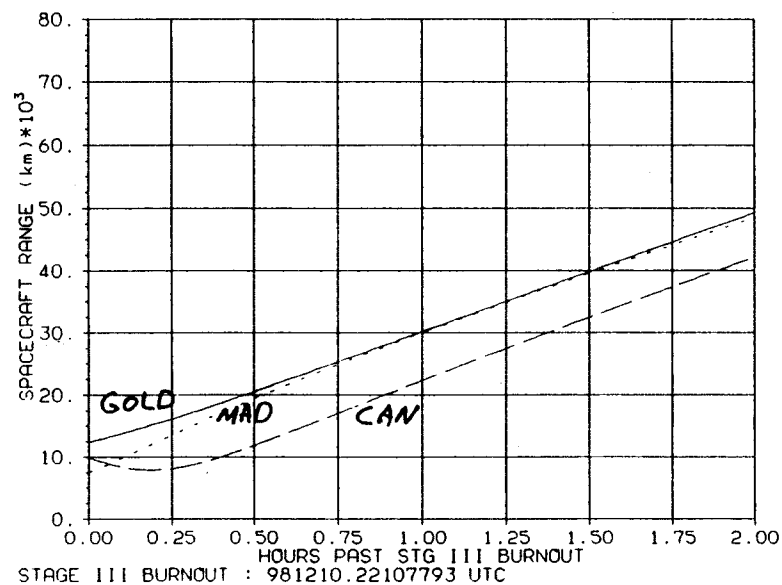
D. Murrow

R. Roncoli

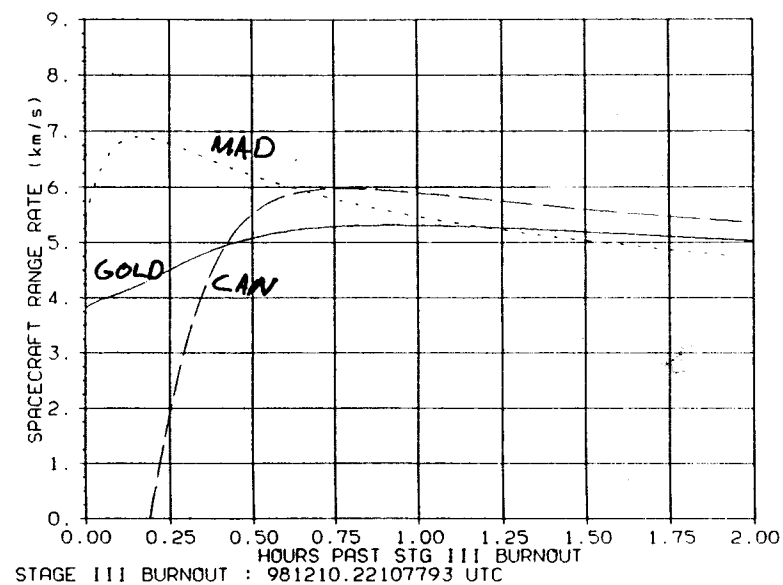
ORBITER DAY 1 (12/10/98) SHORT COAST

TRACKING STATION GEOMETRY (ORBITER): DAY 1 SHORT COAST

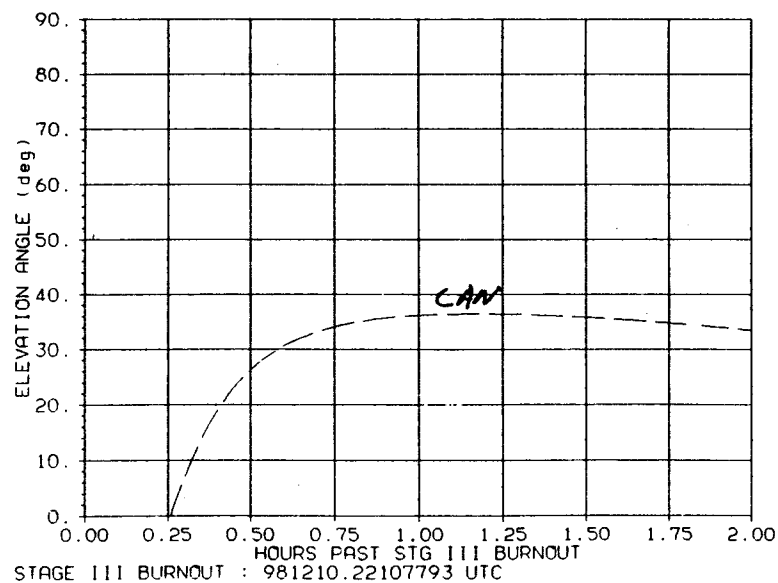
SPACECRAFT RANGE



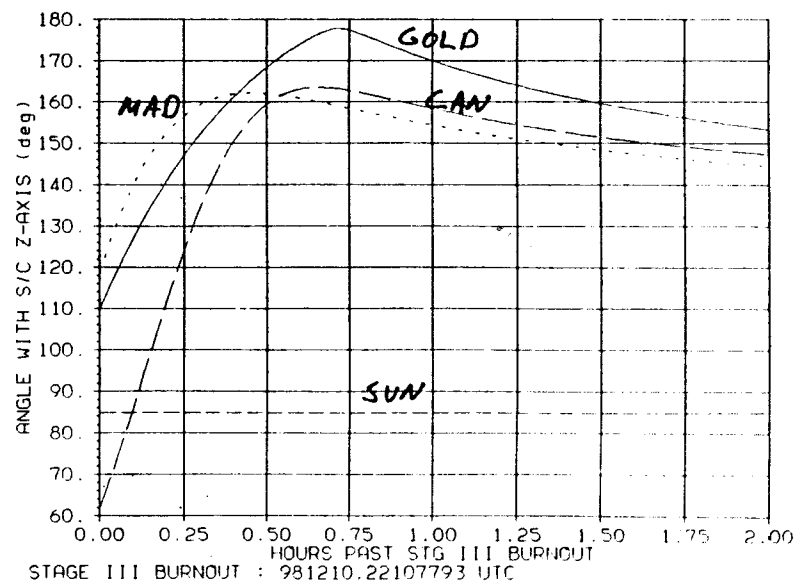
SPACECRAFT RANGE RATE



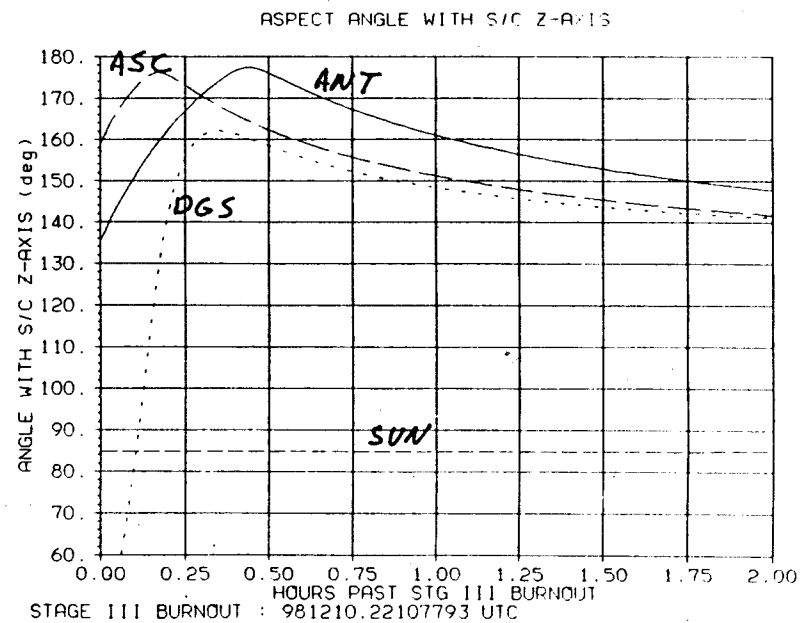
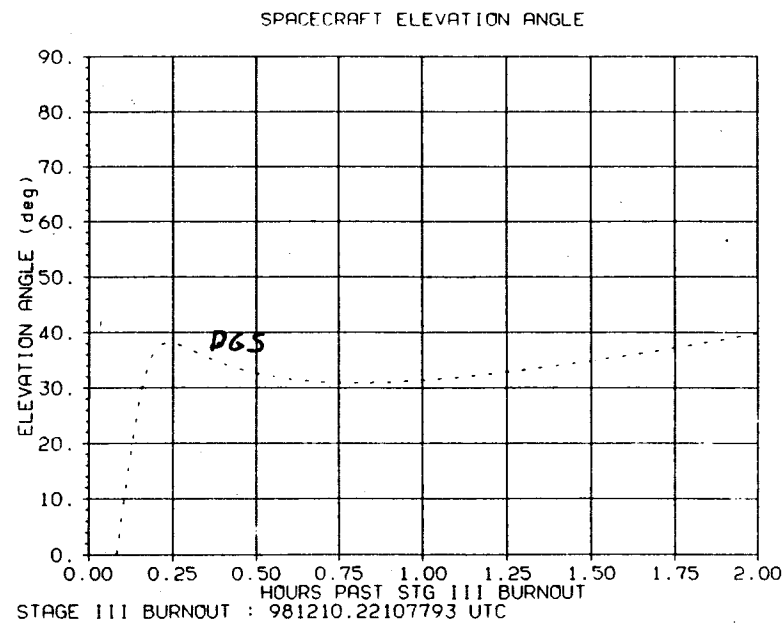
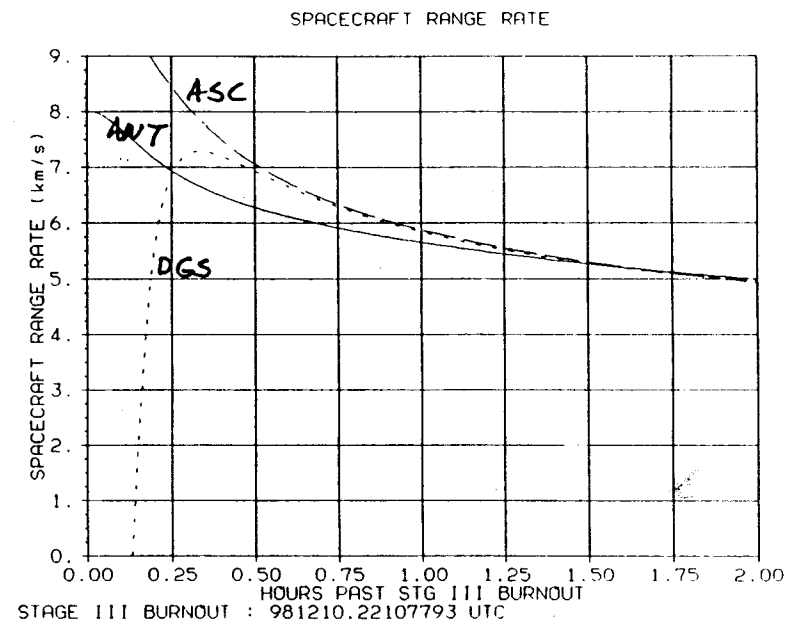
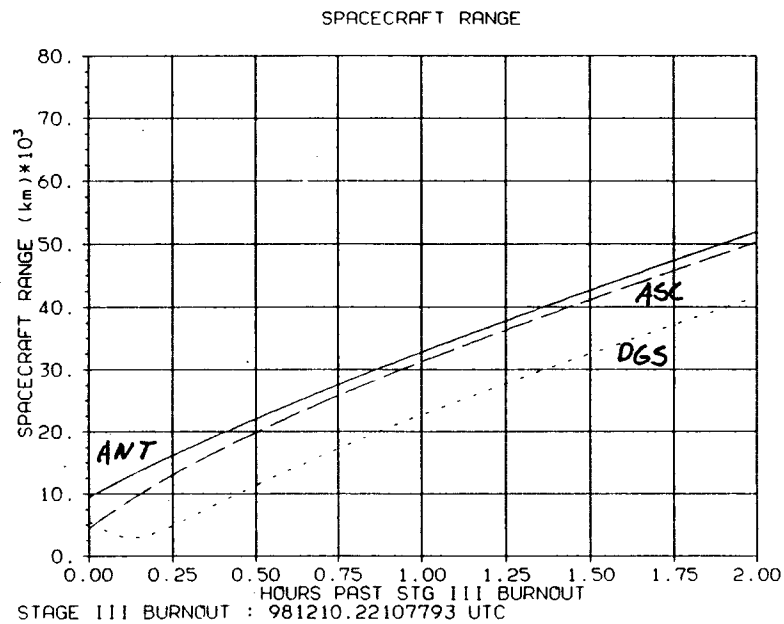
SPACECRAFT ELEVATION ANGLE



ASPECT ANGLE WITH S/C Z-AXIS

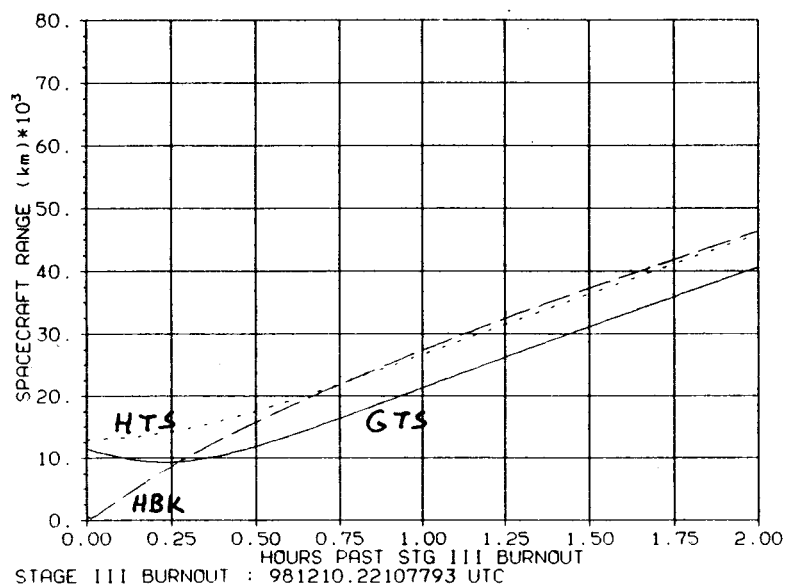


TRACKING STATION GEOMETRY (ORBITER): DAY 1 SHORT COAST

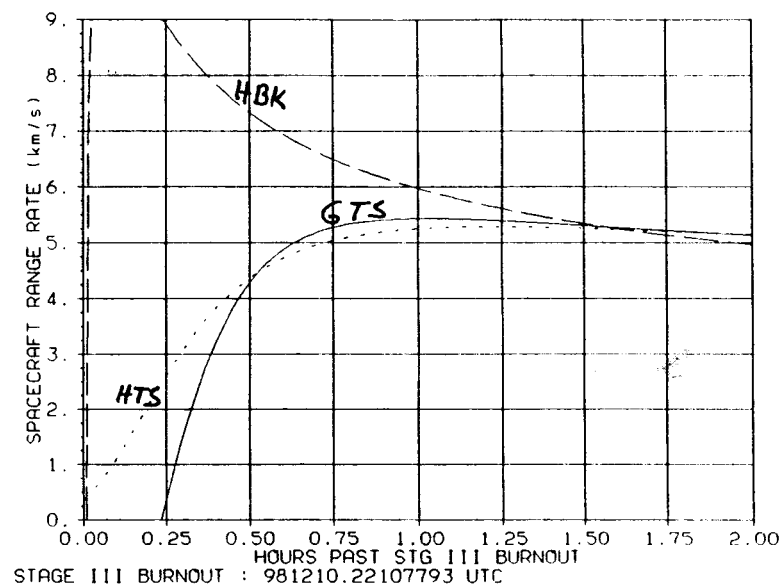


TRACKING STATION GEOMETRY (ORBITER): DAY 1 SHORT COAST

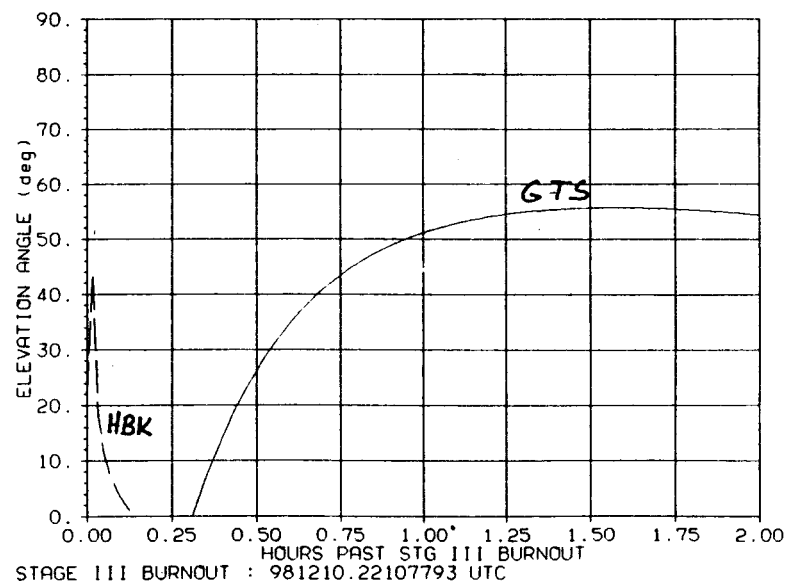
SPACECRAFT RANGE



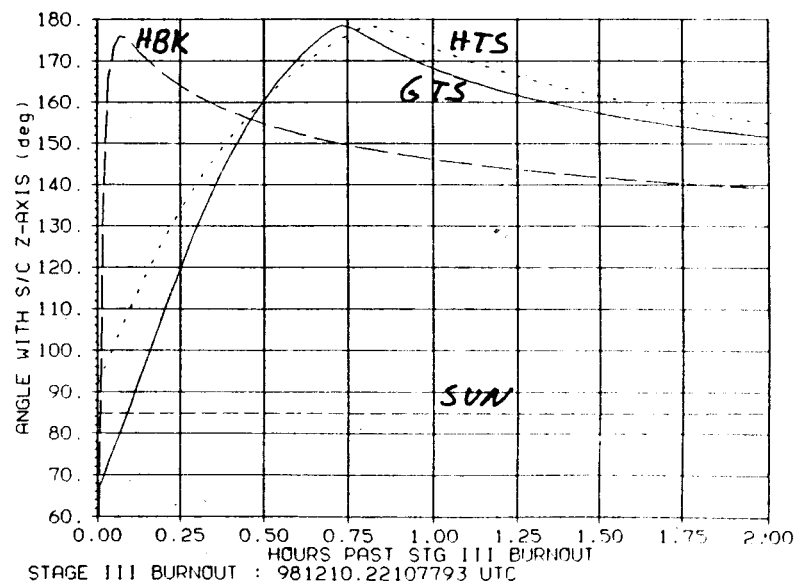
SPACECRAFT RANGE RATE



SPACECRAFT ELEVATION ANGLE

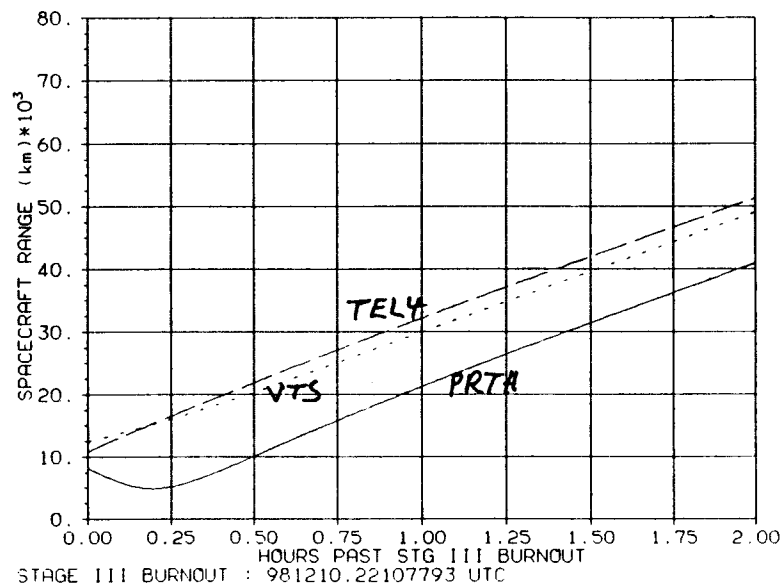


ASPECT ANGLE WITH S/C Z-AXIS

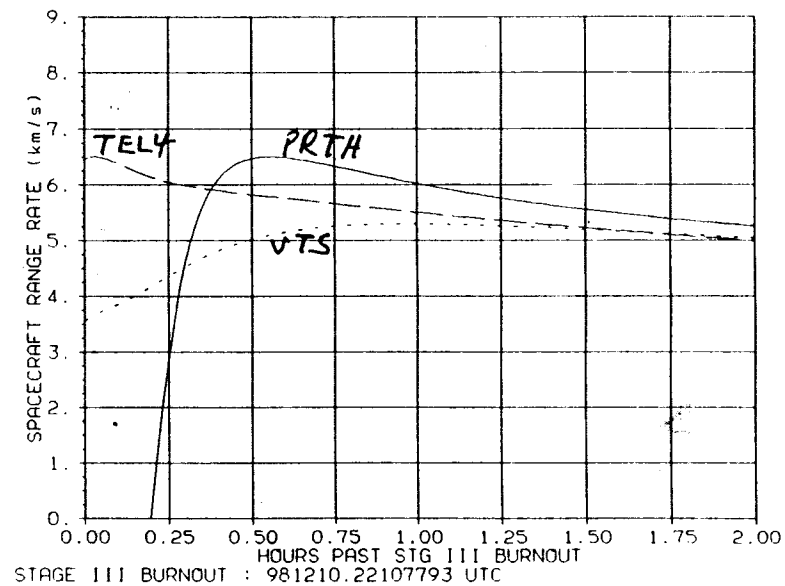


TRACKING STATION GEOMETRY (ORBITER): DAY 1 SHORT COAST

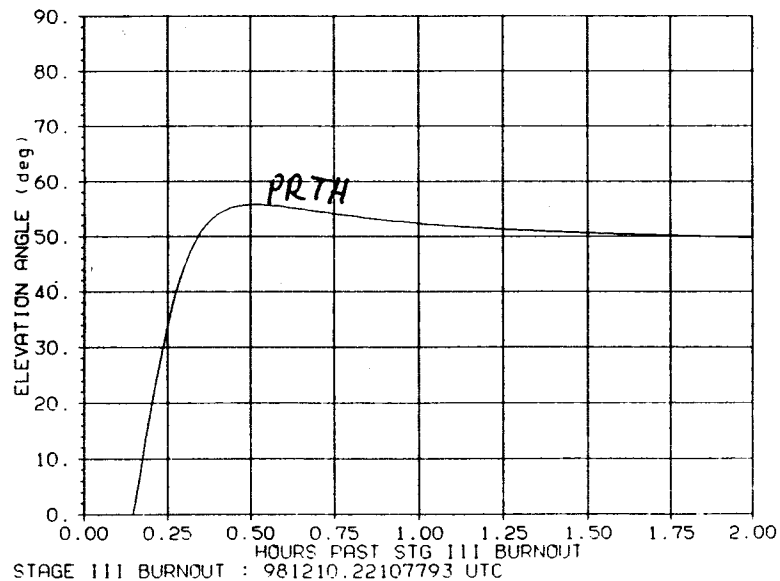
SPACECRAFT RANGE



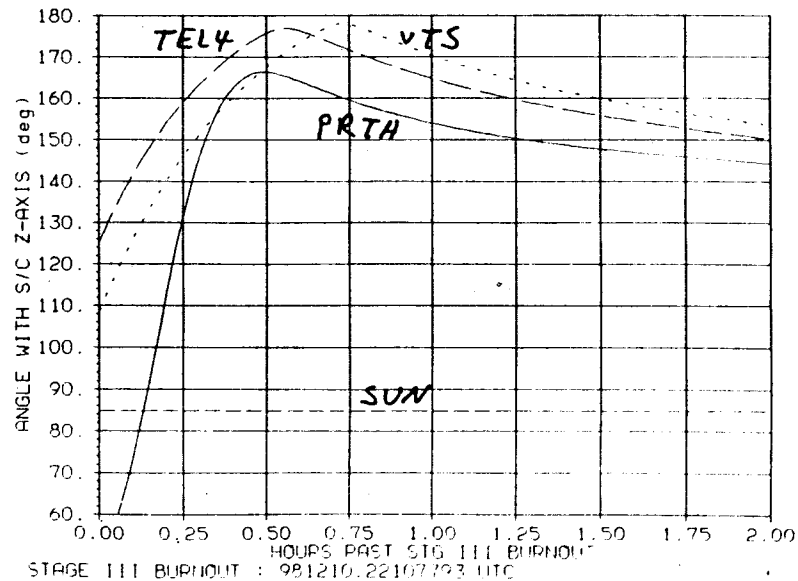
SPACECRAFT RANGE RATE



SPACECRAFT ELEVATION ANGLE

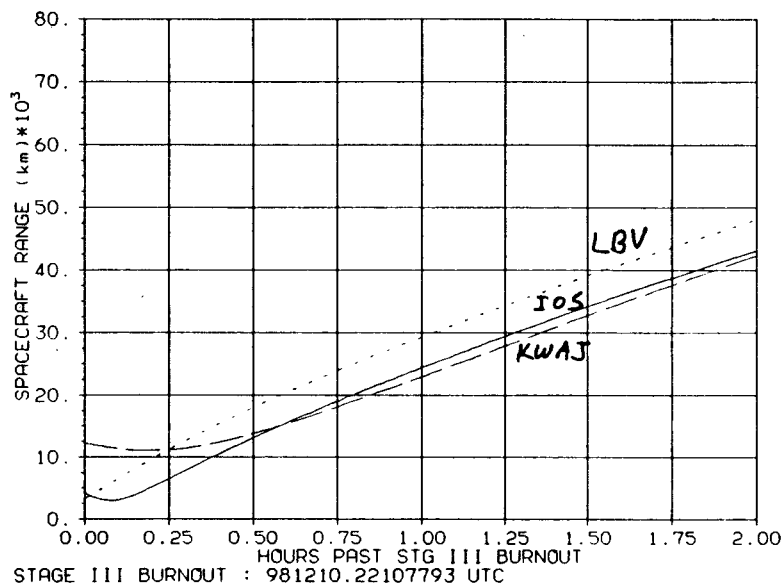


ASPECT ANGLE WITH S/C Z-AXIS

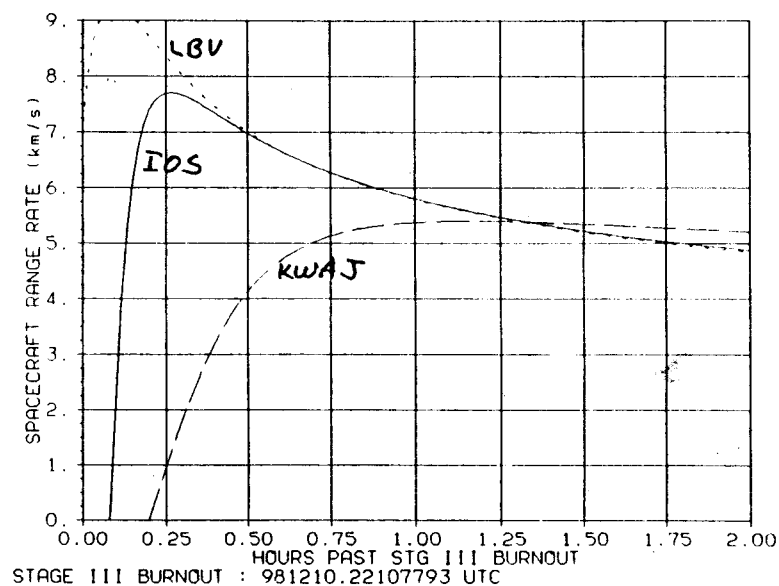


TRACKING STATION GEOMETRY (ORBITER): DAY 1 SHORT COAST

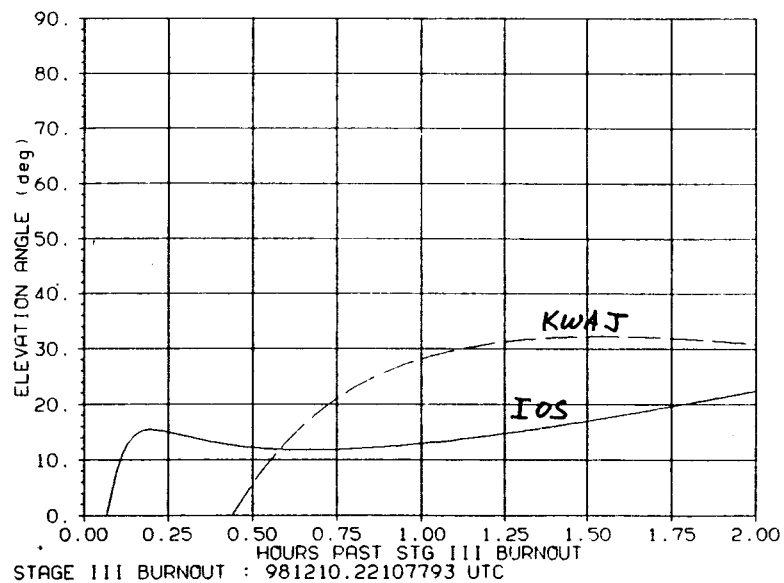
SPACECRAFT RANGE



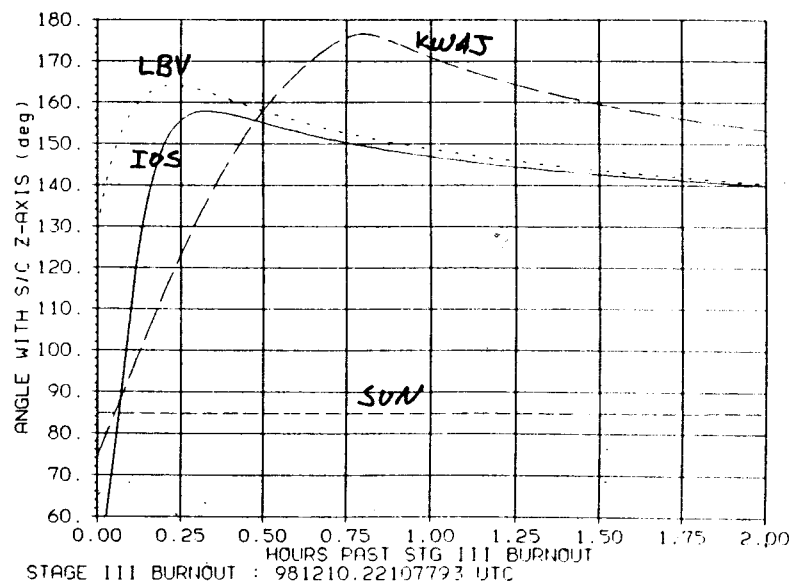
SPACECRAFT RANGE RATE



SPACECRAFT ELEVATION ANGLE



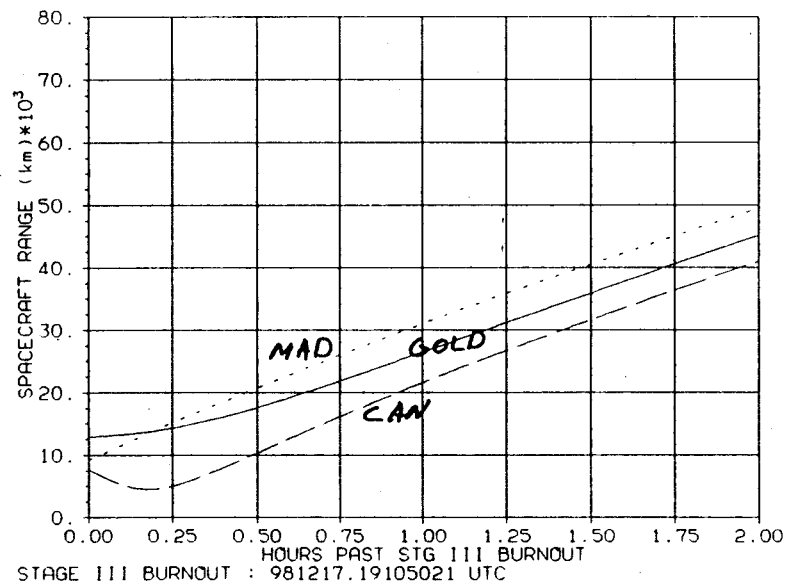
ASPECT ANGLE WITH S/C Z-AXIS



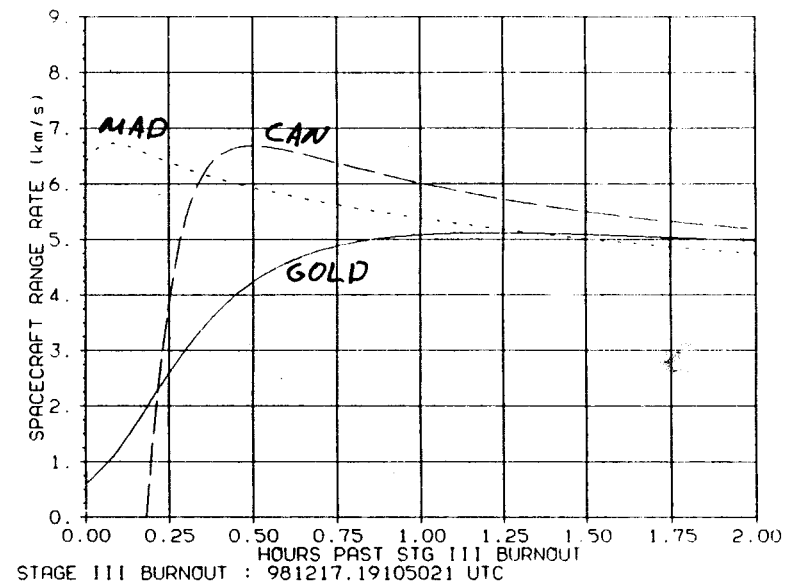
ORBITER DAY 8 (12/17/98) SHORT COAST

TRACKING STATION GEOMETRY (ORBITER): DAY 8 SHORT COAST

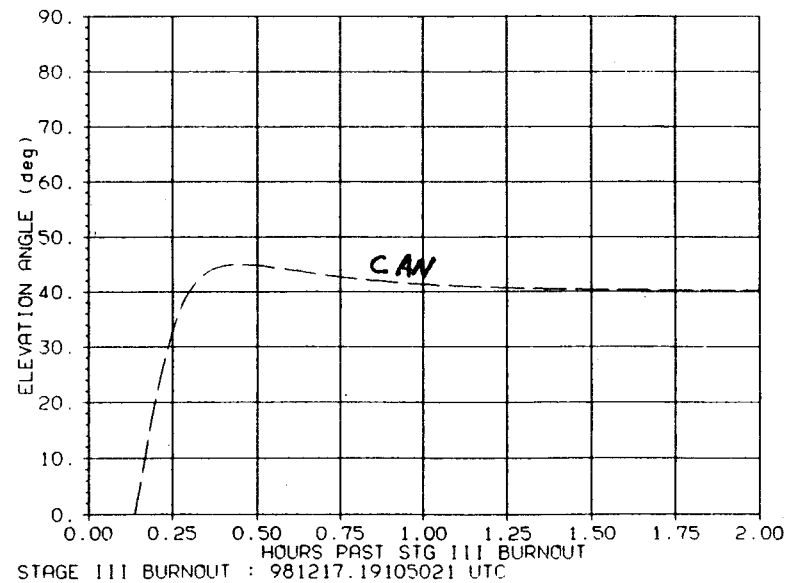
SPACECRAFT RANGE



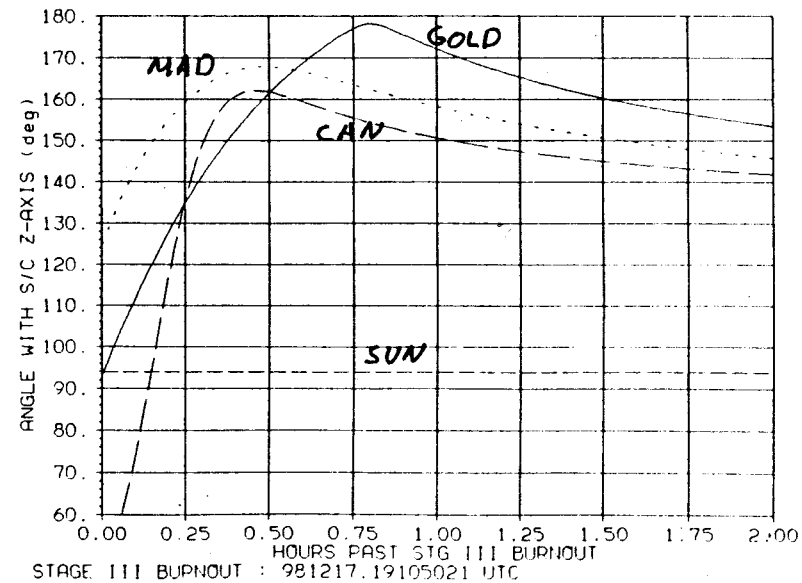
SPACECRAFT RANGE RATE



SPACECRAFT ELEVATION ANGLE

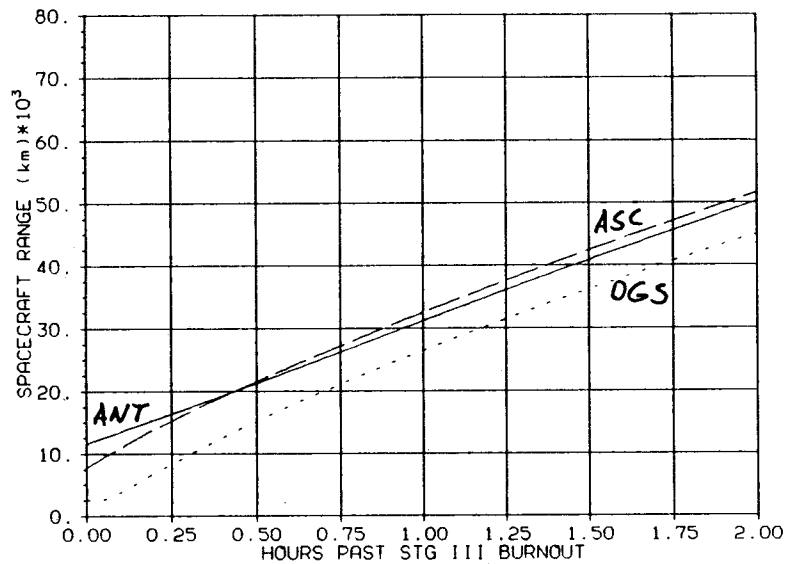


ASPECT ANGLE WITH S/C Z-AXIS

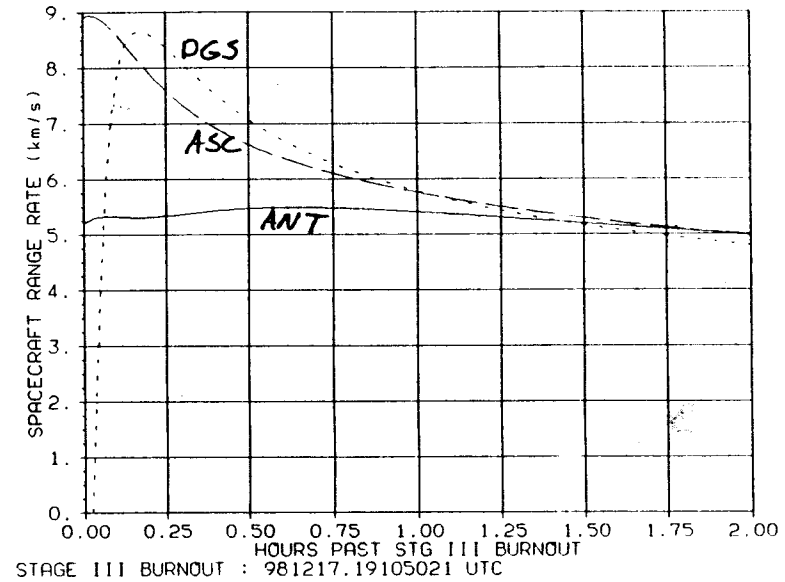


TRACKING STATION GEOMETRY (ORBITER): DAY 8 SHORT COAST

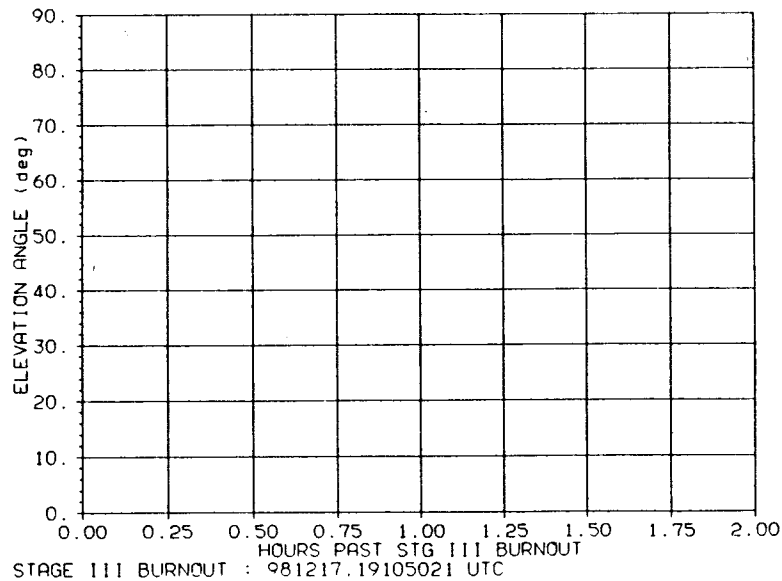
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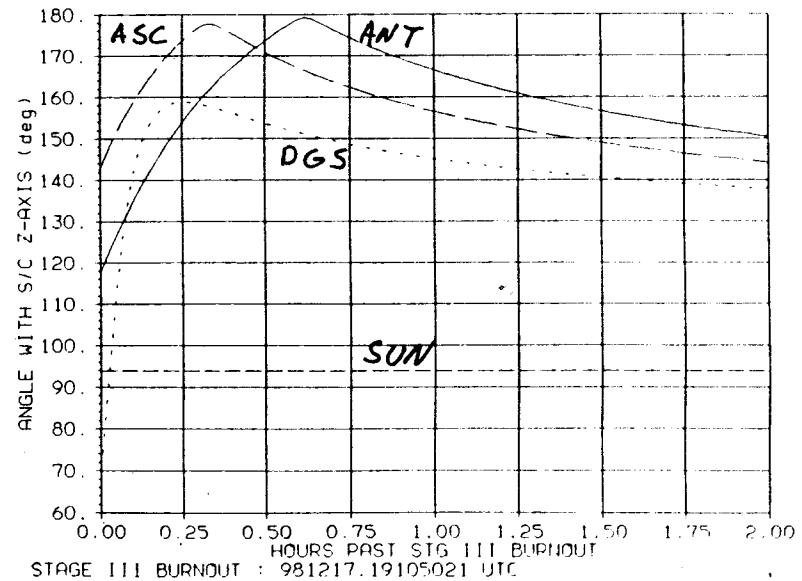
SPACECRAFT RANGE RATE



SPACECRAFT ELEVATION ANGLE

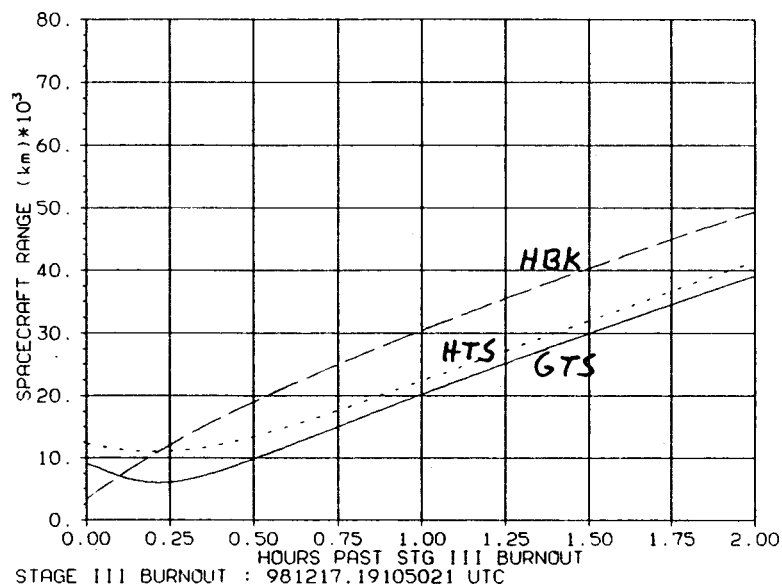


ASPECT ANGLE WITH S/C Z-AXIS

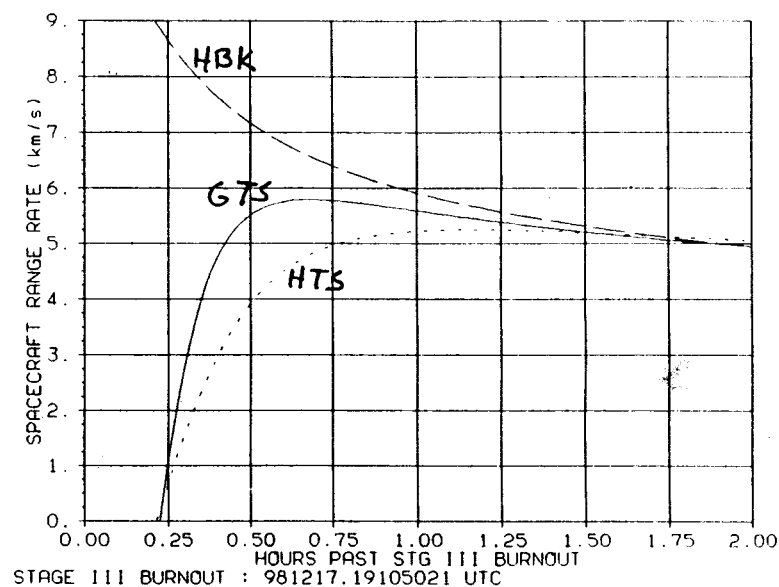


TRACKING STATION GEOMETRY (ORBITER): DAY 8 SHORT COAST

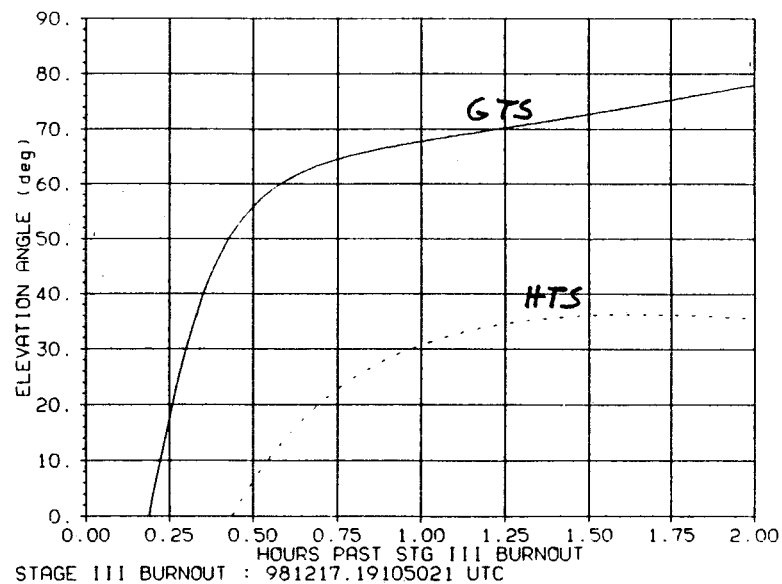
SPACECRAFT RANGE



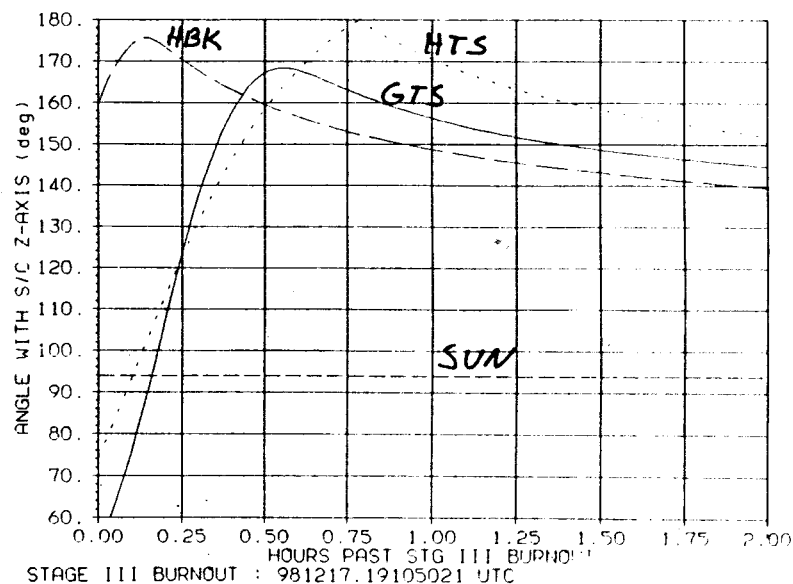
SPACECRAFT RANGE RATE



SPACECRAFT ELEVATION ANGLE

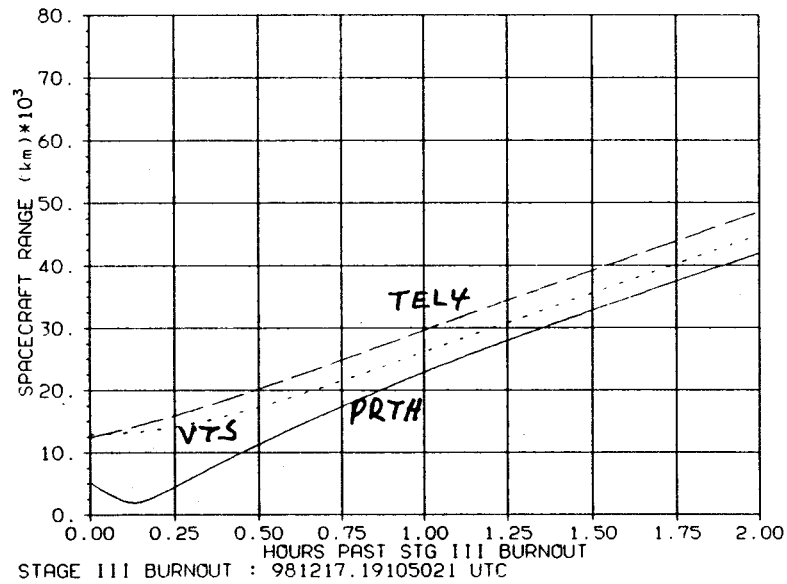


ASPECT ANGLE WITH S/C Z-AXIS

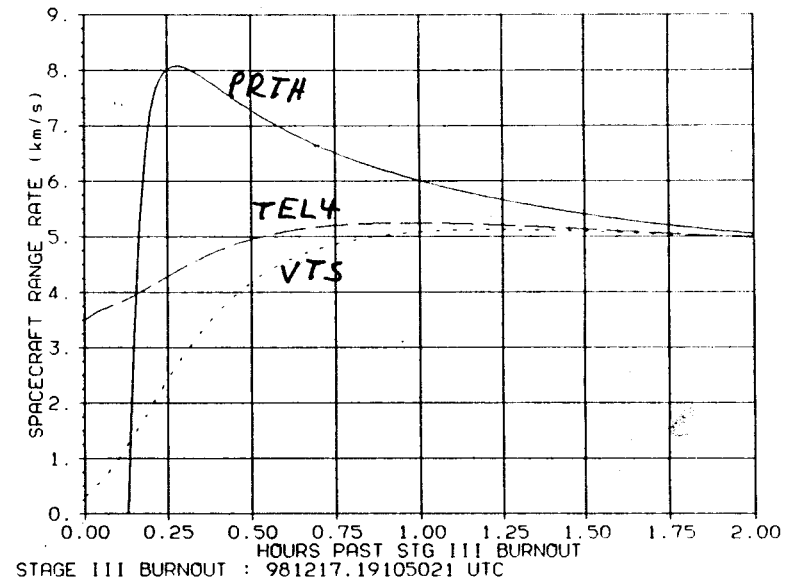


TRACKING STATION GEOMETRY (ORBITER): DAY 8 SHORT COAST

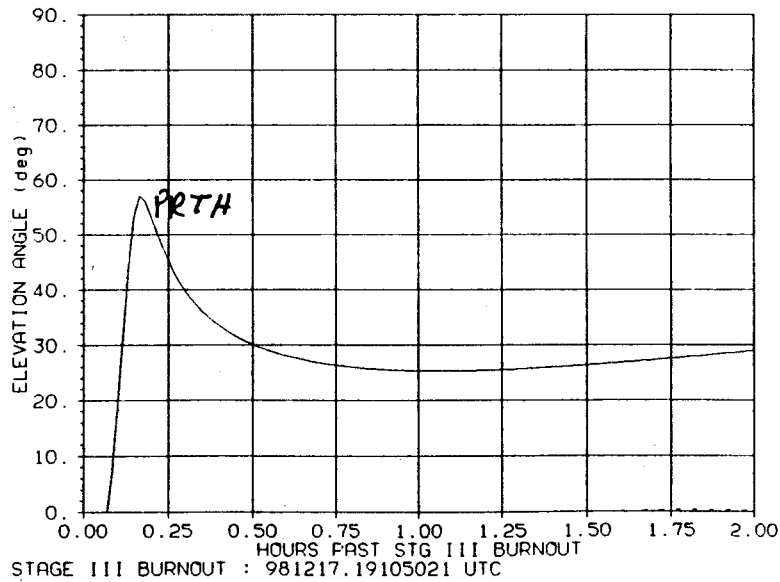
SPACECRAFT RANGE



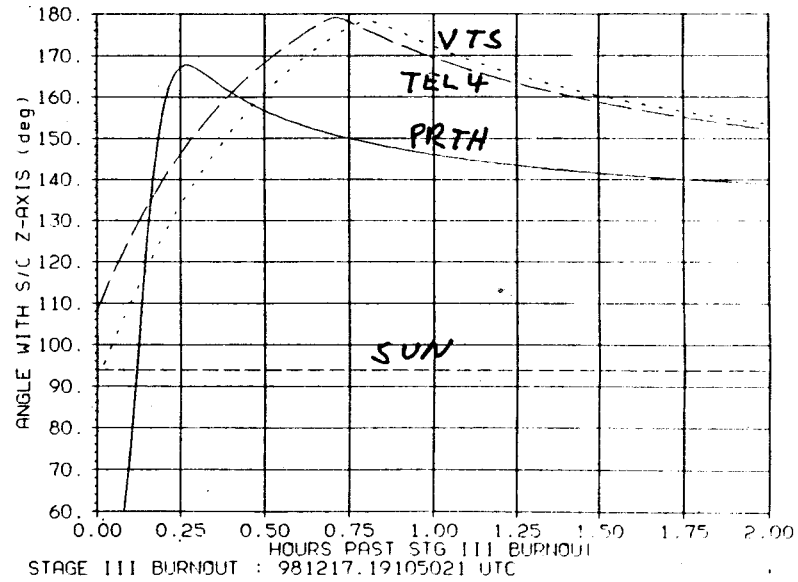
SPACECRAFT RANGE RATE



SPACECRAFT ELEVATION ANGLE

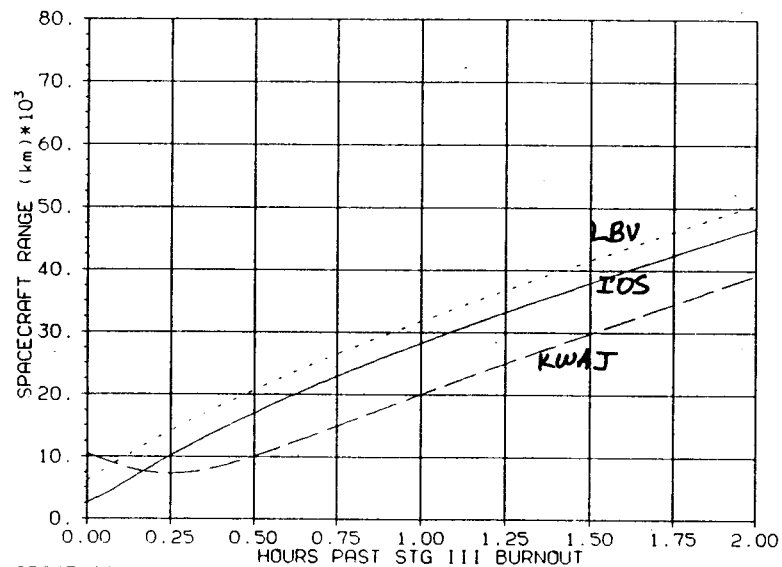


ASPECT ANGLE WITH S/C Z-AXIS

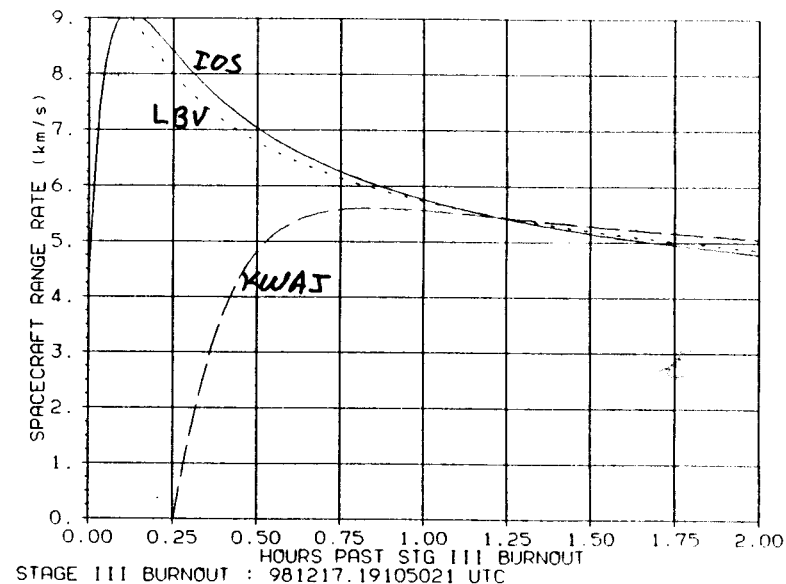


TRACKING STATION GEOMETRY (ORBITER): DAY 8 SHORT COAST

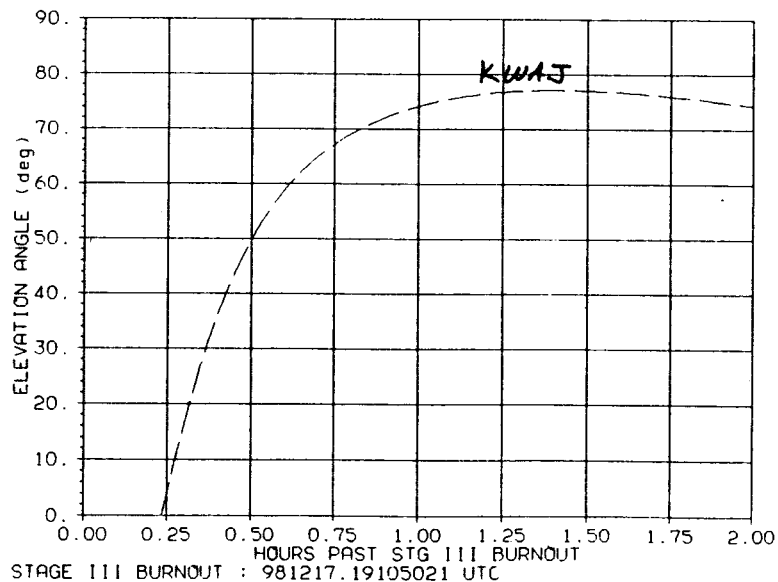
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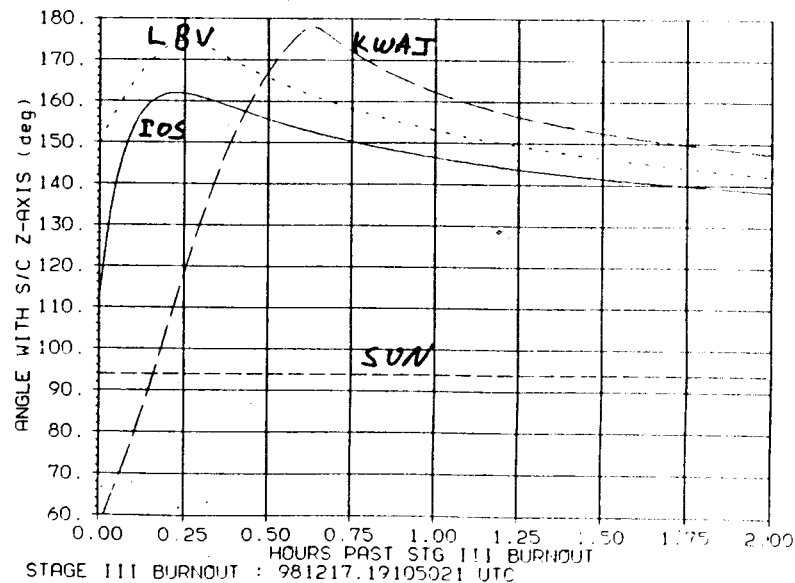
SPACECRAFT RANGE RATE



SPACECRAFT ELEVATION ANGLE



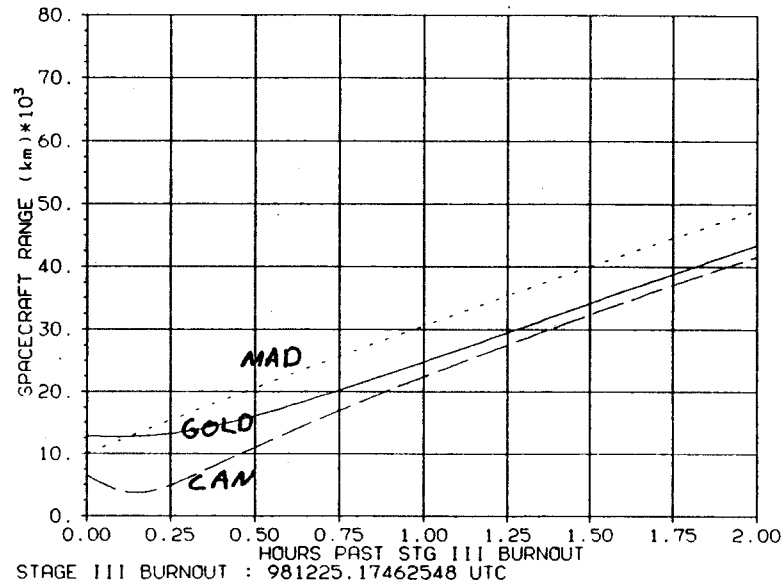
ASPECT ANGLE WITH S/C Z-AXIS



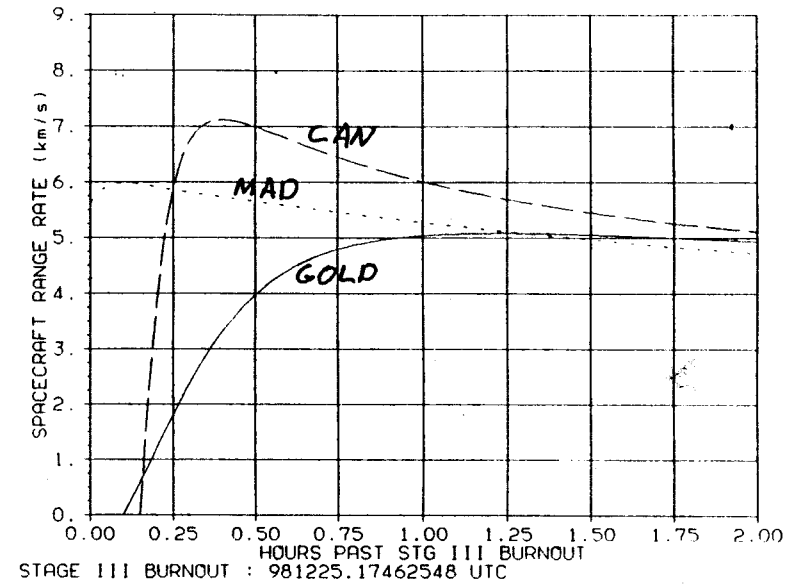
ORBITER DAY 16 (12/25/98) SHORT COAST

TRACKING STATION GEOMETRY (ORBITER): DAY 16 SHORT COAST

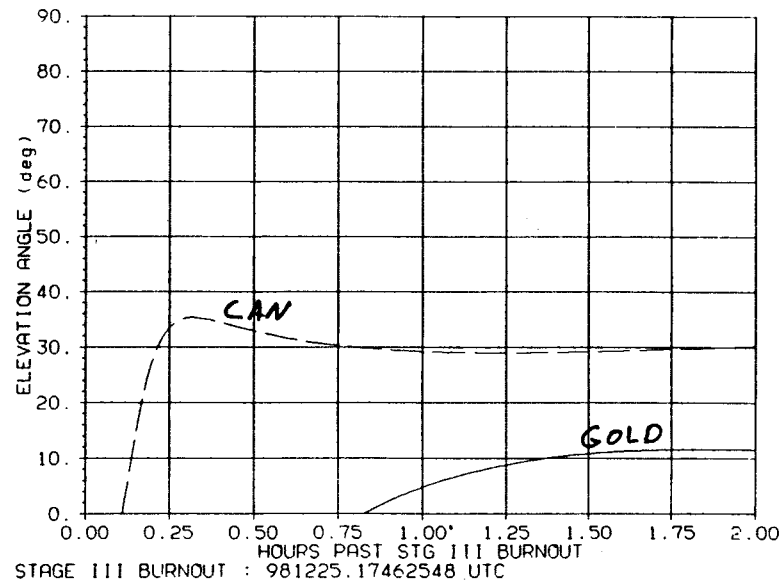
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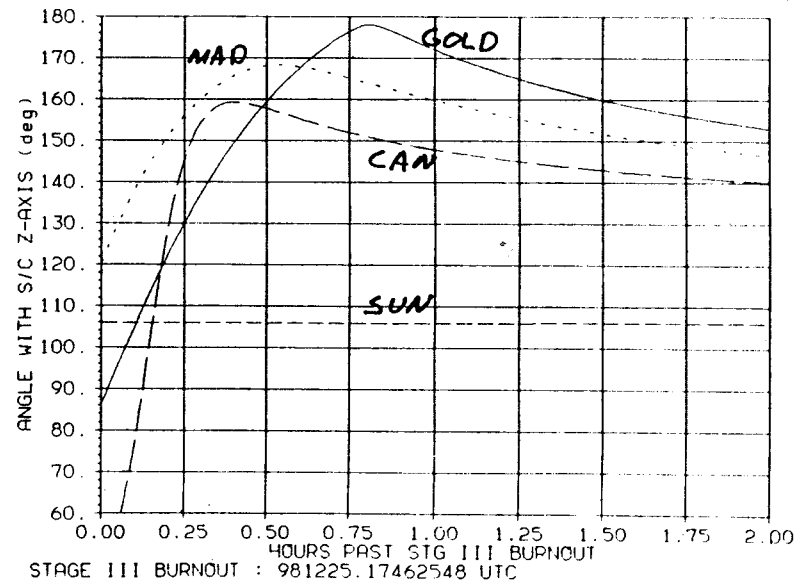
SPACECRAFT RANGE RATE



SPACECRAFT ELEVATION ANGLE

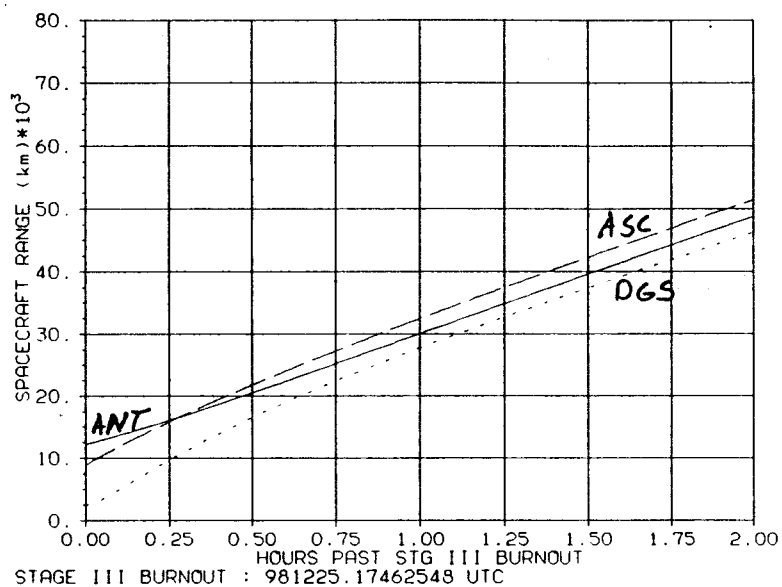


ASPECT ANGLE WITH S/C Z-AXIS

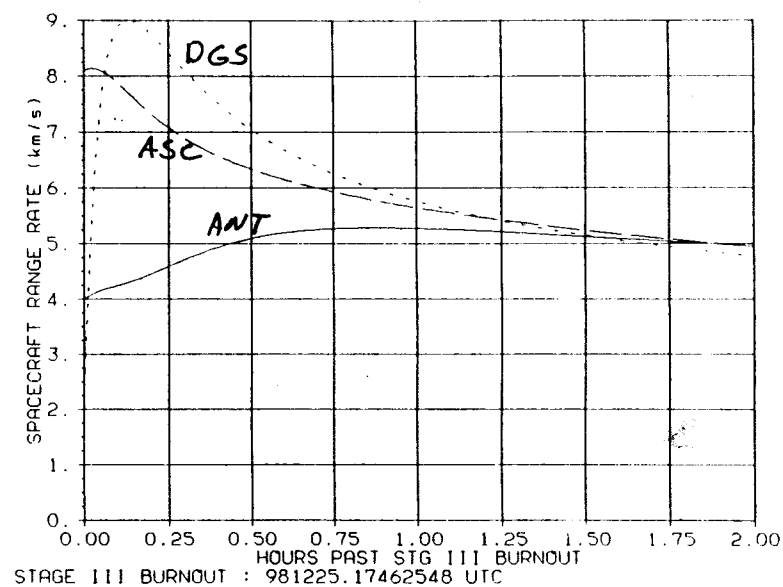


TRACKING STATION GEOMETRY (ORBITER): DAY 16 SHORT COAST

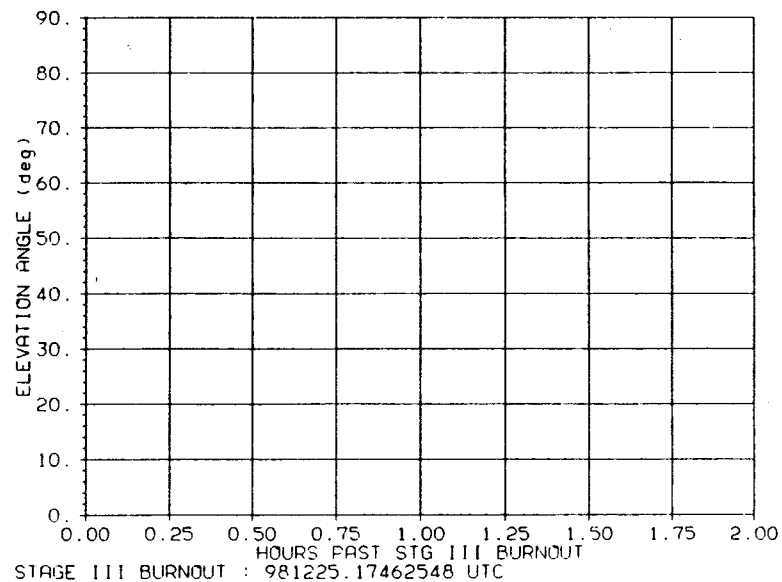
SPACECRAFT RANGE



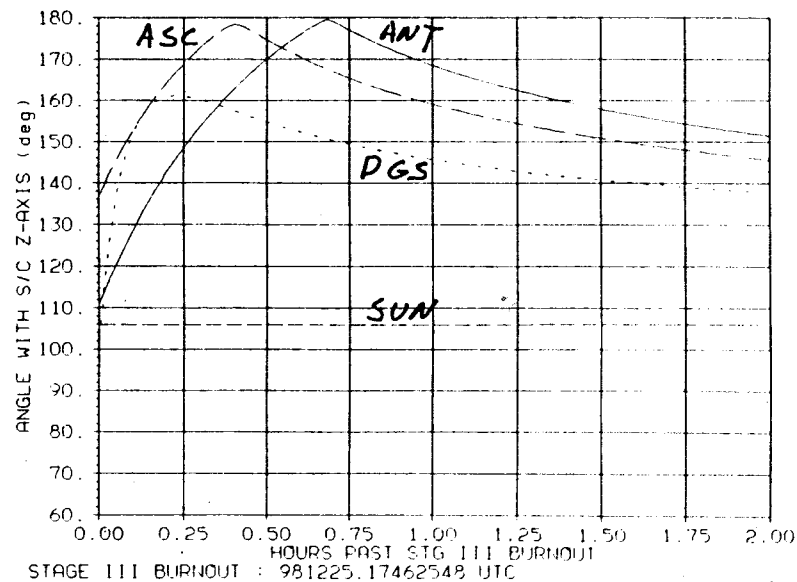
SPACECRAFT RANGE RATE



SPACECRAFT ELEVATION ANGLE

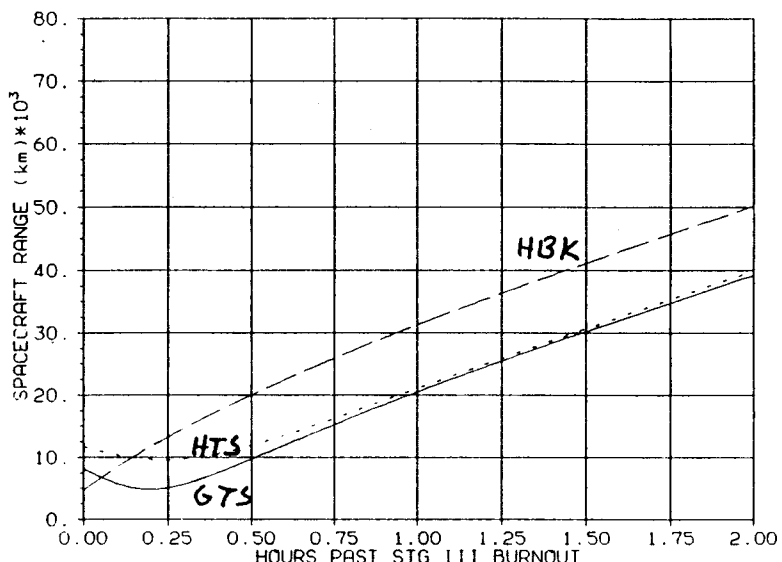


ASPECT ANGLE WITH S/C Z-AXIS

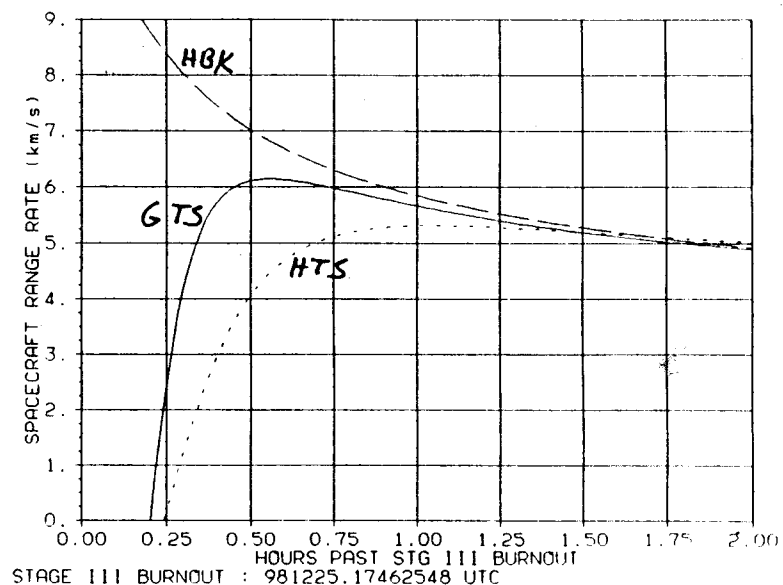


TRACKING STATION GEOMETRY (ORBITER): DAY 16 SHORT COAST

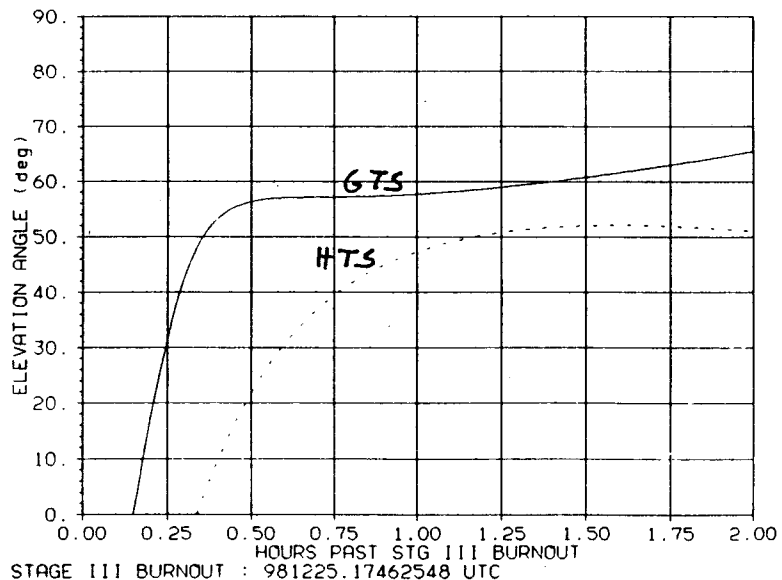
SPACECRAFT RANGE



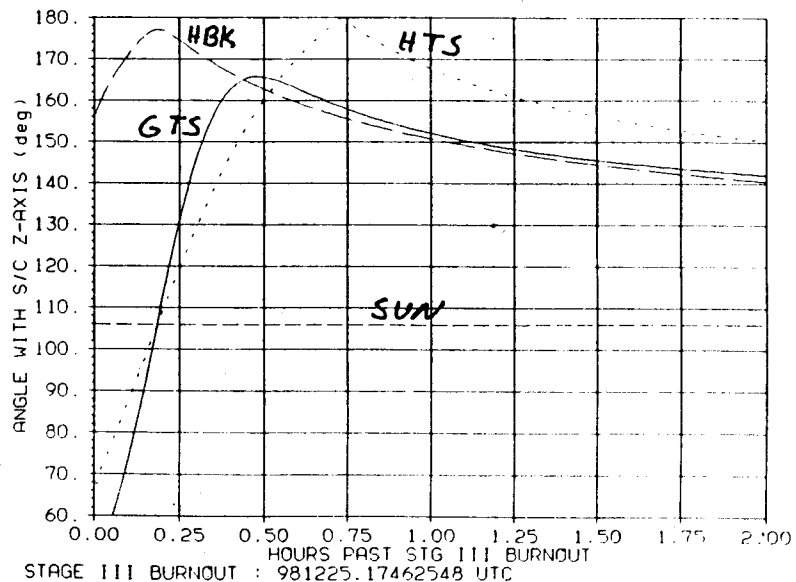
SPACECRAFT RANGE RATE



SPACECRAFT ELEVATION ANGLE

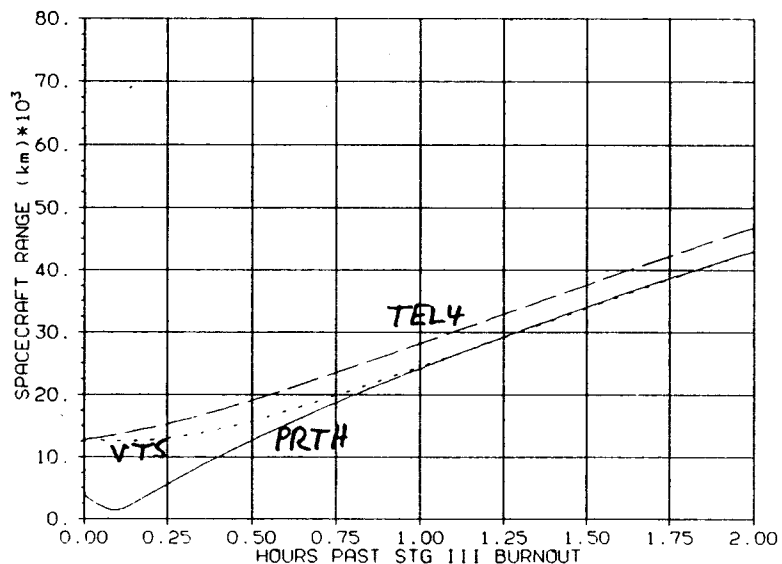


ASPECT ANGLE WITH S/C Z-AXIS

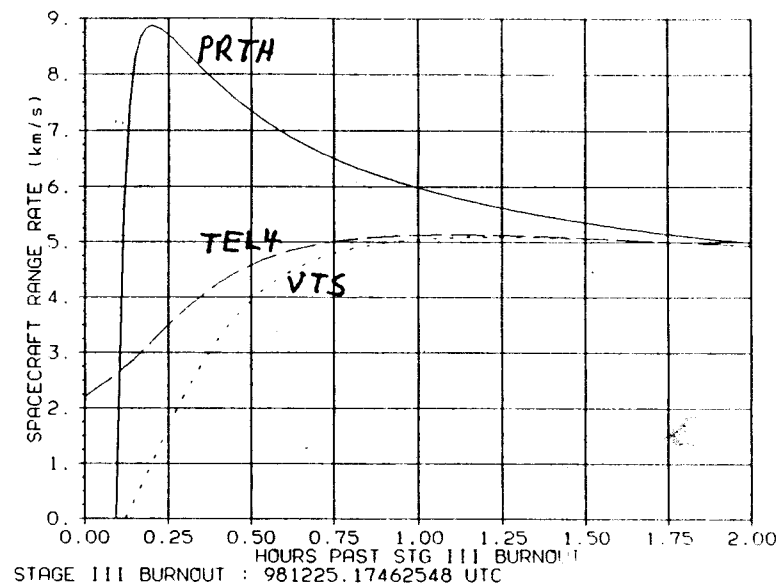


TRACKING STATION GEOMETRY (ORBITER): DAY 16 SHORT COAST

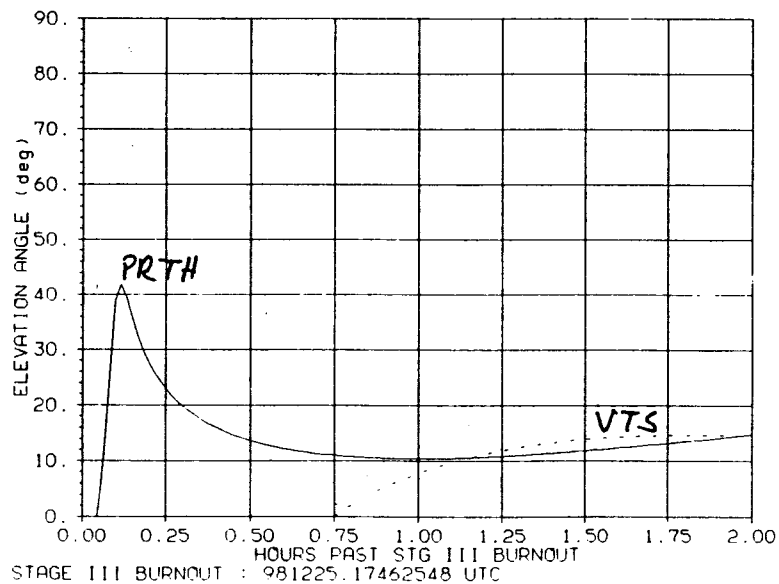
SPACECRAFT RANGE



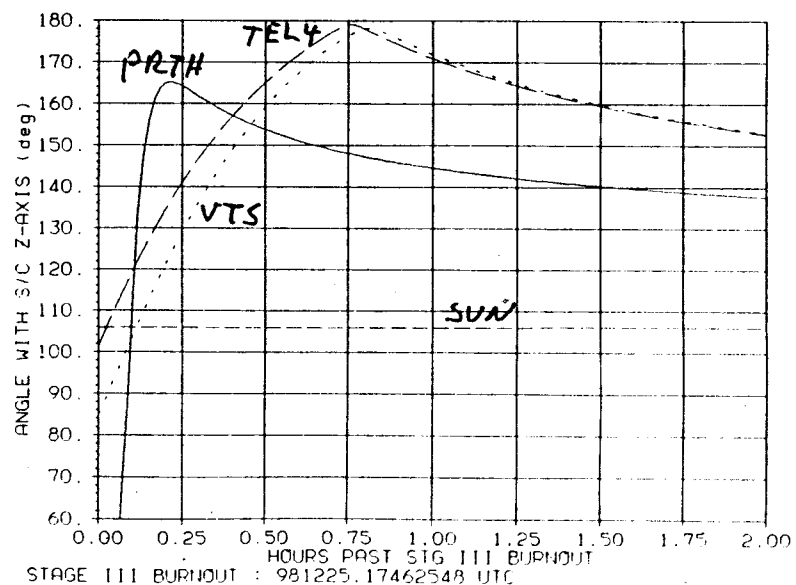
SPACECRAFT RANGE RATE



SPACECRAFT ELEVATION ANGLE

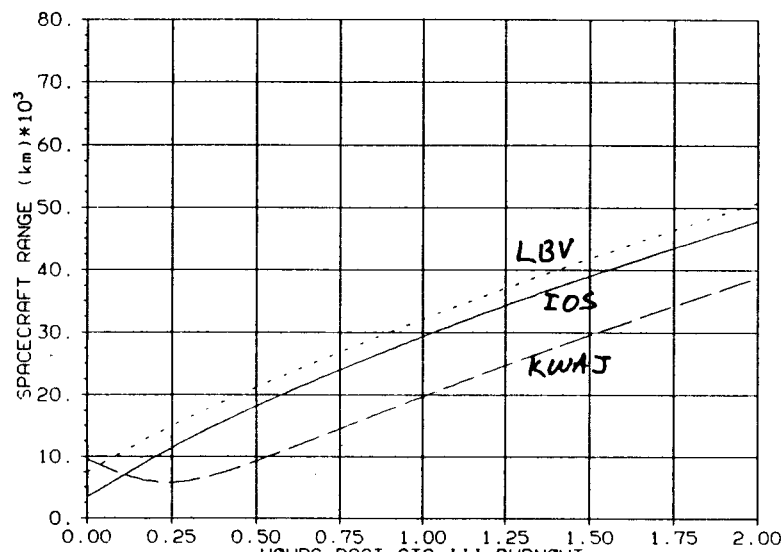


ASPECT ANGLE WITH S/C Z-AXIS

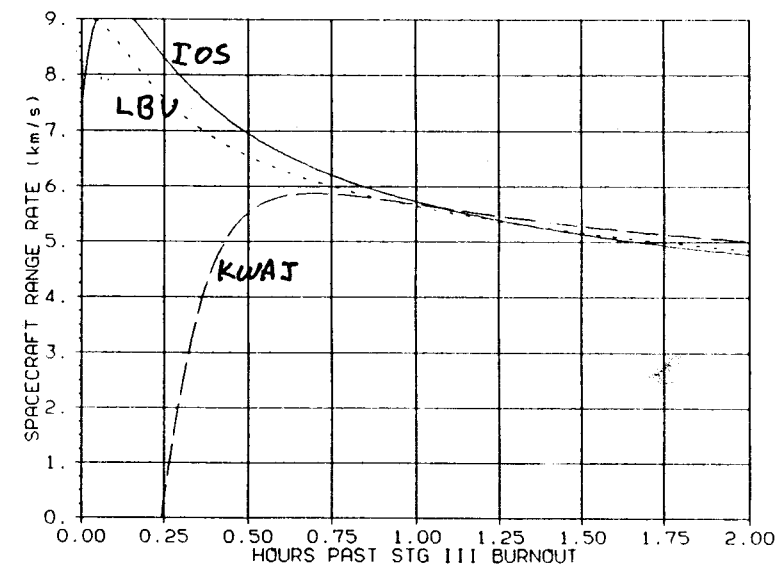


TRACKING STATION GEOMETRY (ORBITER): DAY 16 SHORT COAST

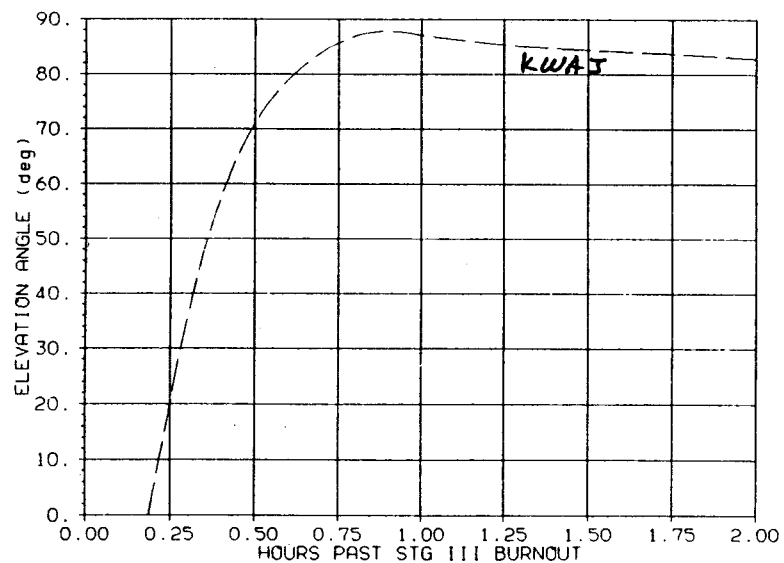
SPACECRAFT RANGE



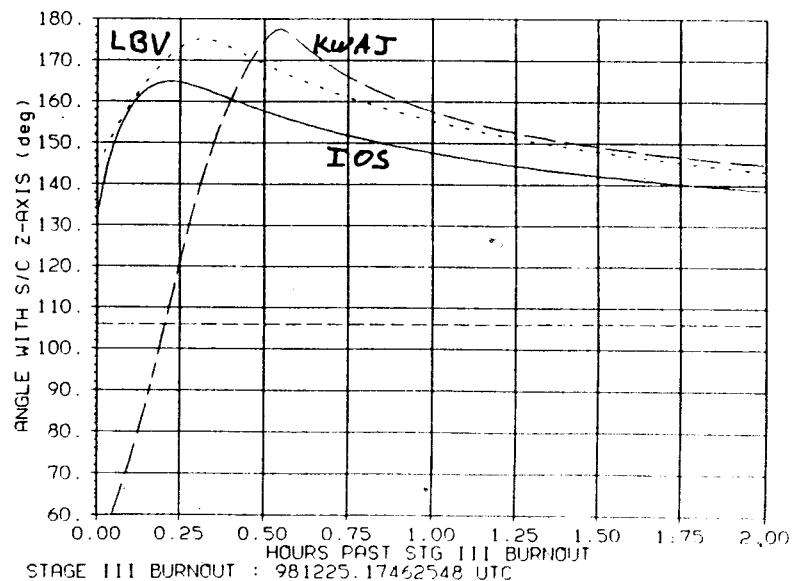
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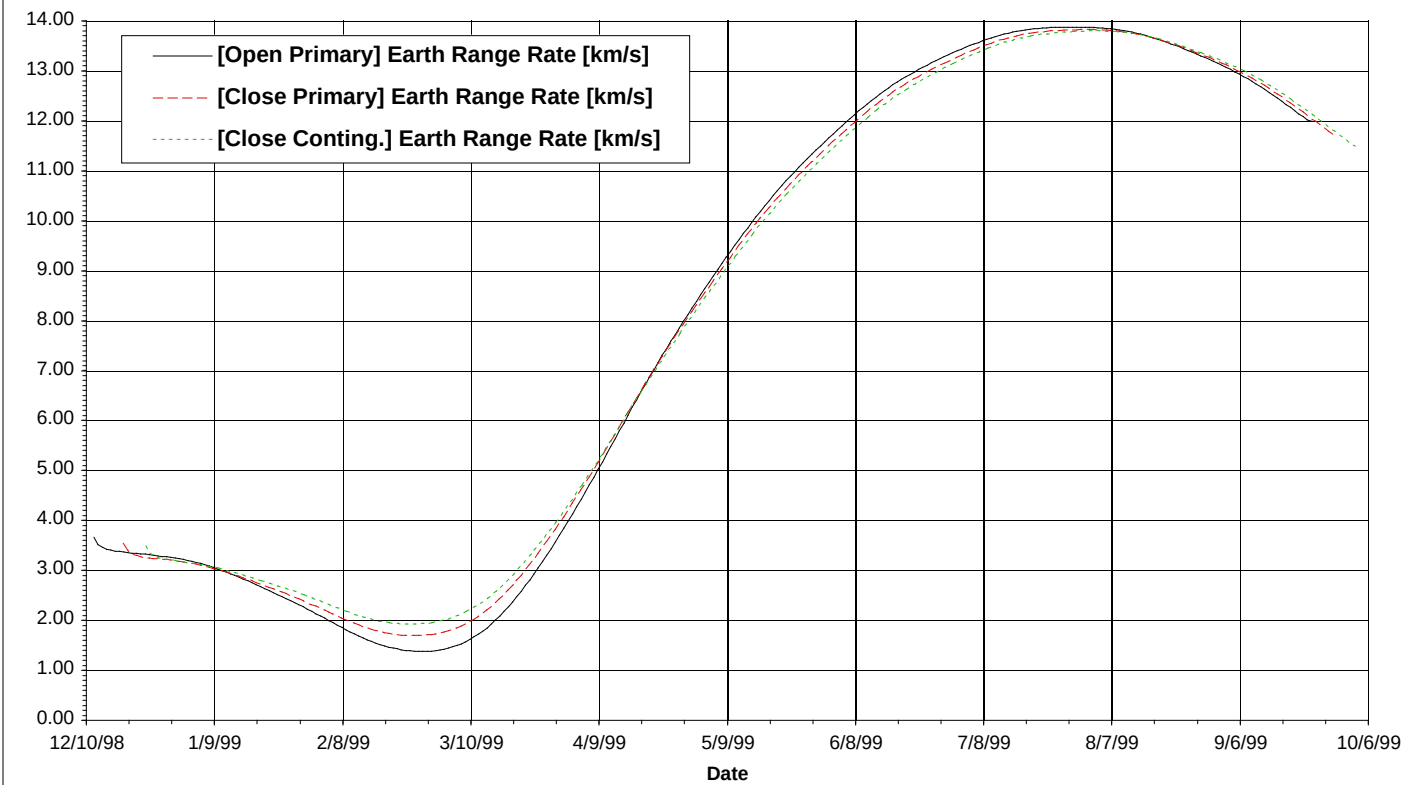
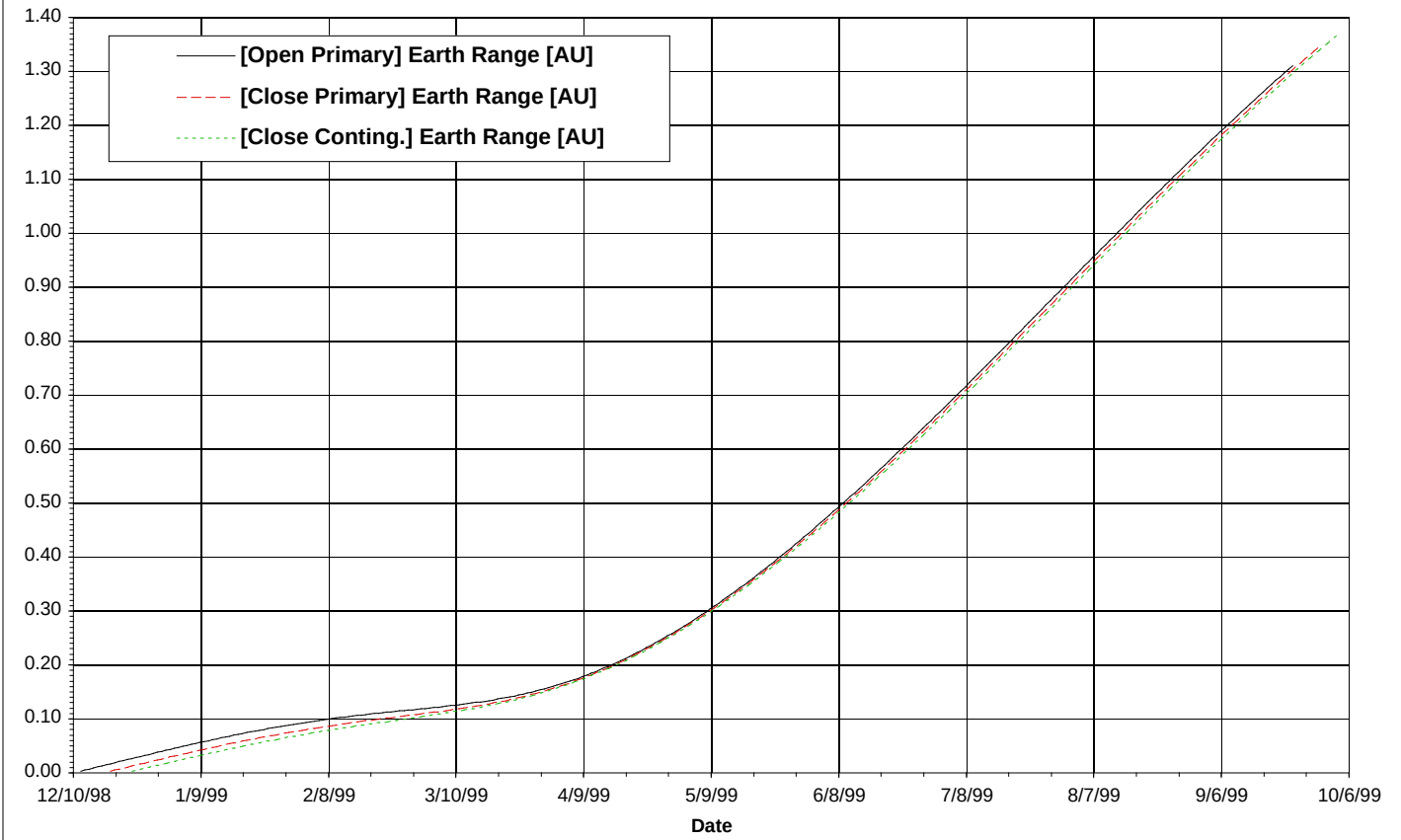
SPACECRAFT ELEVATION ANGLE

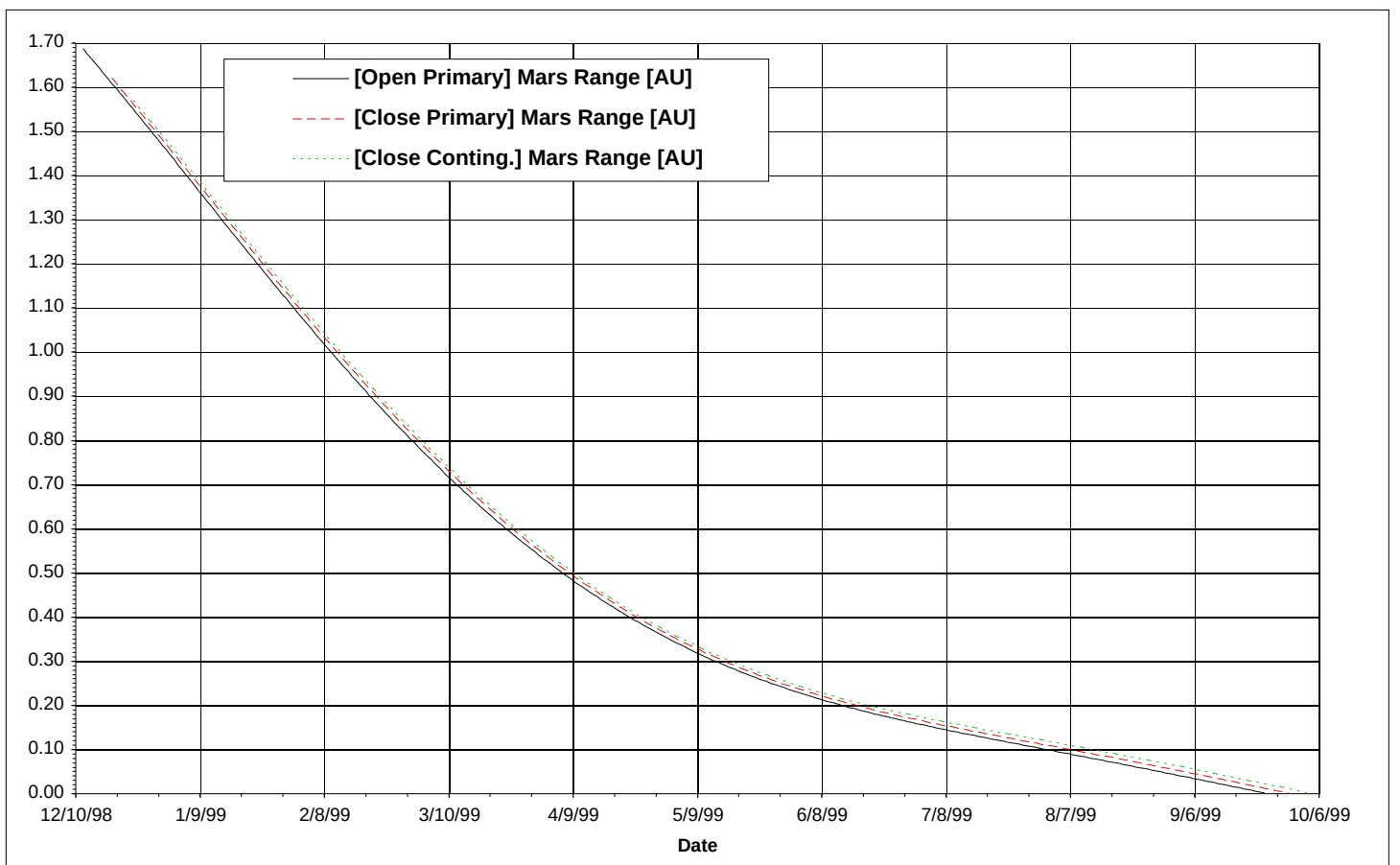
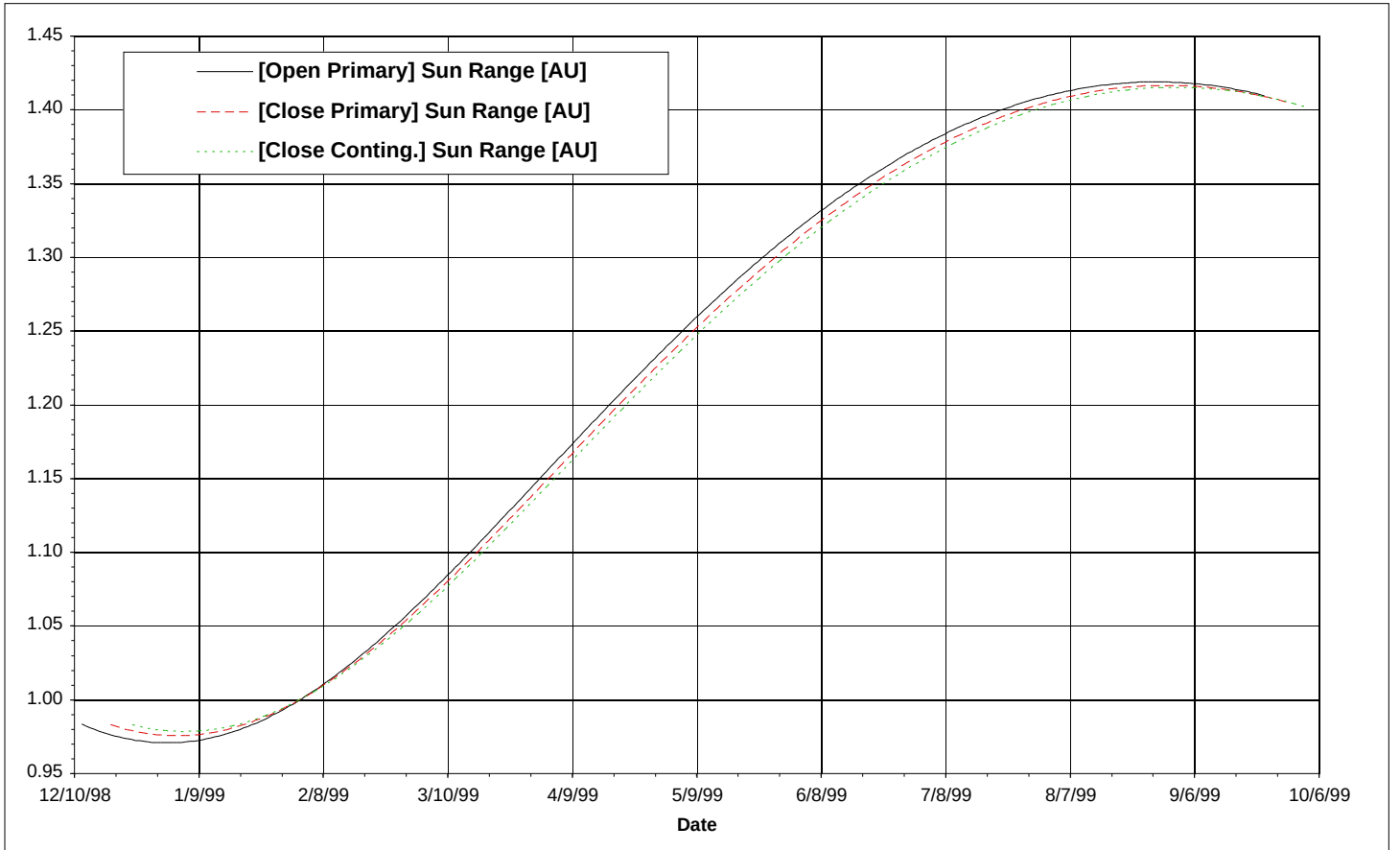


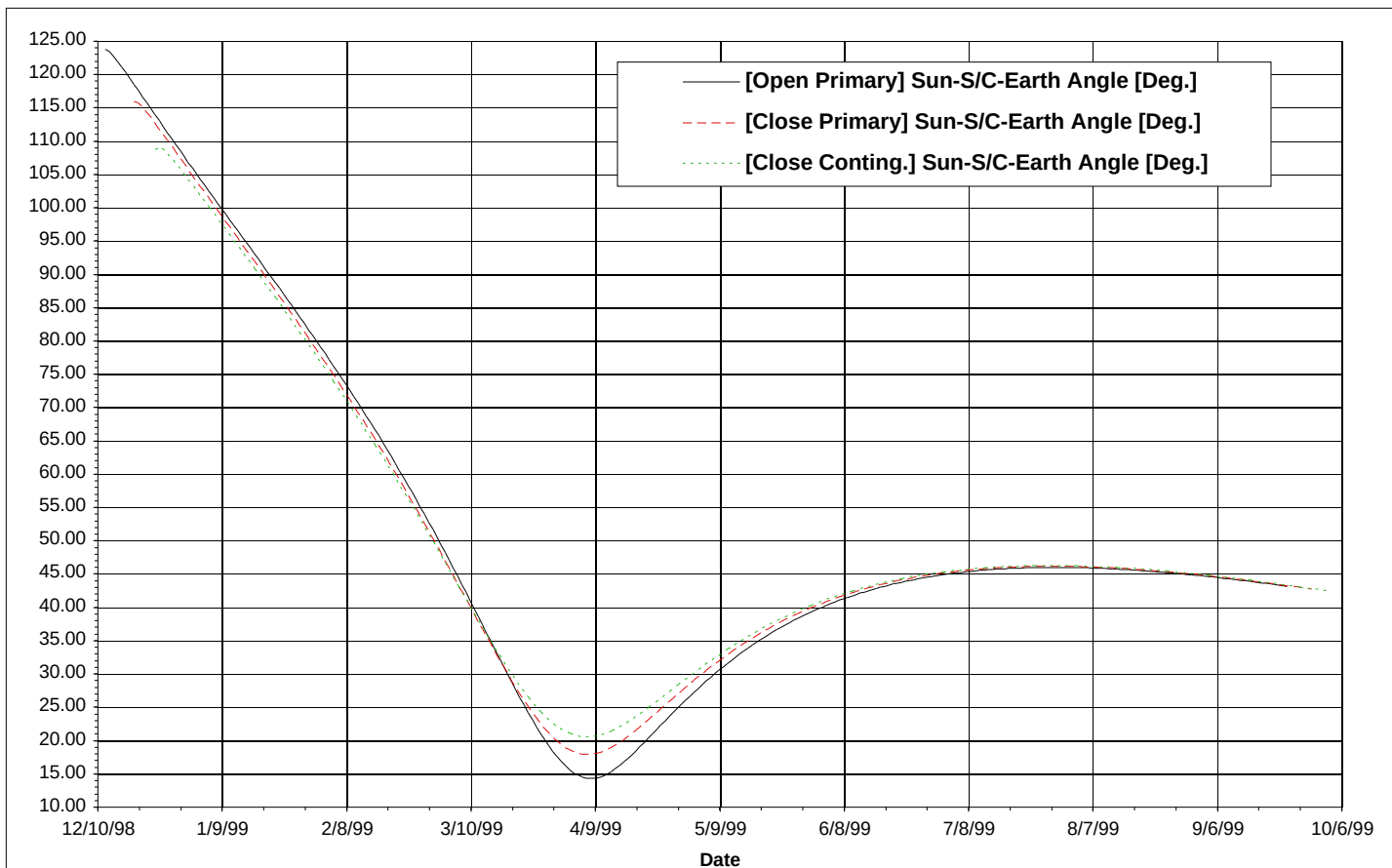
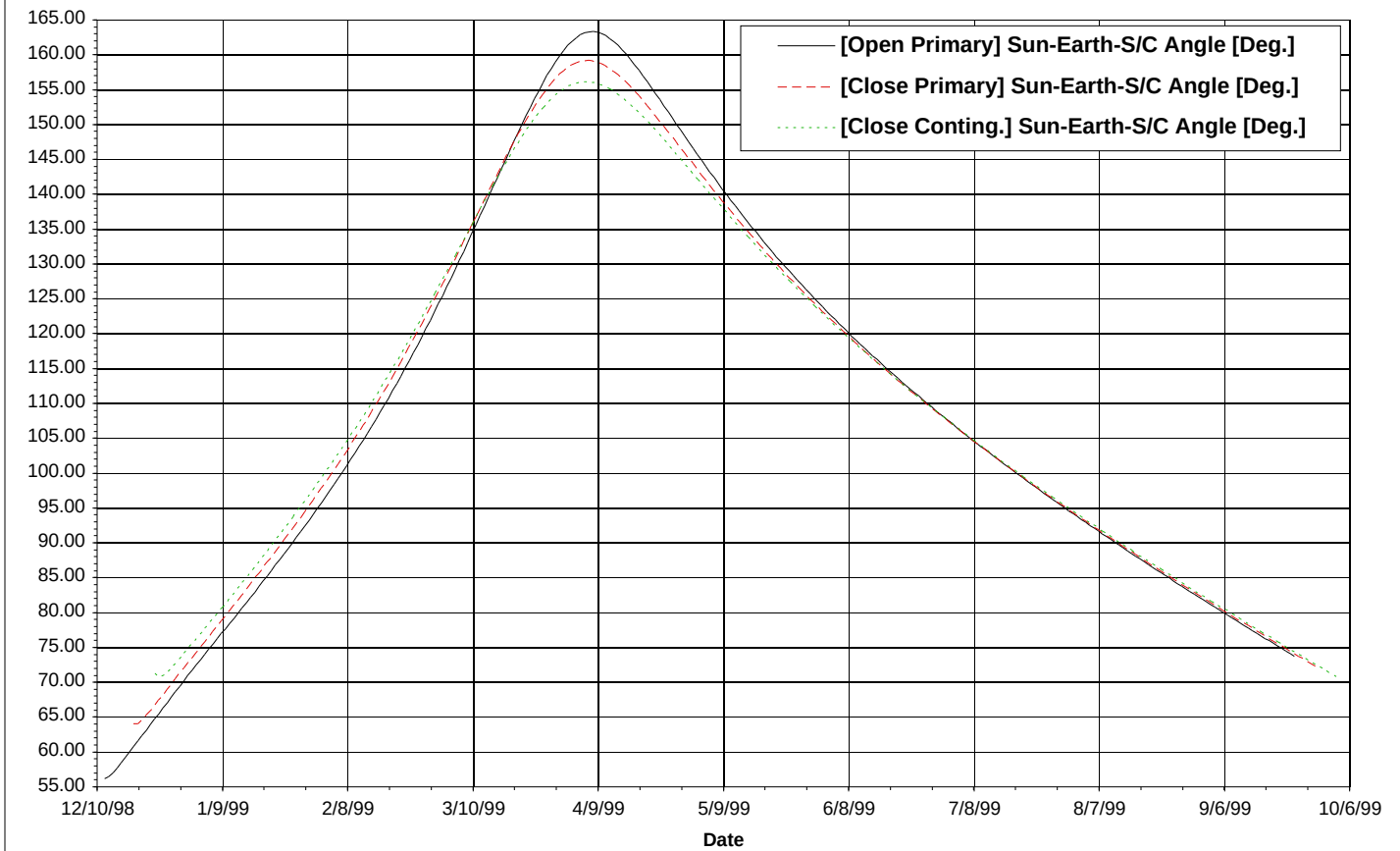
ASPECT ANGLE WITH S/C Z-AXIS

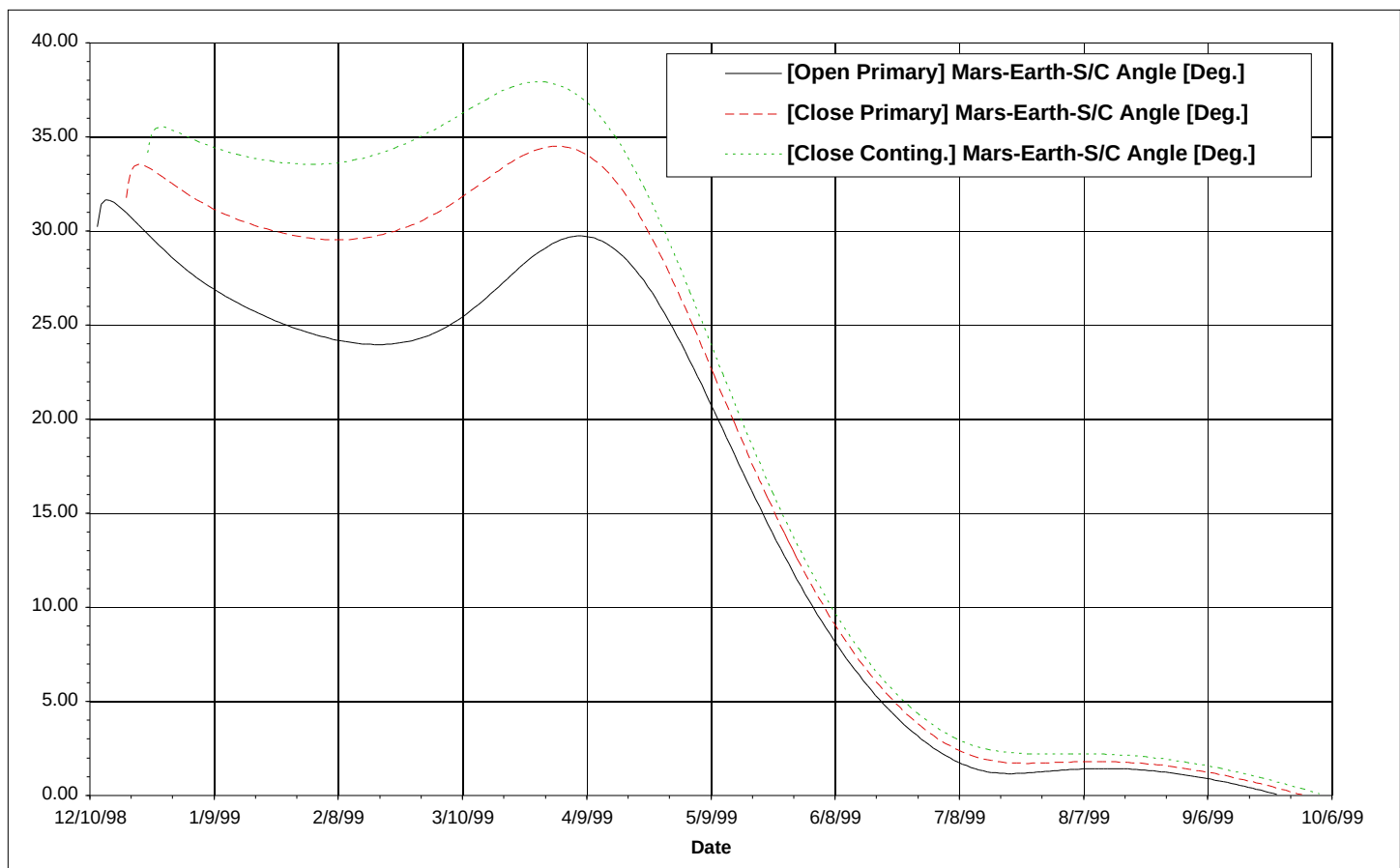
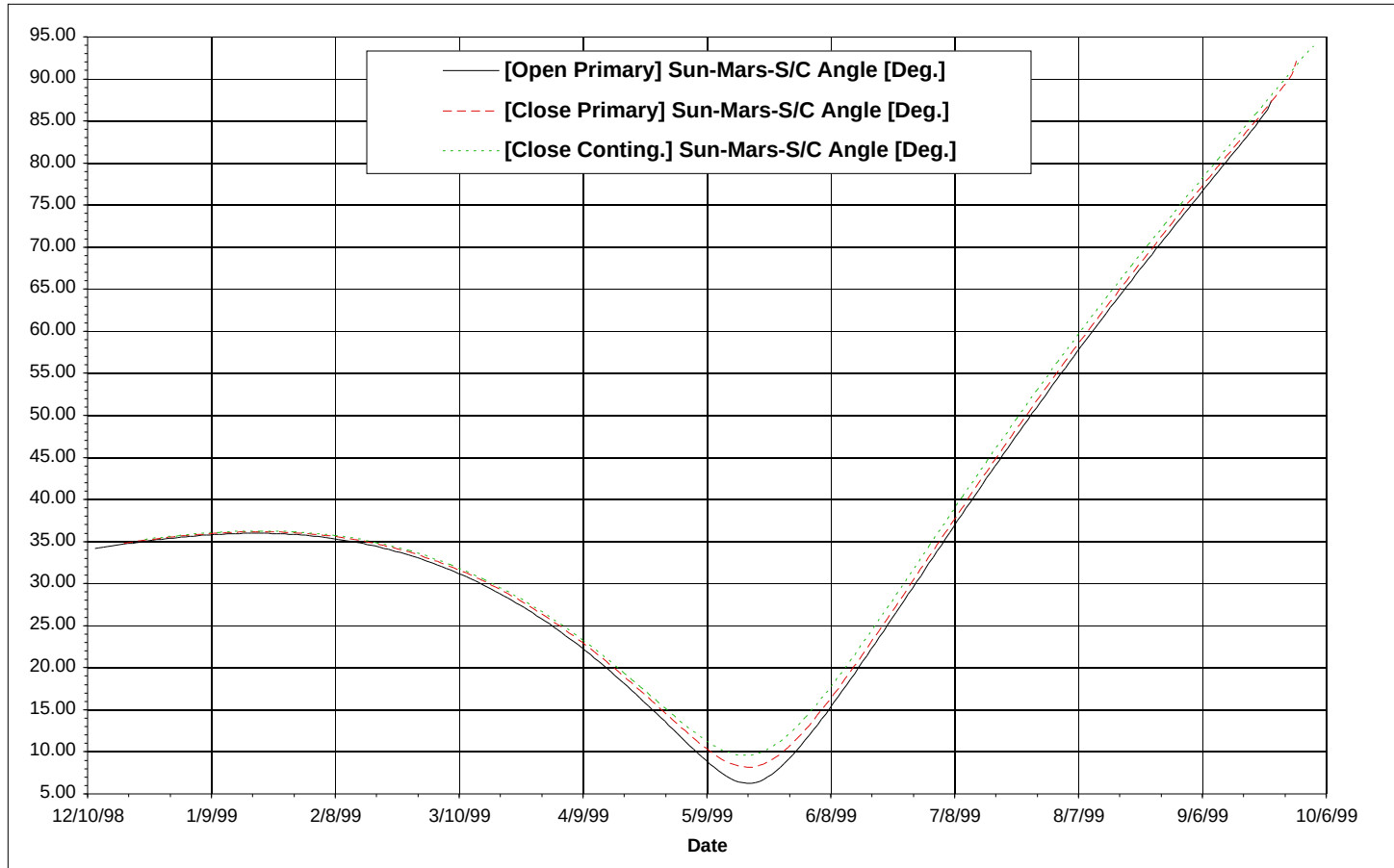


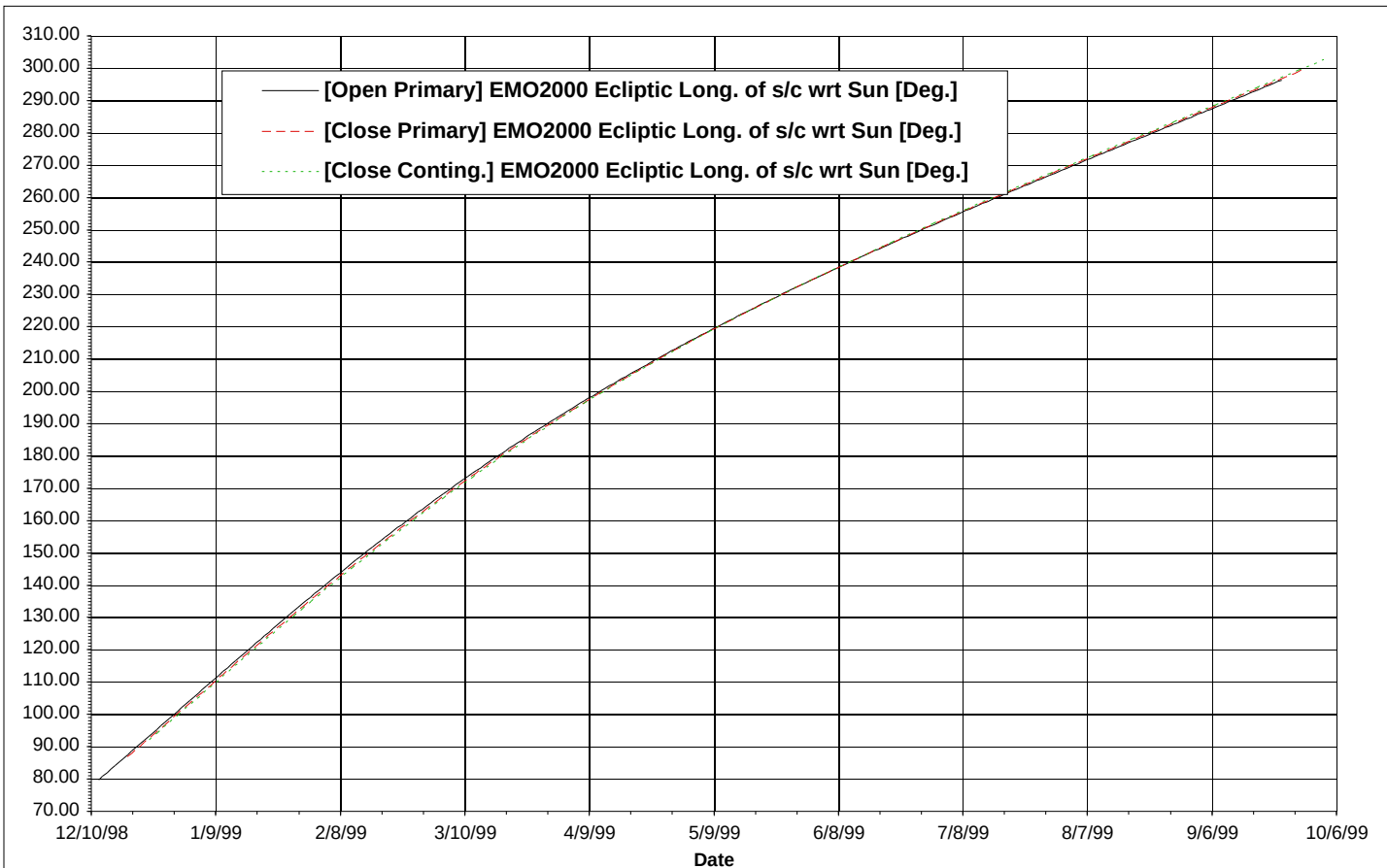
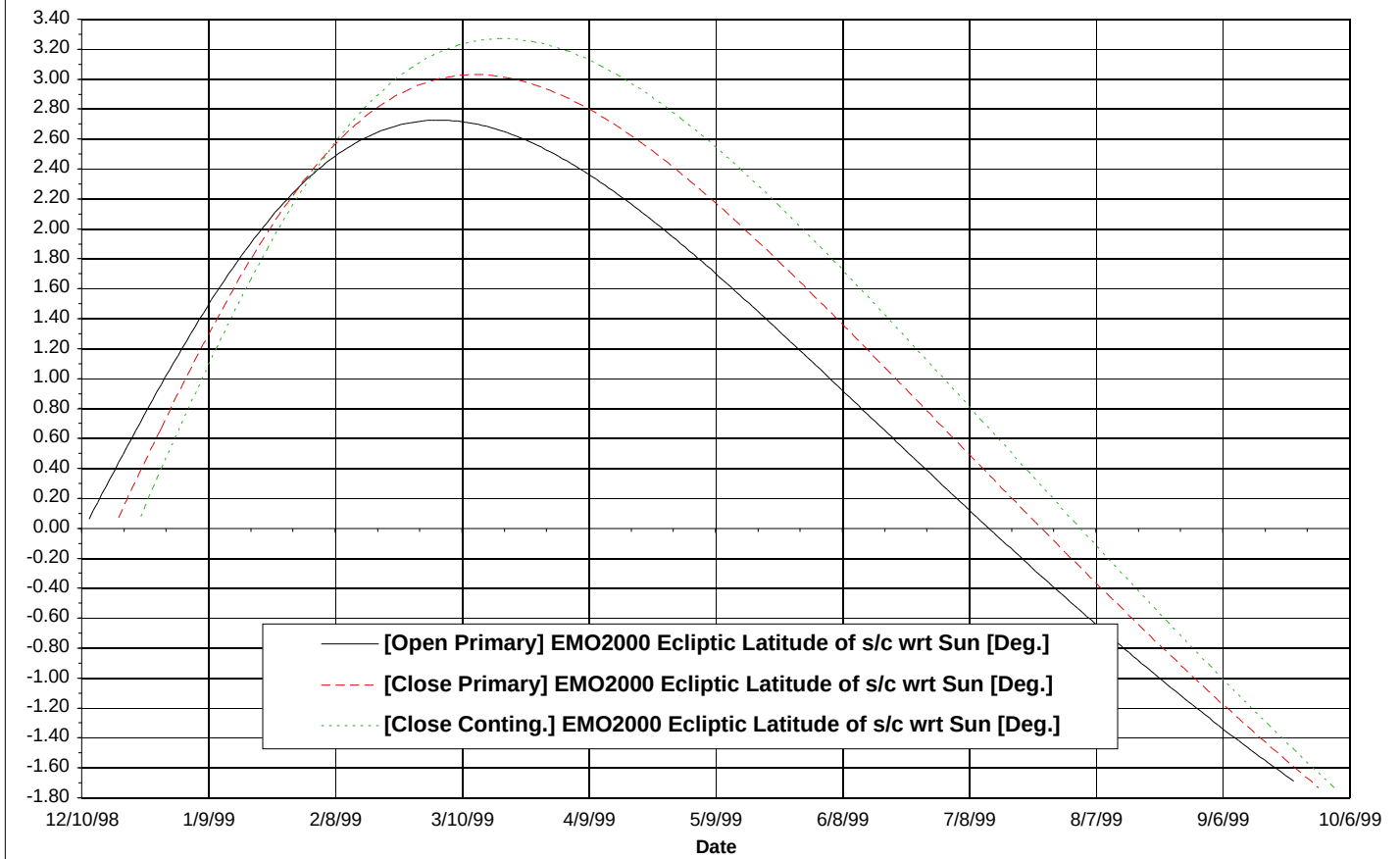
A.3 Orbiter Cruise Trajectory Characteristics

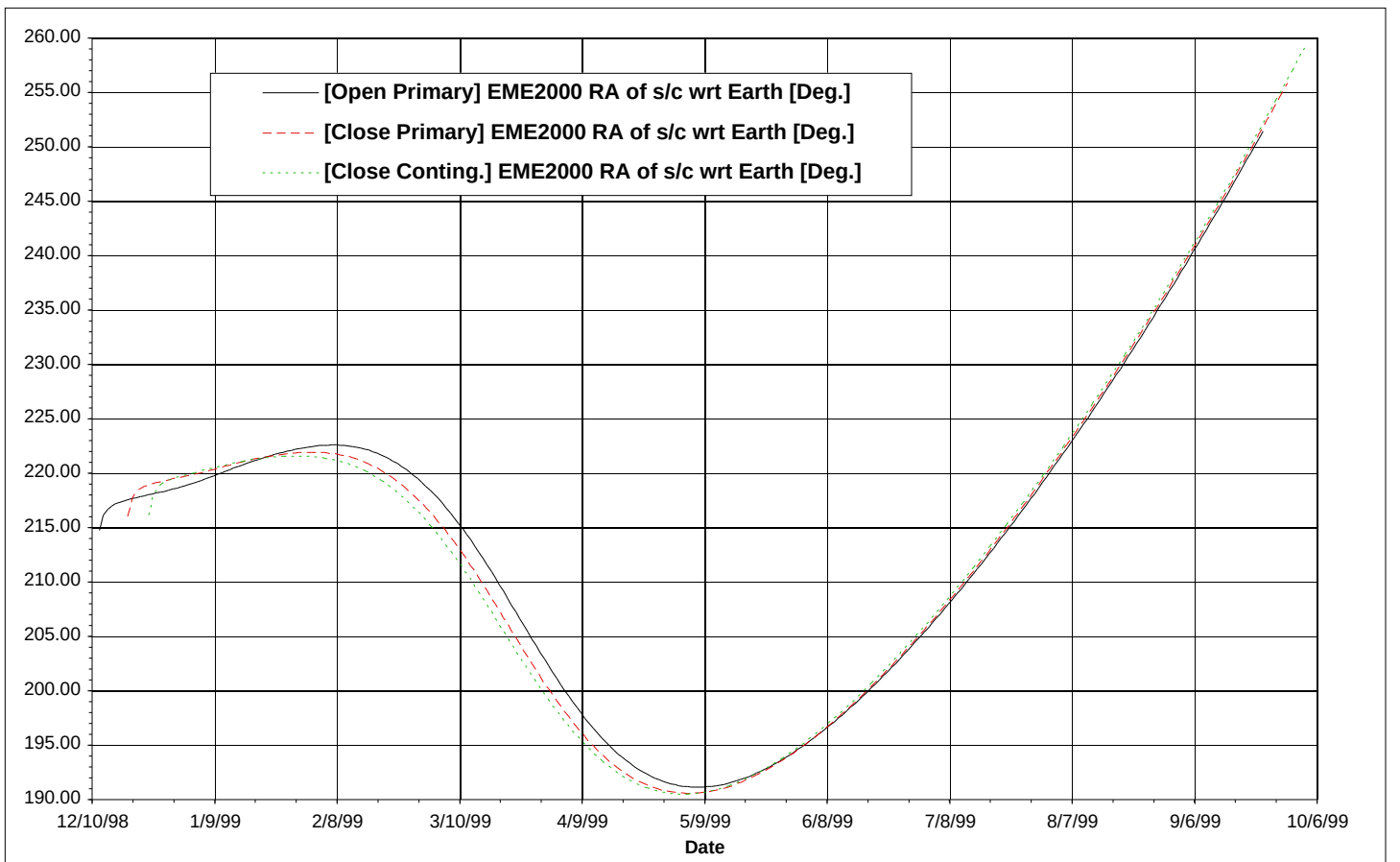
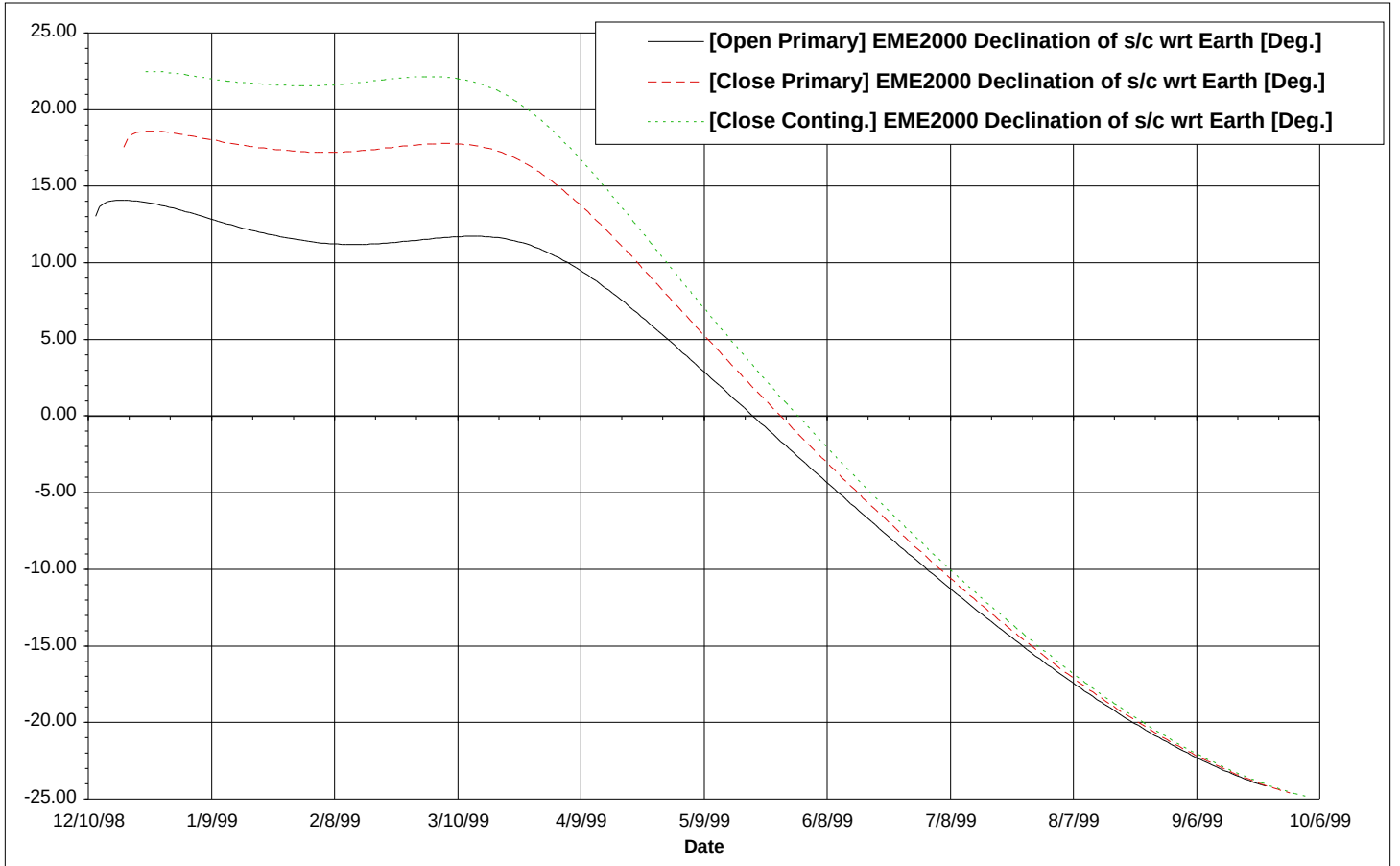












A.4 MOI Illustrations

MOI 9/24/99: View from N. Trajectory Pole

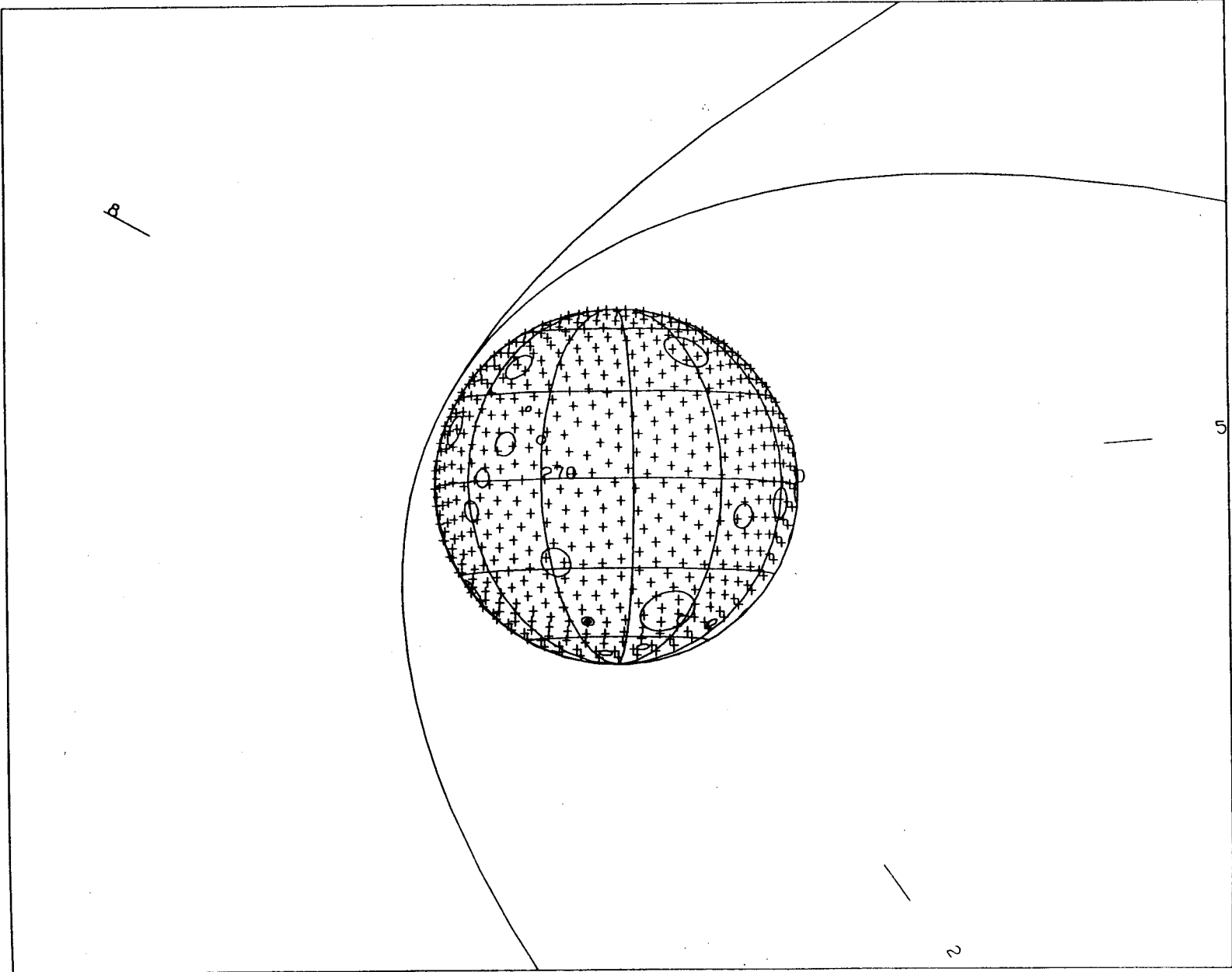


Fig 1

MOI 9/24/99: View from S. Trajectory Pole

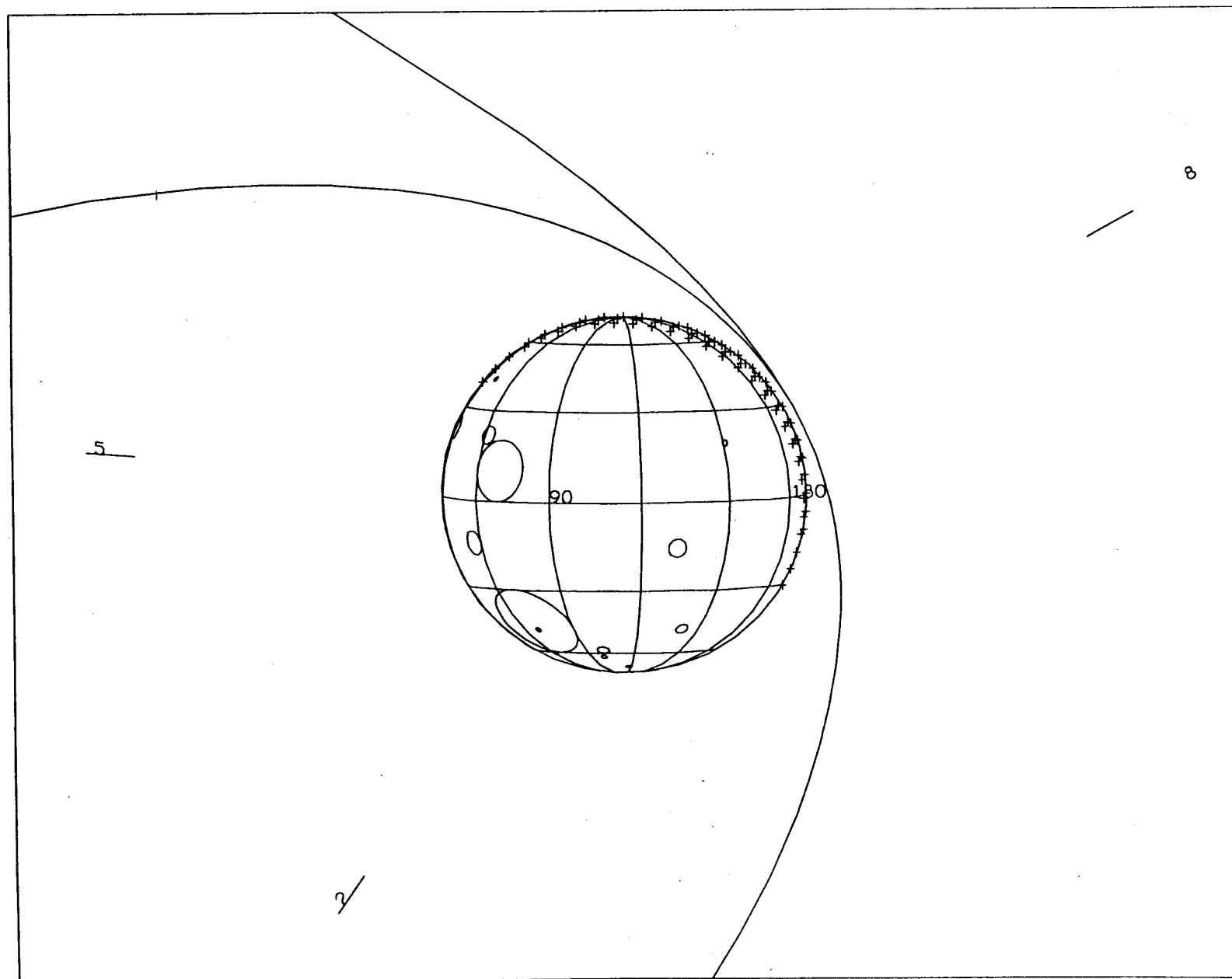


Fig 2

MOI 9/24/99: View from Earth

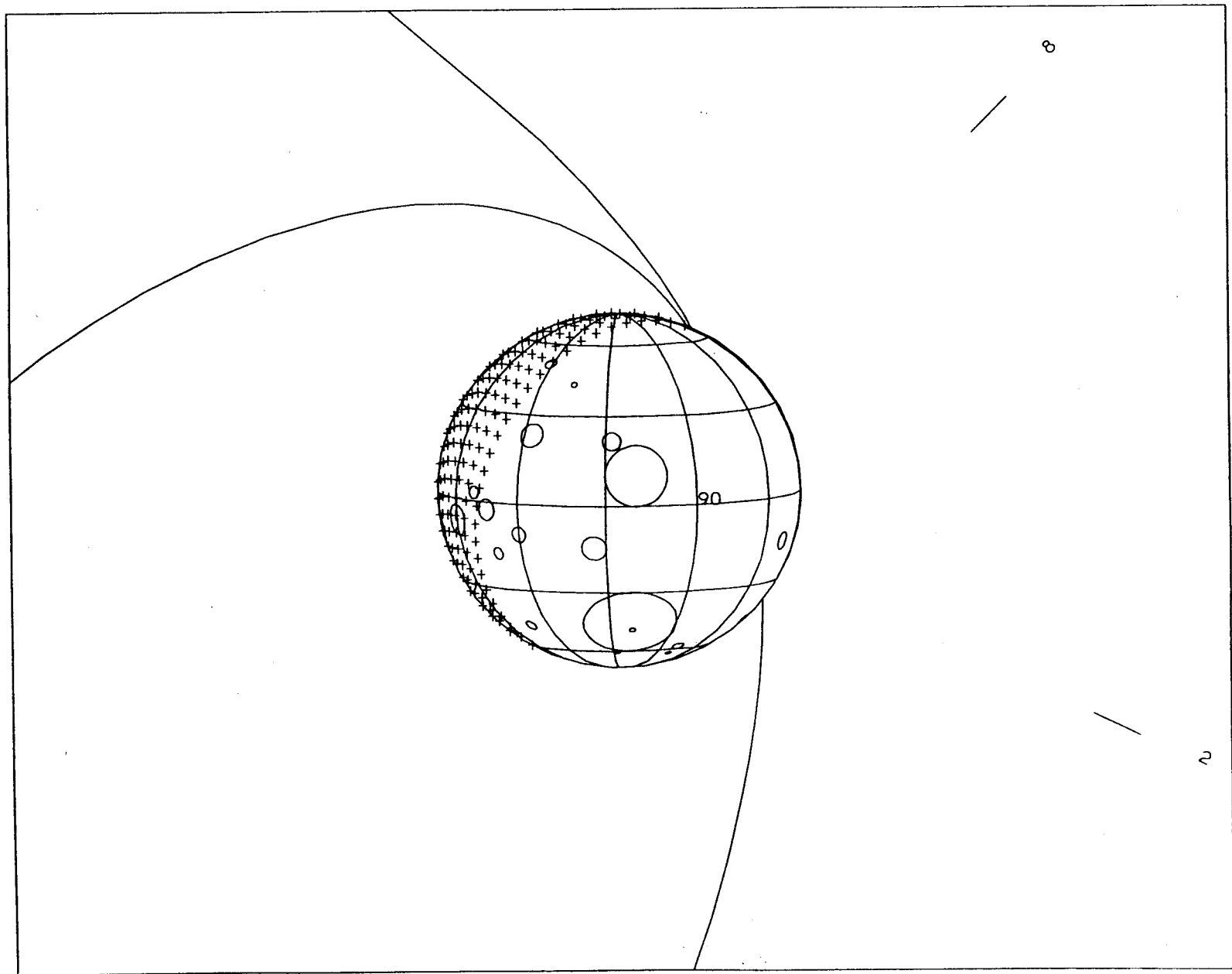


Fig 3

MOI 9/24/99: View from Sun

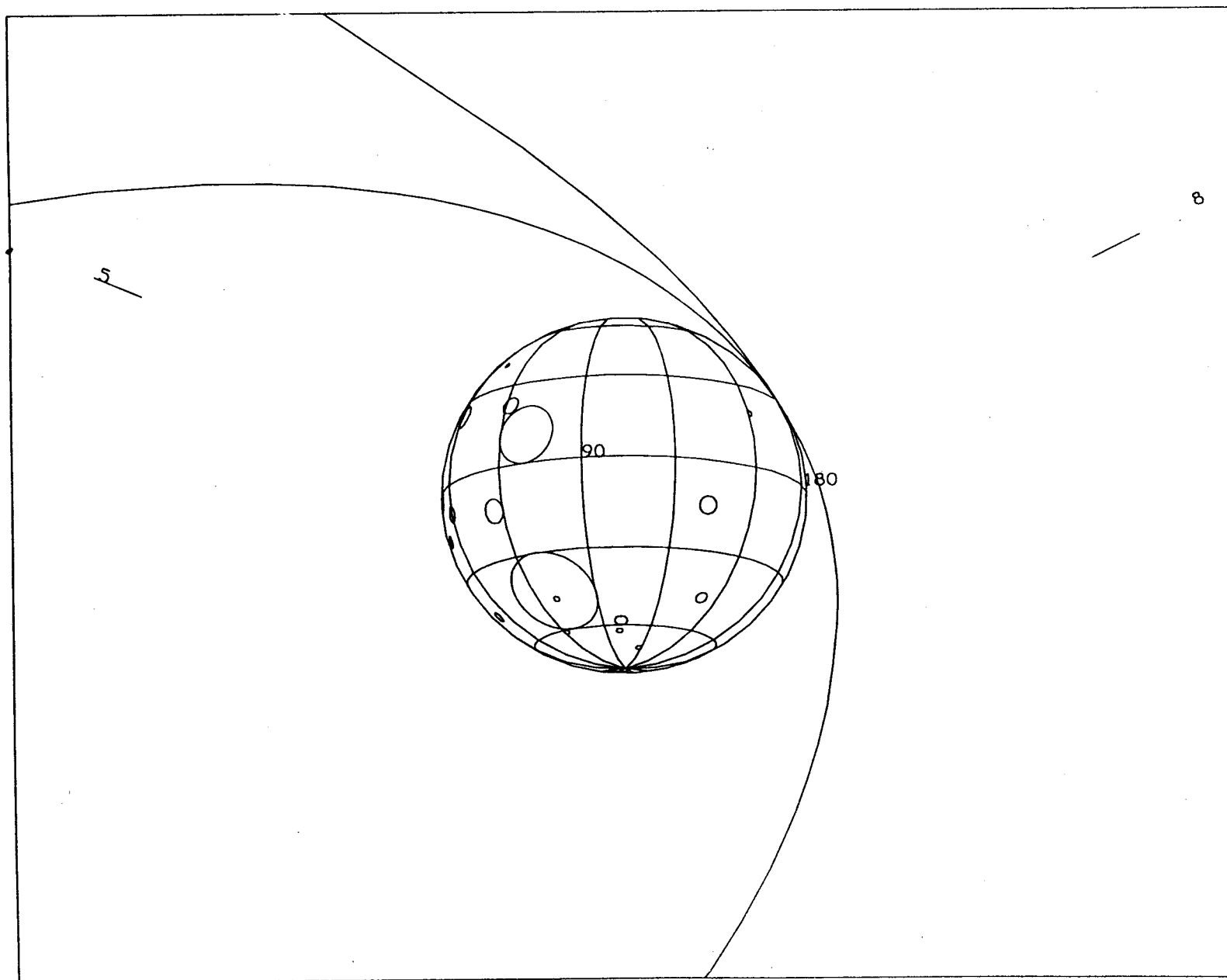
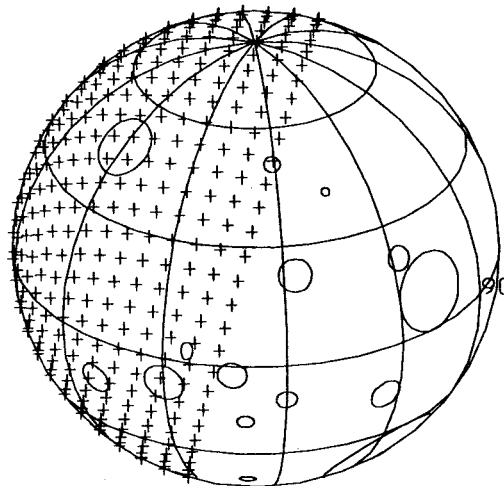


Fig 4

MOI 9/24/99: View from Approach Asymptote

$\frac{p}{|}$



2
5

Fig 1

MOI 9/24/99: s/c View: Closest Appr - 30 min., FOV = 150 deg.

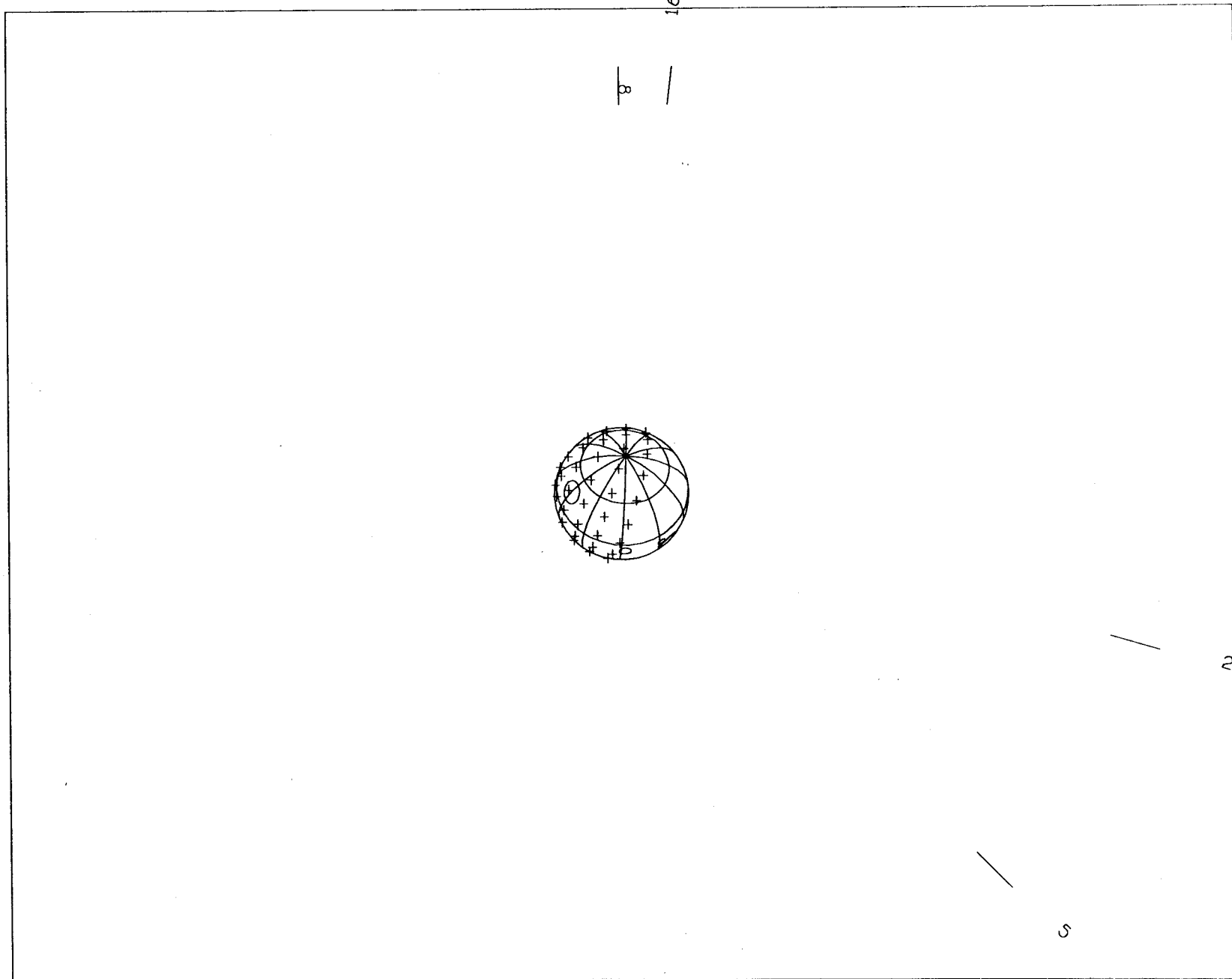


Fig 2

MOI 9/24/99: s/c View: Closest Appr - 25 min., FOV = 150 deg.

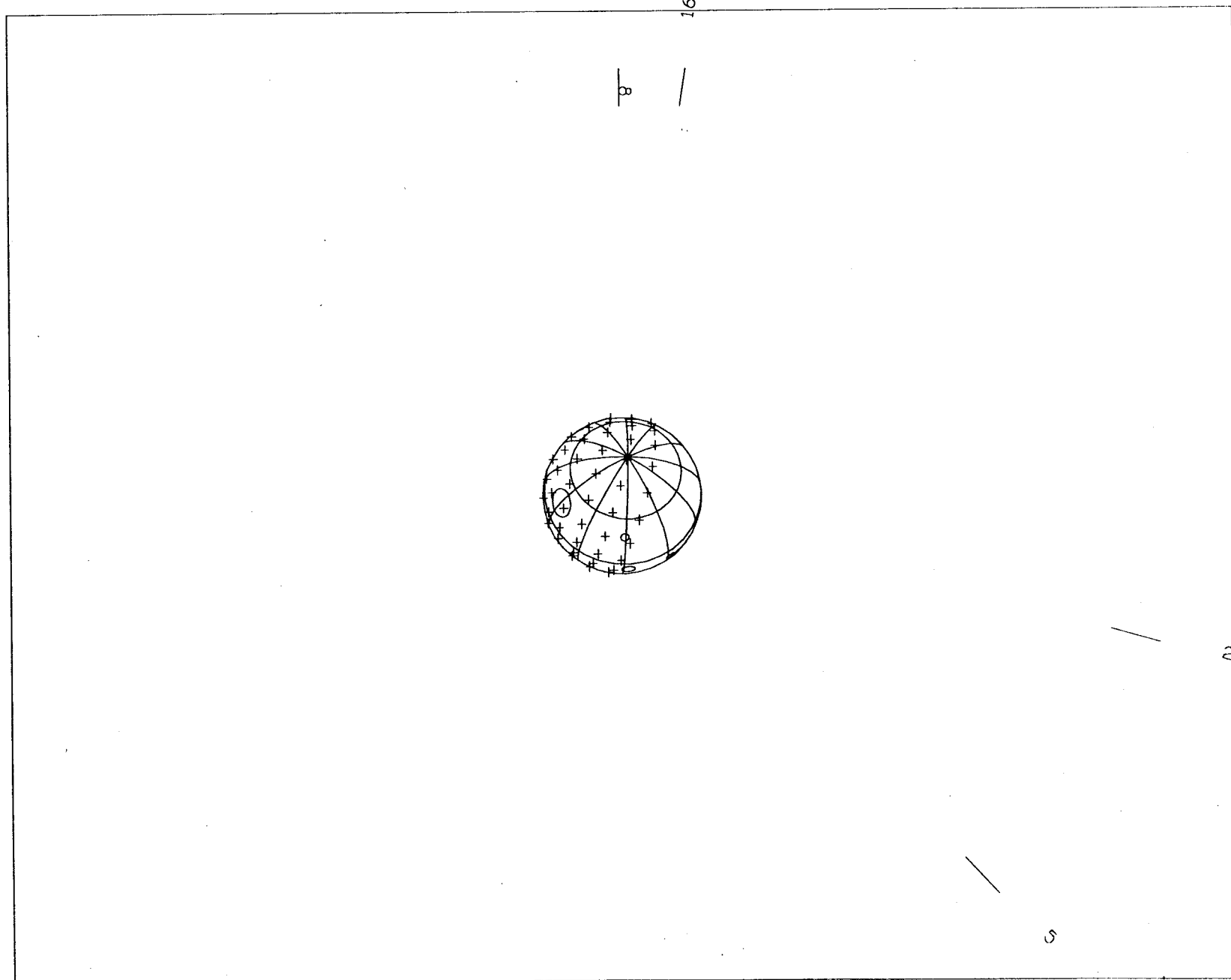


Fig 3

MOI 9/24/99: s/c View: Closest Appr - 20 min., FOV = 150 deg.

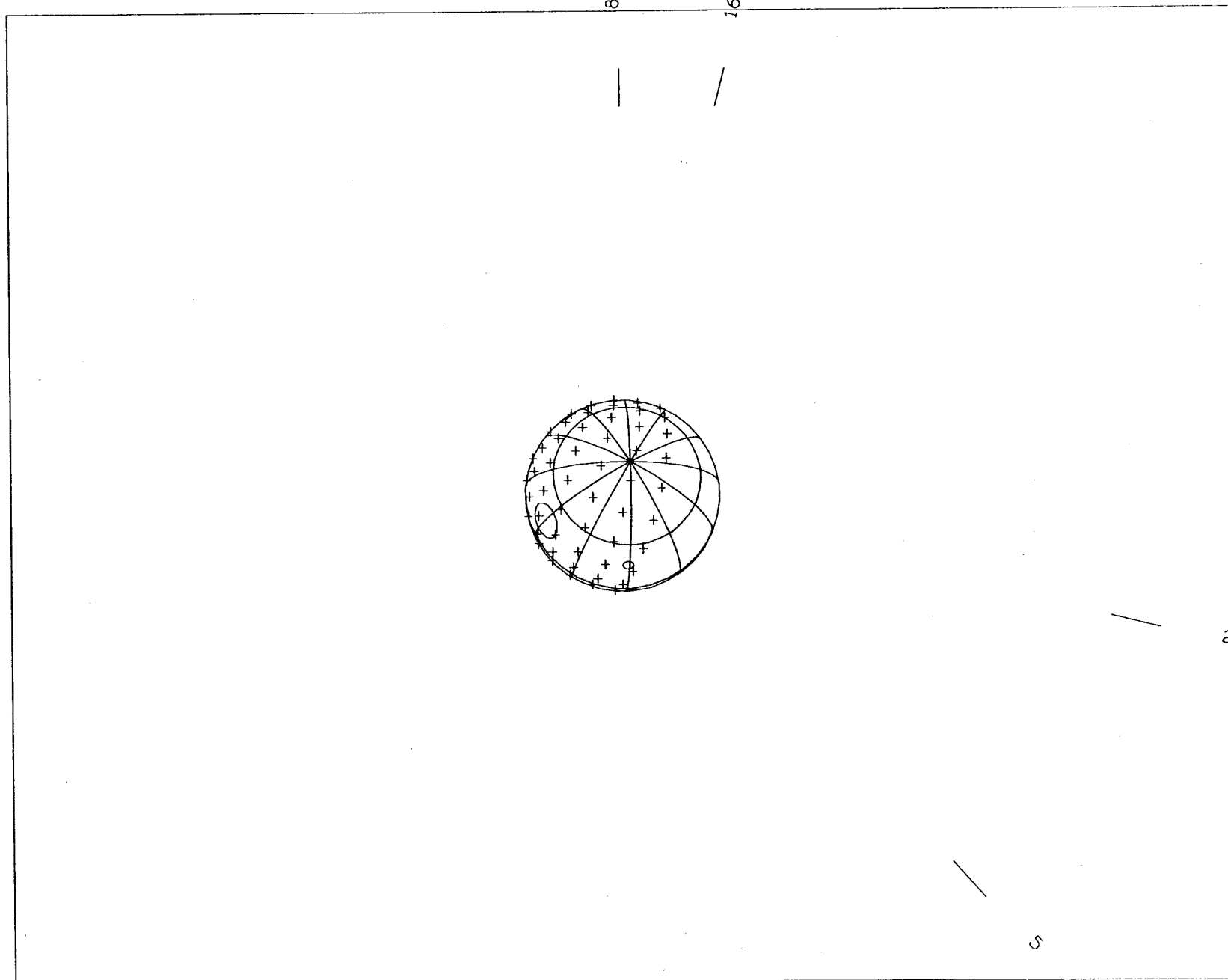


Fig 4

MOI 9/24/99: s/c View: Closest Appr - 15 min., FOV = 150 deg.

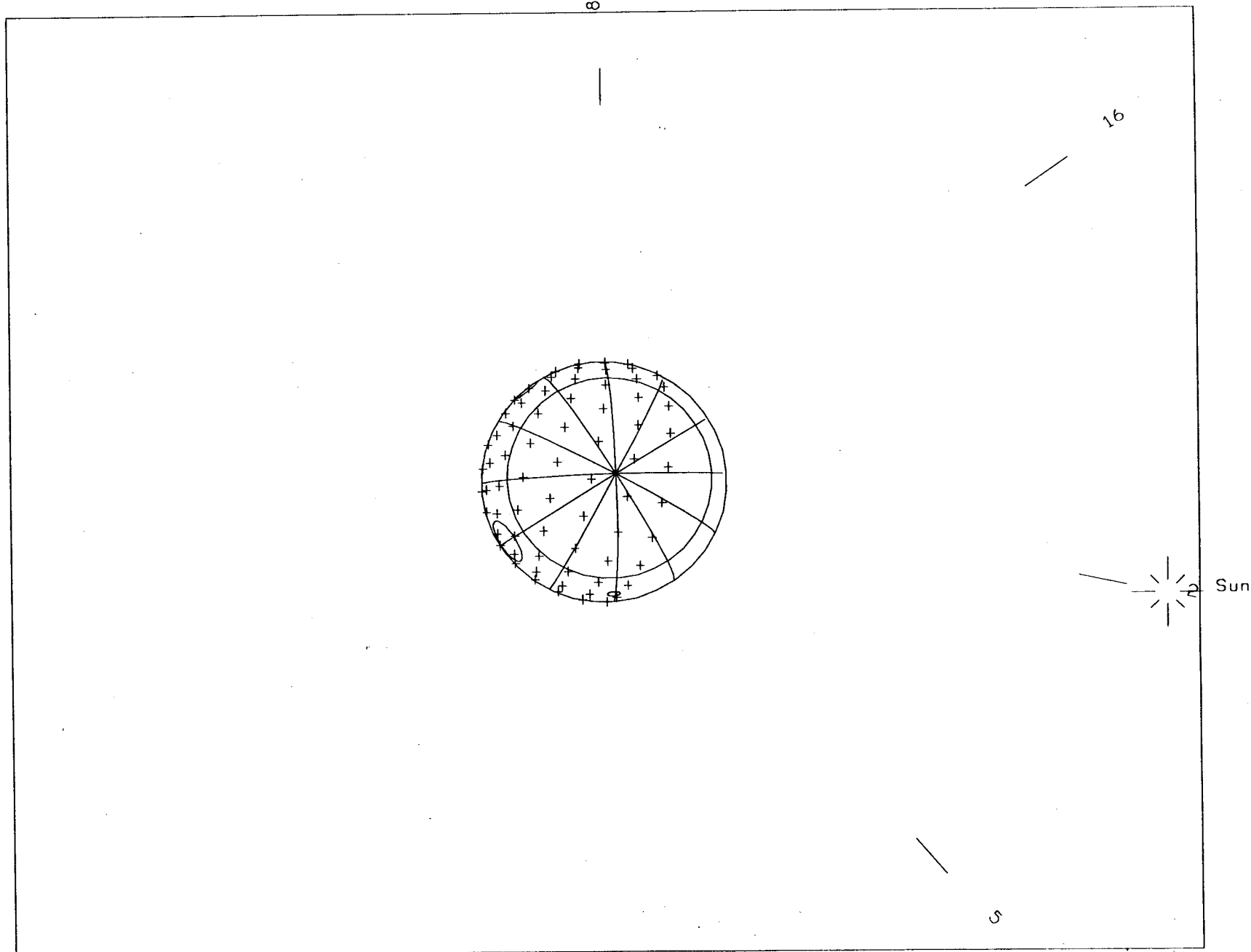


Fig 5

MOI 9/24/99: s/c View: Closest Appr - 10 min., FOV = 150 deg.

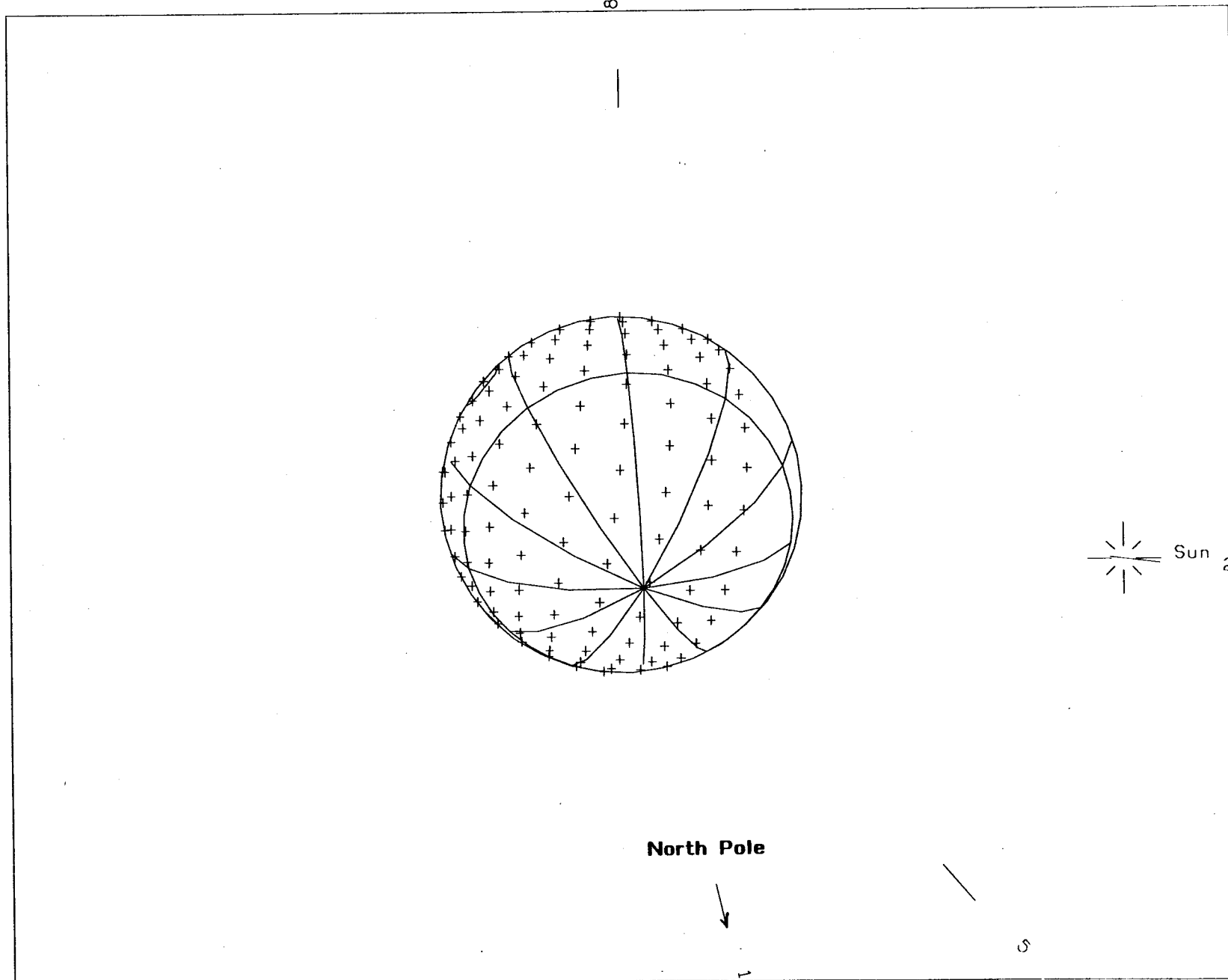


Fig 6

9/24/99: s/c View: Closest Appr - 8 min. MOI start, FOV = 150

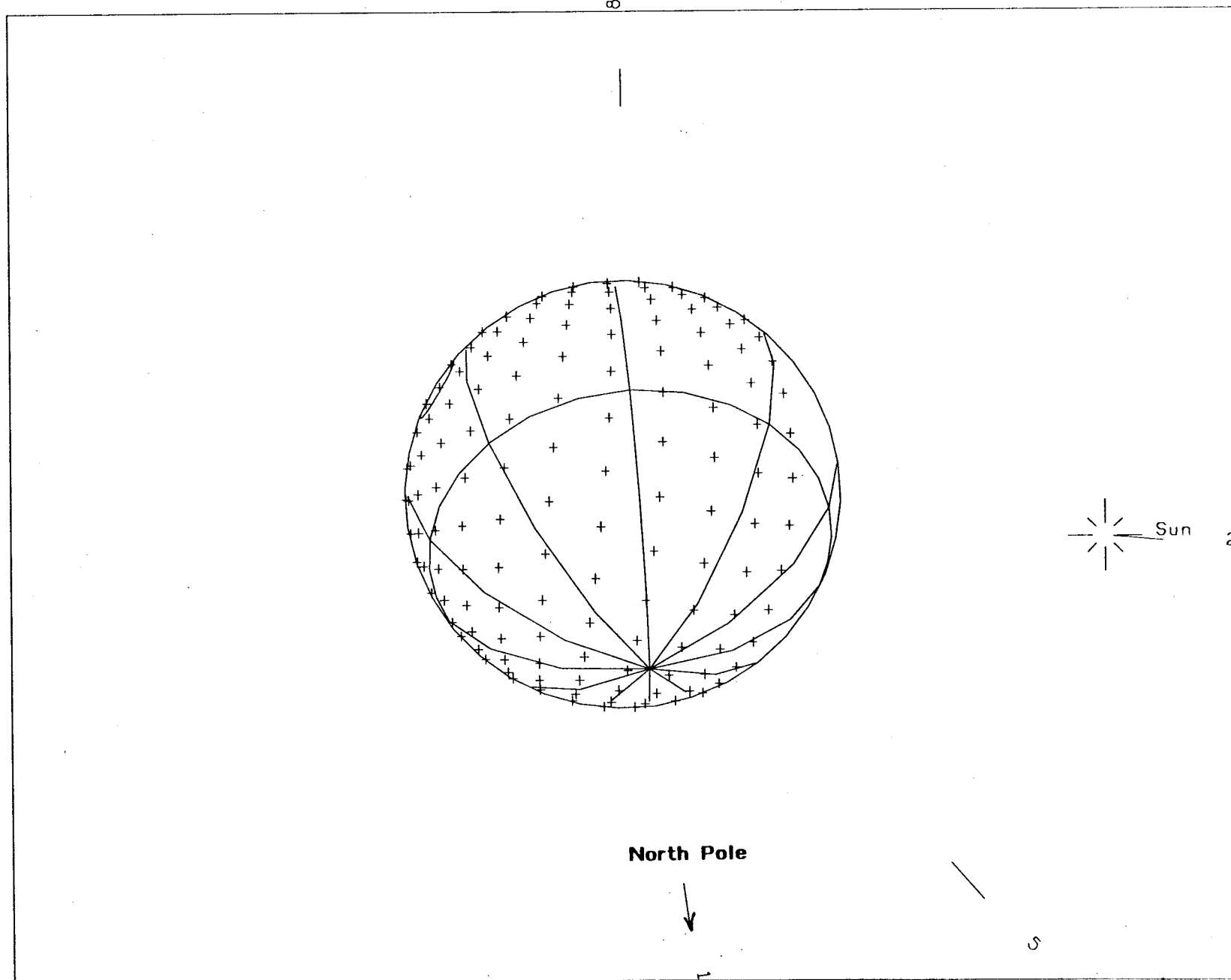


Fig 7 16

MOI 9/24/99: s/c View: Closest Appr - 6 min., FOV = 150 deg.

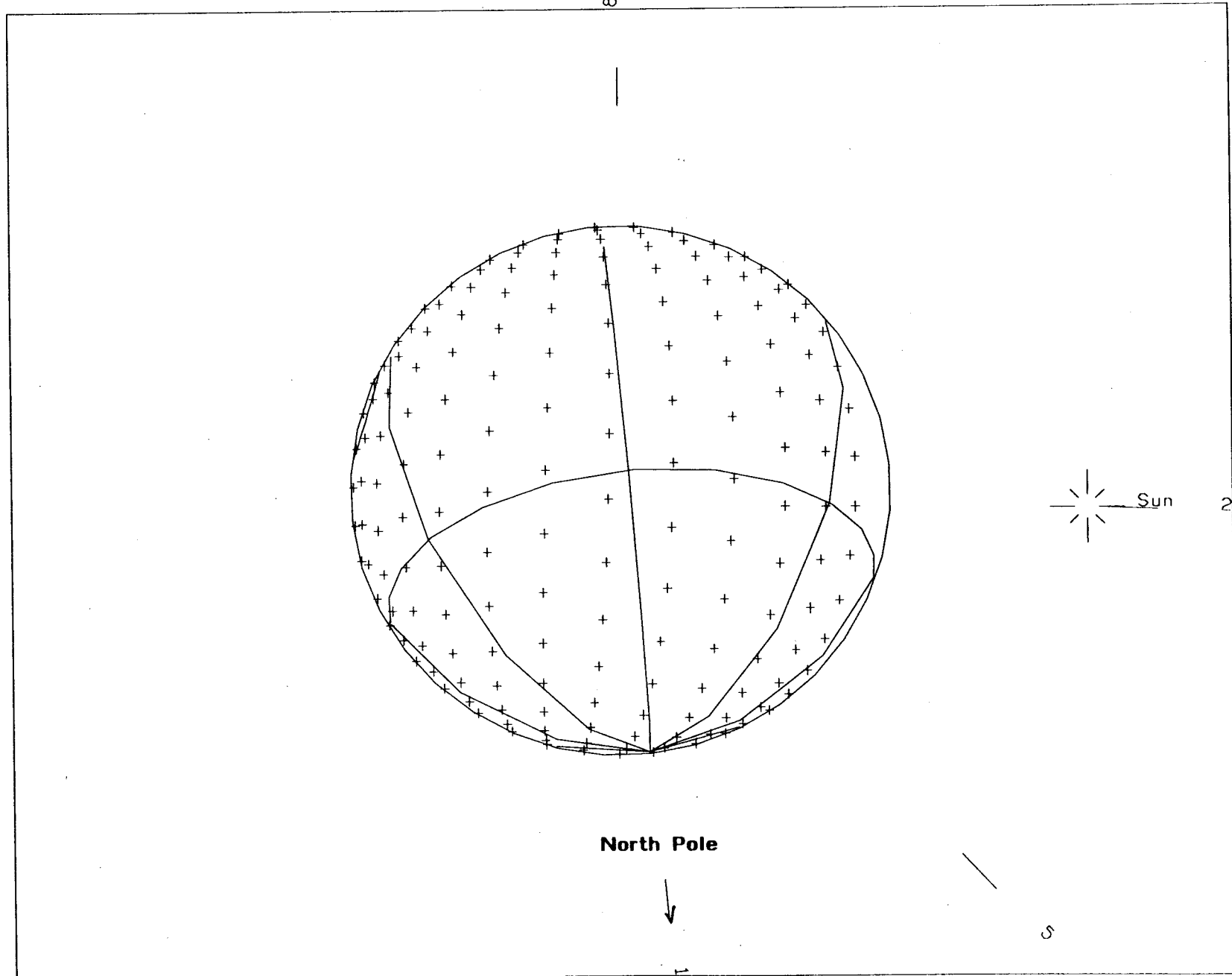


Fig 8⁹⁶

MOI 9/24/99: s/c View: Closest Appr - 4 min., FOV = 150 deg.

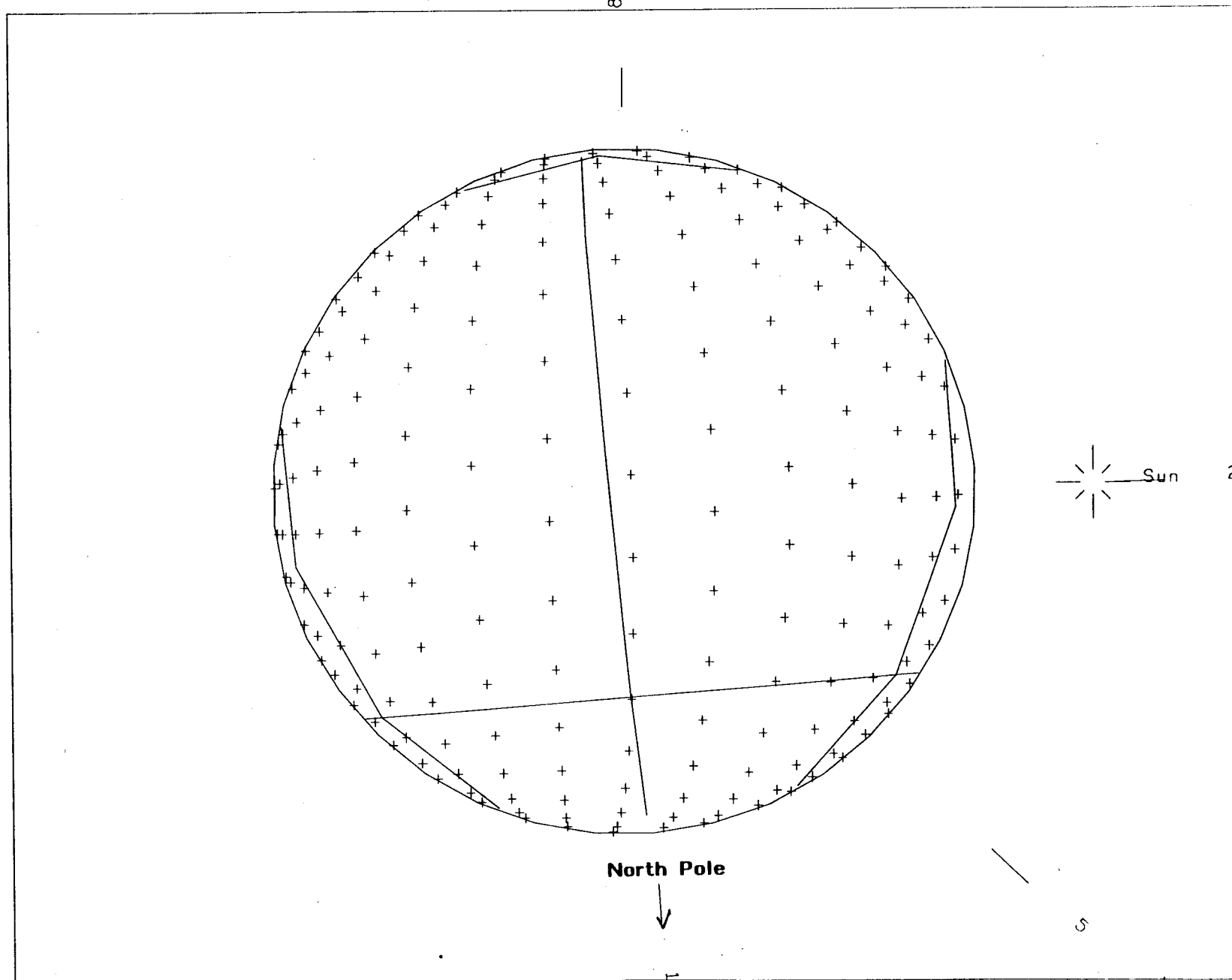


Fig 9

MOI 9/24/99: s/c View: Closest Appr - 2 min., FOV = 150 deg.

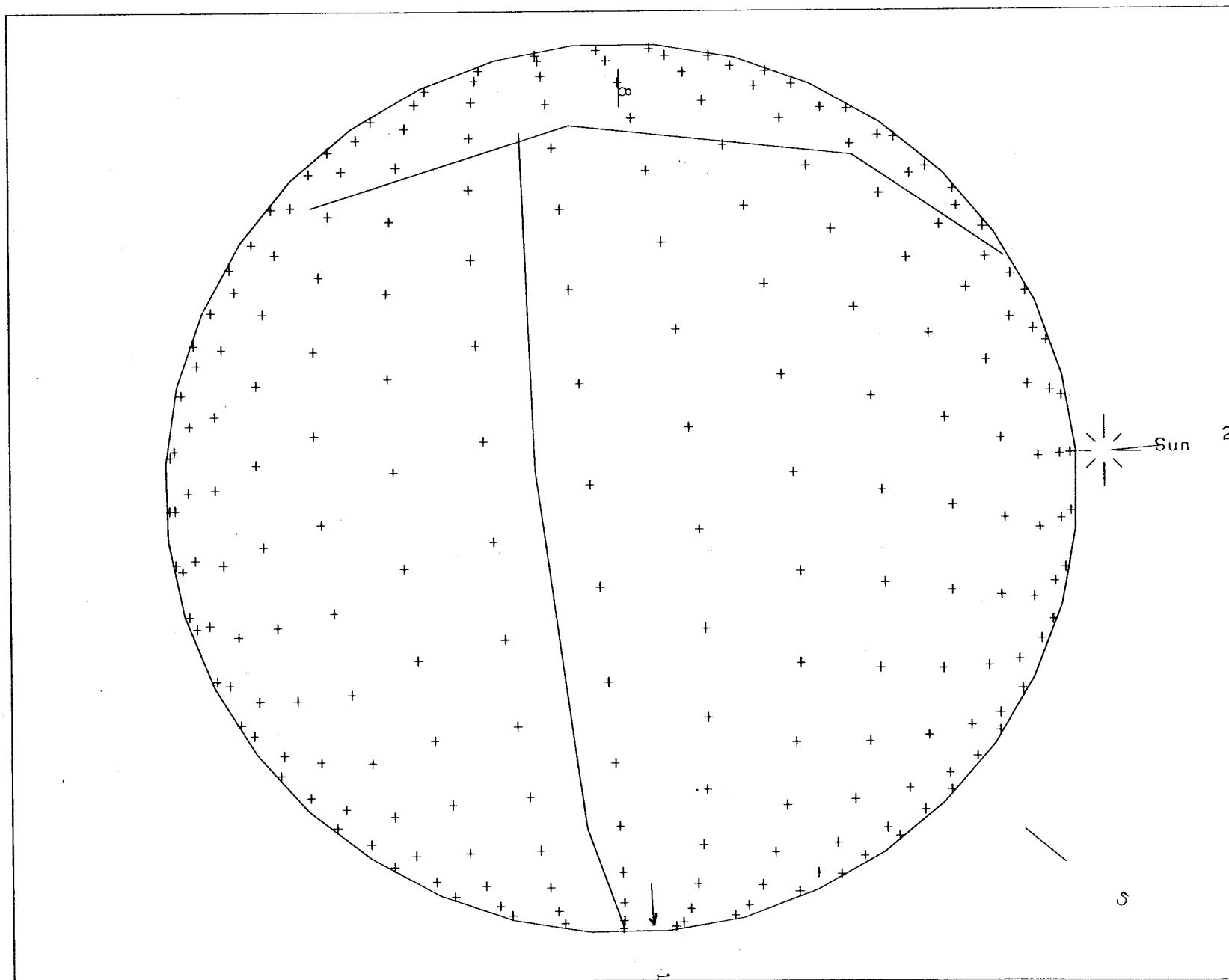


Fig 10

MUJ 9/24/99: s/c View: Closest Approach, FOV = 150 deg.

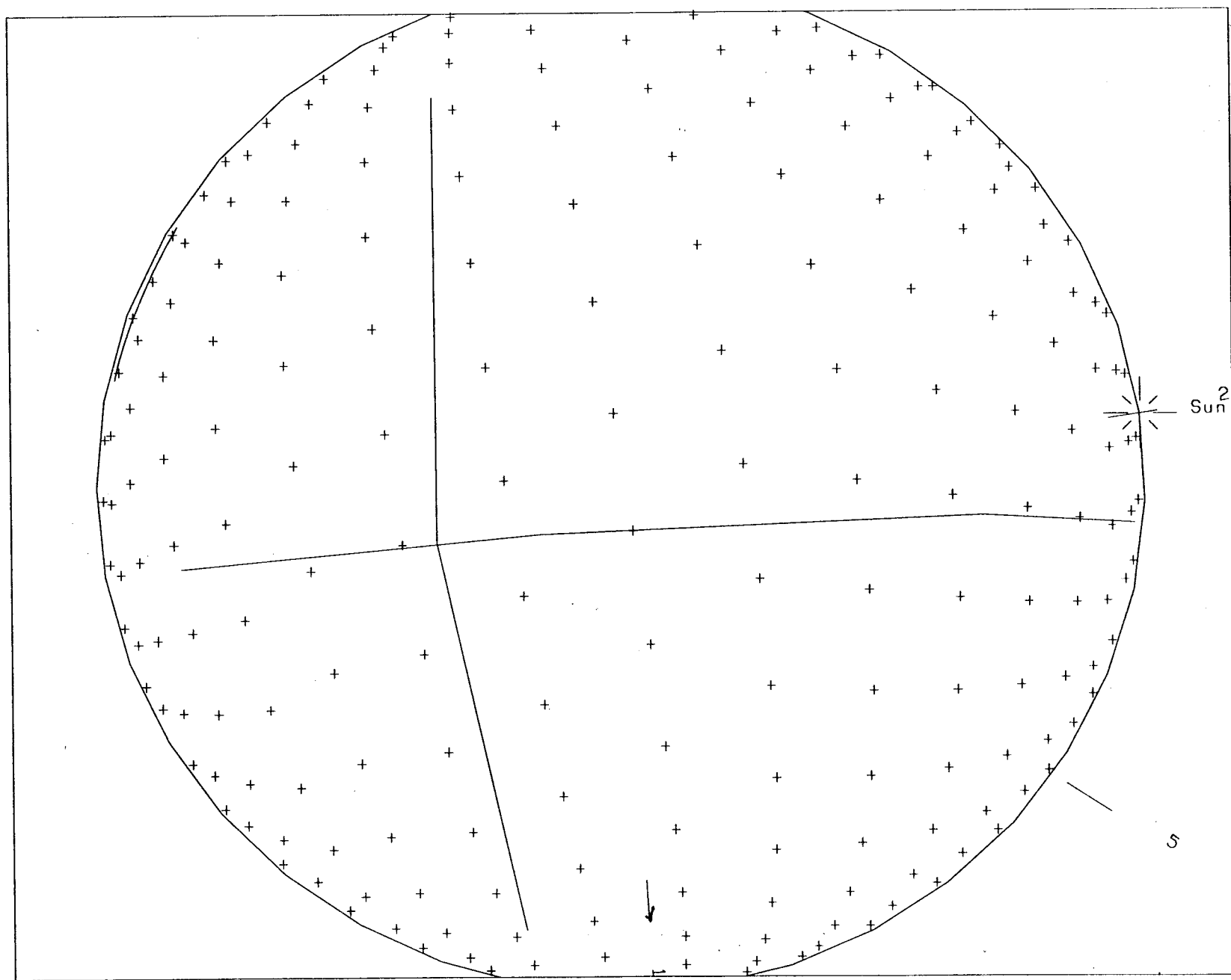


Fig 11

A.5 Aerobraking Database

A.5.1 Open Primary Launch Period: State Data and Strawman Tracking Schedule

A.5.2 Close Primary Launch Period: State Data and Strawman Tracking Schedule

State data are based on CDR aerobraking timelines provided by W. Willcockson 11/96. Strawman tracking schedules are based on the following assumptions, using the 11/96 aerobraking timelines:

- The first post-aeropass track starts 18 minutes from the end of the aeropass, which provides time for the RW slew to the DSN contact orientation and reconfiguration of the Orbiter.
- Tracking duration is the total time the SSPA is on
- Aeropass begin and end times include 5 minute pads at start and end
- 4 on: 5 off ratio is maintained throughout, except during the last 2 days, during which the tracking pass durations are 30 minutes per orbit.

Starting Time for Simulation: Sept. 28, 1999; 22:01 ET (Apoapsis, Last Walkin Maneu

1

Open of Primary MSP Peer Review 11/96, Beg of L/W, Min Mass Config, Data written at periapsis point

Starting Time for Simulation: Sept. 28, 1999; 22:01 ET (Apoapsis, Last Walkin Maneuver)

1/28/99 22:01	45.01	REV#	PERIAPS ALT	PER WRT ELLIPSOID	APPOSIAS ALT	NURNB	QDVN	QHTVNM	INCLIN	ASC NODE	ARGPER	DRAGDUR	BEGIN	END	BEGIN	END	SUN DIST	SUN LAT	SUN LONG	EARTH DIST	EARTH LAT	EARTH LONG	VEPER	DELTA PERI	DELTA LAT	DELTA MEAN	-180 TO 180	DELTA RAN	SOLAR TIME	DRAGDUR (Including 5 min delay eqs)	ANAL	SOLAR				
1/28/99 22:01	45.01	90	96.78	110.09	8612.10	32	0.59	0.26	93.05	356.63	134.20	516.85	0.00	0.00	-365.23	498.64	2.06900E-22	-22.12	103.44	2.36E+08	-10.03	65.50	5.757	4.3563	27.56	137.4	5.73	23.589	3.370	1.620	43:50:57 AM	402.9	-501.5	5015	19271.4826	
1/13/99 04:55	45.25	91	98.50	109.81	8590.39	32	0.59	0.26	93.05	356.65	134.26	494.85	0.00	0.00	-365.50	496.33	2.06910E-22	-22.15	103.60	2.37E+08	-10.11	65.66	5.695	4.3519	28.61	137.9	4.39	23.714	-3.350	1.640	43:45:42 AM	404.4	-502.2	5022	19498.01165	
1/13/99 04:55	45.25	91	98.50	109.81	8590.39	32	0.59	0.26	93.05	356.65	134.26	494.85	0.00	0.00	-365.50	496.33	2.06910E-22	-22.15	103.60	2.37E+08	-10.11	65.66	5.695	4.3519	28.61	137.9	4.39	23.714	-3.350	1.640	43:45:42 AM	404.4	-502.2	5022	19498.01165	
1/13/99 15:20	45.45	93	98.49	109.82	8246.35	32	0.54	0.23	93.04	356.71	133.46	528.19	0.00	0.00	-365.34	495.64	2.06900E-22	-22.18	103.75	2.37E+08	-10.26	65.82	5.683	4.3503	29.63	138.2	4.46	23.838	-3.030	1.640	43:38:41 AM	407.4	-503.2	5032	19621.28026	
1/13/99 20:53	45.95	94	98.20	110.75	8142.40	32	0.49	0.20	93.05	356.73	133.62	453.74	0.00	0.00	-365.96	495.79	2.06900E-22	-22.25	104.06	2.37E+08	-10.33	66.15	5.487	4.3369	20.65	103.8	4.02	24.081	-3.270	1.720	43:33:33 AM	409.3	-504.6	5046	18779.7533	
1/14/99 21:41	46.18	95	99.21	110.84	8019.70	32	0.49	0.21	93.03	356.75	133.42	422.66	0.00	0.00	-366.46	495.71	2.06900E-22	-22.28	104.22	2.37E+08	-10.40	66.30	5.430	4.3307	23.98	122.7	6.18	24.201	-3.250	1.740	43:33:09 AM	411.0	-505.5	5055	18535.26112	
1/14/99 7:47	46.41	96	98.38	110.09	7926.47	32	0.55	0.24	93.04	356.77	133.21	426.03	0.00	0.00	-368.16	493.27	2.06880E-22	-22.31	104.37	2.38E+08	-10.43	66.46	5.379	4.3271	24.84	93.1	3.53	24.319	-3.230	1.760	43:32:46 AM	412.3	-506.2	5062	18352.52063	
1/14/99 13:08	46.63	97	99.40	111.19	7809.70	32	0.47	0.20	93.03	356.80	132.99	352.36	-331.41	-325.33	-367.34	494.90	2.06870E-22	-22.34	104.51	2.39E+08	-10.54	66.62	5.316	4.3211	26.87	116.9	6.09	24.436	-3.200	1.790	43:25:25 AM	414.0	-507.0	5070	18124.115814	
1/14/99 18:28	46.85	98	96.57	108.44	7708.98	33	0.68	0.29	93.03	356.83	132.77	360.82	-346.17	-310.85	-356.68	493.16	2.06870E-22	-22.37	104.66	2.39E+08	-10.61	66.87	5.280	4.3180	29.20	100.8	2.49	24.552	-3.170	1.820	43:24:04 AM	415.5	-507.8	5078	17940.67482	
1/14/99 23:40	47.04	99	96.40	107.40	7581.40	34	0.44	0.19	93.04	356.86	132.60	301.81	-368.40	-326.30	-367.40	492.10	2.06860E-22	-22.40	104.80	2.39E+08	-10.68	67.00	5.260	4.3160	30.80	92.7						43:24:04 AM	415.5	-507.8	5078	17940.67482
1/15/99 01:45	47.29	100	96.92	108.98	7488.98	33	0.62	0.27	93.04	356.87	132.77	301.81	-409.40	-355.46	-368.34	490.16	2.06850E-22	-22.43	104.95	2.39E+08	-10.71	67.07	5.142	4.3107	30.29	92.4	2.76	24.779	-3.130	1.860	43:11:59 AM	418.8	-509.5	5095	17490.13877	
1/15/99 05:38	47.51	101	96.61	108.74	7368.30	33	0.64	0.27	93.04	356.89	132.10	359.54	-473.04	-209.04	-369.54	493.98	2.06850E-22	-22.46	105.09	2.39E+08	-10.82	67.22	5.077	4.3023	31.18	120.0	5.58	24.891	-3.110	1.880	43:07:58 AM	420.8	-510.4	5104	17257.4857	
1/15/99 15:01	47.71	102	97.30	109.51	7284.30	33	0.57	0.24	93.03	356.92	131.88	392.18	-488.40	-195.08	-370.26	493.08	2.06840E-22	-22.49	105.23	2.39E+08	-10.88	67.36	5.011	4.2956	23.93	125.4	6.73	25.001	-3.080	1.910	43:03:30 AM	422.8	-511.4	5114	17016.22086	
1/15/99 20:01	47.92	103	96.32	108.62	7143.70	33	0.64	0.28	93.03	356.95	131.64	407.16	-500.74	-193.37	-369.92	491.53	2.06830E-22	-22.51	105.37	2.39E+08	-10.92	67.51	4.957	4.2913	29.22	99.6	4.26	25.110	-3.050	1.940	43:03:19 AM	424.4	-512.2	5122	16822.38038	
1/16/99 03:48	48.12	104	97.36	109.74	7019.59	33	0.55	0.23	93.04	356.97	131.45	286.30	-526.90	-175.47	-371.26	491.97	2.06830E-22	-22.54	105.51	2.39E+08	-11.02	67.85	4.892	4.2842	29.44	124.2	7.15	25.218	-3.080	1.960	42:59:58 AM	426.5	-513.3	5133	16527.72182	
1/16/99 08:23	48.33	105	96.88	109.59	6931.99	33	0.56	0.24	93.04	356.99	131.21	341.54	-547.18	-170.47	-372.36	490.49	2.06830E-22	-22.57	105.67	2.39E+08	-11.08	67.97	4.848	4.2774	29.44	124.2	7.15	25.218	-3.080	1.960	42:59:58 AM	426.5	-513.3	5133	16527.72182	
1/16/99 13:08	48.53	106	96.92	109.37	6828.10	33	0.54	0.24	93.04	357.01	130.99	417.96	-569.59	-168.32	-372.82	494.19	2.06820E-22	-22.60	105.81	2.39E+08	-11.11	68.15	4.833	4.2742	29.48	101.9	5.19	25.340	-2.990	2.000	42:54:45 AM	428.9	-514.9	5149	16167.57034	
1/16/99 15:26	48.77	107	97.59	110.23	6723.90	33	0.50	0.21	93.03	357.05	130.76	307.23	-582.49	-160.74	-373.60	490.66	2.06810E-22	-22.62	105.91	2.39E+08	-11.24	68.07	4.737	4.2684	29.66	105.2	6.23	25.534	-2.950	2.040	42:50:21 AM	431.6	-515.8	5158	15956.16182	
1/16/99 20:10	48.92	108	96.60	109.33	6640.40	33	0.56	0.24	93.03	357.07	130.51	295.70	-593.93	-159.31	-372.85	490.87	2.06800E-22	-22.65	106.05	2.40E+08	-11.27	68.21	4.693	4.2646	29.85	83.5	3.79	25.638	-2.930	2.060	42:48:41 AM	433.1	-516.6	5166	15785.47325	
1/17/99 05:40	49.12	109	97.27	110.08	6509.70	33	0.50	0.22	93.04	357.09	130.31	298.14	-608.34	-150.34	-376.17	492.18	2.06800E-22	-22.68	106.18	2.40E+08	-11.33	68.34	4.640	4.2584	30.13	103.0	6.21	25.740	-2.910	2.080	42:48:22 AM	435.0	-517.5	5175	15563.82442	
1/17/99 10:28	49.31	110	97.21	110.21	6457.00	33	0.48	0.21	93.03	357.12	130.00	415.44	-637.39	-147.51	-377.61	491.83	2.06790E-22	-22.70	106.30	2.40E+08	-11.39	68.48	4.599	4.2538	30.48	80.4	4.53	25.841	-2.880	2.110	42:48:05 AM	436.5	-518.3	5183	15399.47260	
1/17/99 15:05	49.50	111	94.63	109.63	6361.36	33	0.68	0.29	93.04	357.14	129.81	362.26	-646.52	-140.65	-377.12	491.83	2.06790E-22	-22.73	106.43	2.40E+08	-11.45	68.61	4.550	4.2497	30.48	80.4	4.53	25.841	-2.880	2.130	42:47:45 AM	438.5	-519.1	5191	15213.11027	
1/17/99 19:05	49.88	112	94.60	109.68	6256.46	37	0.44	0.17	93.04	357.16	129.54	342.74	-678.74	-137.40	-378.44	491.83	2.06790E-22	-22.76	106.54	2.40E+08	-11.51	68.74	4.501	4.2430	30.48	80.4	4.53	25.841	-2.880	2.150	42:47:25 AM	440.5	-520.0	5200	15039.78426	
1/17/99 23:08	50.08	113	95.10	109.28	6171.40	33	0.61	0.26	93.03	357.20	129.33	395.92	-677.70	-131.24	-379.27	493.59	2.06780E-22	-22.78	106.68	2.40E+08	-11.57	68.87	4.451	4.2390	30.12	85.4	3.10	26.138	-2.890	2.190	42:47:12 AM	442.0	-521.0	5210	14832.72291	
1/18/99 03:24	50.68	114	94.68	108.77	6073.10	33	0.64	0.27	93.04	357.22	129.07	245.01	-700.24	-113.43	-379.60	494.99	2.06770E-22	-22.80	106.81	2.40E+08	-11.63	68.90	4.400	4.2334	30.13	98.3	5.55	26.235	-2.780	2.210	42:46:54 AM	444.0	-522.0	5220	14615.88286	
1/18/99 07:50	50.95	115	95.70	109.05	5967.80	38	0.54	0.23	93.01	357.25	128.85	360.67	-717.35	-106.36	-379.73	496.97	2.06760E-22	-22.83	106.93	2.41E+08	-11.69	69.21	4.347	4.2263	30.08	105.3	7.18	26.331	-2.750	2.240	42:46:38 AM	446.2	-523.1	5231	14440.90853	
1/18/99 15:45	50.43	116	95.10	108.55	5889.40	38	0.57	0.24	93.04	357.27	128.59	394.69	-734.46	-111.14	-377.86	496.53	2.06760E-22	-22.85	107.05	2.41E+08	-11.74	69.25	4.307	4.2219	30.44	104.0	7.84	26.338	-2.626	2.260	42:46:20 AM	447.8	-523.9	5239	14247.96541	
1/18/99 19:23	50.81	117	95.21	108.74	5794.10	38	0.55	0.23	93.03	357.30	128.37	326.20	-750.08	-101.93	-378.40	497.29	2.06750E-22	-22.88	107.17	2.41E+08	-11.81	69.37	4.259	4.2158	30.29	95.3	6.60	26.520	-2.700	2.290	42:46:05 AM	449.9	-524.9	5249	14058.39089	
1/18/99 23:08	51.29	118	95.21	108.74	5702.20	38	0.49	0.23	93.04	357.32	128.12	349.38	-782.42	-91.27	-379.40	498.12	2.06750E-22	-22.91	107.28	2.41E+08	-11.84	69.48	4.250	4.2107	30.29	95.3	6.60	26.520	-2.700	2.310	42:45:45 AM	451.9	-525.9	5259	13879.98426	
1/19/99 03:24	51.90	119	93.07	108.79	5618.60	39	0.71	0.29	93.02	357.36	127.87	316.83	-775.57	-86.65	-379.95	500.11	2.06740E-22	-22.93	107.40	2.41E+08	-11.90	69.62	4.140	4.2062	30.17	84.2	3.24	26.640	-2.640	2.350	42:45:35 AM	453.7	-526.9	5269	13709.98426	
1/19/99 05:10	51.33	120	95.13	108.83	5515.40	40	0.53	0.22	93.03	357.38	127.64	340.16	-798.79	-81.47	-384.07	501.33	2.06740E-22	-22.95	107.52	2.41E+08	-11.96	69.74	4.120	4.1979	30.12	102.9	8.34	26.785	-2.620							

Open of Primary

MSP Peer Review 11/96, Beg of LW, Min Mass Config. Data written at periapsis point

9/28/99 22:01	DAY#	REV#	PERIAPS ALT	PER WRT ELLIPSOID	APOAPSIS ALT	NEURN	QDYN	QHTDYN	INCLIN	ASC NODE	ARGPER	DRAGOUR	SUN ECLIPSE BEGIN	SUN ECLIPSE END	EARTH OCCULT BEGIN	EARTH OCCULT END	SUN DIST	SUN LAT	SUN LONG	EARTH DIST	EARTH LAT	EARTH LONG	PERIOD	VPER	DELT PERIOD	DELT APO	DELT V	DELT MEAN SUN	RAAN	DELT RAAN	SOLAR TIME	DRAGDUR	(Including 5 min delay segs)			AND SOLAR									
9/28/99 22:01	59.07	179	86.20	105.59	2222.10	48	0.31	0.12	92.93	359.23	110.63	371.22	-1349.30	156.40	-413.04	644.16	2.06730E+08	-23.72	112.95	2.49E+08	-14.29	75.51	2.590	3.8963	58.1	37.0	4.28	30.956	-0.770	4:20	4:16:03 AM	685.4	-642.7	642.7	7331.890894										
11/27/99 21:18	59.18	180	84.82	104.31	2183.70	48	0.34	0.13	92.96	359.27	109.65	887.57	-1352.70	163.33	-414.23	646.53	2.06730E+08	-23.73	113.03	2.49E+08	-14.32	75.59	2.573	3.8921	62.6	39.4	4.18	31.012	-0.730	4:20	4:15:59 AM	690.3	-645.1	645.1	7283.46639										
11/27/99 4:34	59.29	181	85.09	104.56	2148.20	48	0.33	0.13	92.97	359.30	109.33	881.63	-1356.50	170.88	-416.96	658.02	2.06730E+08	-23.74	113.10	2.49E+08	-14.35	75.68	2.554	3.8861	66.3	43.3	6.00	31.089	-0.700	4:20	4:15:53 AM	695.8	-647.9	647.9	7190.57342										
11/27/99 7:26	59.39	182	85.83	105.47	2109.80	48	0.29	0.11	92.93	359.33	109.81	875.36	-1362.70	174.65	-418.80	669.86	2.06730E+08	-23.75	113.17	2.49E+08	-14.39	75.74	2.538	3.8801	68.8	39.3	5.99	31.124	-0.670	4:20	4:15:47 AM	700.9	-650.5	650.5	7123.040737										
11/27/99 9:59	59.50	183	85.57	105.32	2068.10	48	0.29	0.11	92.90	359.37	108.55	862.49	-1366.40	176.66	-416.16	680.55	2.06730E+08	-23.76	113.25	2.49E+08	-14.42	75.82	2.573	3.8755	53.4	34.8	4.58	31.180	-0.630	4:20	4:15:43 AM	705.6	-652.8	652.8	7063.058654										
11/27/99 12:32	59.61	184	85.66	105.50	2030.10	48	0.28	0.11	92.94	359.40	108.12	879.04	-1369.70	182.62	-415.19	688.86	2.06730E+08	-23.77	113.32	2.49E+08	-14.45	75.90	2.508	3.8705	54.6	36.0	5.06	31.235	-0.600	4:20	4:15:37 AM	710.6	-655.3	655.3	7003.150758										
11/27/99 15:01	59.71	185	85.06	104.97	1994.90	48	0.29	0.11	92.98	359.43	107.81	862.52	-1374.50	188.35	-415.66	673.93	2.06730E+08	-23.78	113.39	2.49E+08	-14.48	75.97	2.493	3.8660	54.4	35.2	4.46	31.290	-0.570	4:20	4:15:31 AM	715.1	-675.7	675.7	6923.53132										
11/27/99 17:31	59.81	186	84.61	104.59	1960.00	48	0.29	0.11	92.96	359.46	107.48	845.38	-1380.50	193.46	-418.02	679.49	2.06730E+08	-23.79	113.46	2.49E+08	-14.51	76.05	2.476	3.8614	53.6	34.9	4.59	31.344	-0.540	4:20	4:15:25 AM	719.8	-679.2	679.2	6860.550459										
11/27/99 20:01	59.92	187	86.13	106.20	1923.60	48	0.24	0.09	92.92	359.50	107.10	885.49	-1385.20	197.79	-418.35	684.66	2.06730E+08	-23.80	113.53	2.49E+08	-14.54	76.12	2.463	3.8550	52.8	36.4	6.37	31.399	-0.500	4:20	4:15:22 AM	765.7	-682.8	682.8	6789.429234										
11/27/99 22:29	60.02	188	82.00	102.23	1887.20	49	0.36	0.14	92.92	359.55	106.73	880.10	-1390.00	200.27	-414.94	688.06	2.06730E+08	-23.81	113.60	2.49E+08	-14.57	76.20	2.446	3.8529	61.0	36.4	2.12	31.453	-0.450	4:20	4:15:18 AM	773.2	-686.6	686.6	6730.820274										
11/28/99 0:56	60.12	189	80.85	101.07	1841.00	49	0.39	0.15	92.93	359.59	106.34	897.00	-1392.30	211.13	-421.16	699.65	2.06730E+08	-23.82	113.67	2.49E+08	-14.60	76.27	2.426	3.8472	71.4	46.2	5.76	31.506	-0.410	4:20	4:15:18 AM	783.1	-691.6	691.6	6651.151116										
11/28/99 3:22	60.22	190	79.57	99.88	1789.70	49	0.43	0.17	92.96	359.63	105.90	762.82	-1398.30	219.67	-424.05	705.51	2.06730E+08	-23.82	113.74	2.49E+08	-14.63	76.35	2.404	3.8406	78.9	51.3	6.58	31.559	-0.370	4:20	4:15:15 AM	794.6	-697.3	697.3	6560.512331										
11/28/99 5:46	60.32	191	80.07	100.45	1734.90	49	0.40	0.15	92.97	359.66	105.56	526.18	-1405.40	227.95	-427.57	716.04	2.06730E+08	-23.83	113.81	2.49E+08	-14.66	76.42	2.382	3.8320	81.3	54.8	8.59	31.612	-0.340	4:20	4:15:09 AM	807.4	-703.7	703.7	6465.760507										
11/28/99 8:08	60.42	192	80.85	101.30	1686.30	49	0.35	0.14	92.92	359.69	105.19	458.76	-1414.70	232.66	-428.73	723.81	2.06730E+08	-23.84	113.88	2.49E+08	-14.69	76.49	2.362	3.8240	71.3	48.6	7.98	31.664	-0.310	4:20	4:15:04 AM	819.2	-709.6	709.6	6378.174805										
11/28/99 10:31	60.52	193	80.43	100.99	1642.40	49	0.35	0.13	92.90	359.73	104.66	591.52	-1421.40	235.74	-427.10	730.31	2.06730E+08	-23.85	113.95	2.49E+08	-14.71	76.57	2.344	3.8176	65.9	43.9	6.43	31.715	-0.270	4:20	4:15:01 AM	830.4	-715.2	715.2	6300.953319										
11/28/99 12:52	60.62	194	80.52	101.17	1597.00	49	0.34	0.13	92.93	359.77	104.15	804.34	-1424.80	243.34	-425.42	738.34	2.06730E+08	-23.86	114.01	2.49E+08	-14.74	76.64	2.325	3.8104	67.2	45.4	7.13	31.767	-0.230	4:20	4:14:58 AM	842.5	-721.2	721.2	6224.287056										
11/28/99 15:12	60.72	195	80.06	100.77	1552.50	49	0.34	0.13	92.90	359.80	103.77	636.12	-1431.10	249.44	-426.04	749.37	2.06730E+08	-23.87	114.08	2.49E+08	-14.77	76.71	2.307	3.8038	66.5	44.5	6.66	31.818	-0.200	4:20	4:14:53 AM	854.9	-727.4	727.4	6145.280109										
11/28/99 17:30	60.81	196	79.13	99.90	1508.40	49	0.36	0.14	92.97	359.83	103.41	888.26	-1439.50	258.00	-430.74	756.92	2.06730E+08	-23.88	114.15	2.49E+08	-14.80	76.78	2.288	3.7975	66.5	44.1	6.32	31.868	-0.170	4:20	4:14:48 AM	867.5	-733.8	733.8	6064.03898										
11/28/99 19:47	60.91	197	80.29	101.14	1462.20	49	0.31	0.12	92.93	359.87	102.95	450.73	-1445.80	264.37	-431.21	766.51	2.06730E+08	-23.89	114.21	2.49E+08	-14.83	76.85	2.270	3.7891	66.3	46.2	8.36	31.918	-0.130	4:20	4:14:46 AM	881.5	-740.8	740.8	5984.434729										
11/28/99 22:01	61.00	198	81.49	102.41	1421.00	49	0.27	0.10	92.91	359.92	102.50	546.58	-1452.60	268.89	-428.80	773.67	2.06730E+08	-23.90	114.28	2.49E+08	-14.85	76.92	2.253	3.7814	58.7	41.2	7.67	31.968	-0.080	4:20	4:14:43 AM	894.6	-747.3	747.3	5912.380088										
11/28/99 0:19	61.10	199	80.93	101.93	1384.70	49	0.28	0.11	92.92	359.97	102.07	526.78	-1457.00	273.05	-426.44	781.87	2.06730E+08	-23.91	114.34	2.49E+08	-14.88	76.98	2.238	3.7759	54.0	36.3	5.58	32.017	-0.030	4:20	4:14:40 AM	906.5	-753.3	753.3	5848.003668										
11/28/99 2:33	61.19	200	79.17	100.24	1348.80	49	0.32	0.12	92.95	0.81	101.62	957.85	-1461.10	280.47	-427.19	790.63	2.06730E+08	-23.91	114.40	2.49E+08	-14.91	77.05	2.222	3.7709	58.0	37.8	4.98	32.066	0.014	5:04	4:14:45 AM	919.6	-759.8	759.8	5779.428464										
11/28/99 4:47	61.28	201	79.38	99.51	1303.00	49	0.33	0.12	92.90	0.85	101.16	516.66	-1464.80	290.86	-430.66	803.24	2.06730E+08	-23.92	114.47	2.49E+08	-14.94	77.12	2.204	3.7641	65.0	43.8	6.80	32.114	0.049	5:09	4:14:43 AM	935.3	-767.7	767.7	5702.845007										
11/28/99 6:59	61.37	202	79.45	100.63	1258.80	49	0.29	0.11	92.97	0.88	100.79	514.61	-1470.80	299.23	-432.80	816.18	2.06740E+08	-23.93	114.53	2.49E+08	-14.96	77.19	2.187	3.7557	62.7	44.2	8.40	32.162	0.080	5:09	4:14:38 AM	952.0	-776.0	776.0	5625.765020										
11/28/99 9:10	61.47	203	79.78	101.02	1221.00	49	0.27	0.10	92.90	0.13	100.34	753.17	-1478.60	301.85	-431.68	824.98	2.06740E+08	-23.94	114.59	2.50E+08	-14.99	77.25	2.172	3.7489	54.4	37.8	6.80	32.210	0.125	5:15	4:14:37 AM	967.1	-783.5	783.5	5556.099313										
11/28/99 11:21	61.56	204	79.24	100.54	1180.40	49	0.27	0.10	92.88	0.17	99.75	533.86	-1482.20	308.66	-429.13	831.96	2.06740E+08	-23.95	114.66	2.50E+08	-15.01	77.32	2.157	3.7429	5																				

6/24/97

Tracking Schedule - open LP

period	Start	Periapase	End	Start	Track 1 duration	End	Off 1 duration	Start	Track 2 duration	End	Off 2 duration	Start	Track3 duration	End	Off 3 duration
h	Aeropass		Aeropass	Track 1 [post peri]	h	Track 1	h	Track 2	h	Track 2	h	Track 3	h	Track 3	h
25.81	9/29/99 10:53	9/29/99 11:01	9/29/99 11:09	9/29/99 11:27	4.00	9/29/99 15:27	5.00	9/29/99 20:27	4.00	9/30/99 0:27	5.00	9/30/99 5:27	3.30	9/30/99 8:44	4.12
25.20	9/30/99 12:18	9/30/99 12:26	9/30/99 12:33	9/30/99 12:51	4.00	9/30/99 16:51	5.00	9/30/99 21:51	4.00	10/1/99 1:51	5.00	10/1/99 6:51	3.02	10/1/99 9:53	3.78
24.59	10/1/99 13:06	10/1/99 13:14	10/1/99 13:21	10/1/99 13:39	4.00	10/1/99 17:39	5.00	10/1/99 22:39	4.00	10/2/99 2:39	5.00	10/2/99 7:39	2.75	10/2/99 10:25	3.44
23.98	10/2/99 13:18	10/2/99 13:26	10/2/99 13:33	10/2/99 13:51	4.00	10/2/99 17:51	5.00	10/2/99 22:51	4.00	10/3/99 2:51	5.00	10/3/99 7:51	2.49	10/3/99 10:20	3.11
23.37	10/3/99 12:54	10/3/99 13:01	10/3/99 13:09	10/3/99 13:27	4.00	10/3/99 17:27	5.00	10/3/99 22:27	4.00	10/4/99 2:27	5.00	10/4/99 7:27	2.23	10/4/99 9:41	2.78
22.81	10/4/99 11:54	10/4/99 12:02	10/4/99 12:10	10/4/99 12:28	4.00	10/4/99 16:28	5.00	10/4/99 21:28	4.00	10/5/99 1:28	5.00	10/5/99 6:28	1.98	10/5/99 8:27	2.48
22.31	10/5/99 10:22	10/5/99 10:30	10/5/99 10:37	10/5/99 10:55	4.00	10/5/99 14:55	5.00	10/5/99 19:55	4.00	10/5/99 23:55	5.00	10/6/99 4:55	1.75	10/6/99 6:40	2.18
21.79	10/6/99 8:18	10/6/99 8:25	10/6/99 8:33	10/6/99 8:51	4.00	10/6/99 12:51	5.00	10/6/99 17:51	4.00	10/6/99 21:51	5.00	10/7/99 2:51	1.49	10/7/99 4:20	1.86
21.21	10/7/99 5:39	10/7/99 5:46	10/7/99 5:54	10/7/99 6:12	4.00	10/7/99 10:12	5.00	10/7/99 15:12	4.00	10/7/99 19:12	5.00	10/8/99 0:12	1.25	10/8/99 1:27	1.56
20.60	10/8/99 2:27	10/8/99 2:34	10/8/99 2:42	10/8/99 3:00	4.00	10/8/99 7:00	5.00	10/8/99 12:00	4.00	10/8/99 16:00	5.00	10/8/99 21:00	1.03	10/8/99 22:02	1.29
20.21	10/8/99 22:46	10/8/99 22:54	10/8/99 23:01	10/8/99 23:19	4.00	10/9/99 3:19	5.00	10/9/99 8:19	4.00	10/9/99 12:19	5.00	10/9/99 17:19	0.81	10/9/99 18:08	1.01
19.64	10/9/99 18:36	10/9/99 18:43	10/9/99 18:51	10/9/99 19:09	4.00	10/9/99 23:09	5.00	10/10/99 4:09	4.00	10/10/99 8:09	5.00				
19.21	10/10/99 13:56	10/10/99 14:04	10/10/99 14:12	10/10/99 14:30	4.00	10/10/99 18:30	5.00	10/10/99 23:30	4.00	10/11/99 3:30	5.00				
18.79	10/11/99 8:51	10/11/99 8:59	10/11/99 9:06	10/11/99 9:24	4.00	10/11/99 13:24	5.00	10/11/99 18:24	4.00	10/11/99 22:24	5.00				
18.29	10/12/99 3:18	10/12/99 3:26	10/12/99 3:34	10/12/99 3:52	4.00	10/12/99 7:52	5.00	10/12/99 12:52	4.00	10/12/99 16:52	5.00				
17.92	10/12/99 21:21	10/12/99 21:29	10/12/99 21:36	10/12/99 21:54	4.00	10/13/99 1:54	5.00	10/13/99 6:54	3.85	10/13/99 10:46	4.81				
17.52	10/13/99 15:01	10/13/99 15:09	10/13/99 15:16	10/13/99 15:34	4.00	10/13/99 19:34	5.00	10/14/99 0:34	3.67	10/14/99 4:14	4.59				
17.13	10/14/99 8:16	10/14/99 8:24	10/14/99 8:32	10/14/99 8:50	4.00	10/14/99 12:50	5.00	10/14/99 17:50	3.51	10/14/99 21:20	4.39				
16.82	10/15/99 1:10	10/15/99 1:18	10/15/99 1:25	10/15/99 1:43	4.00	10/15/99 5:43	5.00	10/15/99 10:43	3.35	10/15/99 14:04	4.19				
16.41	10/15/99 17:42	10/15/99 17:50	10/15/99 17:58	10/15/99 18:16	4.00	10/15/99 22:16	5.00	10/16/99 3:16	3.21	10/16/99 6:28	4.01				
16.12	10/16/99 9:56	10/16/99 10:03	10/16/99 10:11	10/16/99 10:29	4.00	10/16/99 14:29	5.00	10/16/99 19:29	3.07	10/16/99 22:33	3.84				
15.82	10/17/99 1:50	10/17/99 1:58	10/17/99 2:06	10/17/99 2:24	4.00	10/17/99 6:24	5.00	10/17/99 11:24	2.90	10/17/99 14:18	3.63				
15.43	10/17/99 17:22	10/17/99 17:30	10/17/99 17:37	10/17/99 17:55	4.00	10/17/99 21:55	5.00	10/18/99 2:55	2.77	10/18/99 5:42	3.47				
15.09	10/18/99 8:36	10/18/99 8:44	10/18/99 8:52	10/18/99 9:10	4.00	10/18/99 13:10	5.00	10/18/99 18:10	2.63	10/18/99 20:48	3.29				
14.81	10/18/99 23:32	10/18/99 23:40	10/18/99 23:48	10/19/99 0:06	4.00	10/19/99 4:06	5.00	10/19/99 9:06	2.52	10/19/99 11:37	3.15				
14.57	10/19/99 14:12	10/19/99 14:20	10/19/99 14:27	10/19/99 14:45	4.00	10/19/99 18:45	5.00	10/19/99 23:45	2.38	10/20/99 2:08	2.97				
14.30	10/20/99 4:33	10/20/99 4:41	10/20/99 4:49	10/20/99 5:07	4.00	10/20/99 9:07	5.00	10/20/99 14:07	2.27	10/20/99 16:23	2.84				
14.04	10/20/99 18:40	10/20/99 18:48	10/20/99 18:55	10/20/99 19:13	4.00	10/20/99 23:13	5.00	10/21/99 4:13	2.18	10/21/99 6:24	2.72				
13.76	10/21/99 8:34	10/21/99 8:41	10/21/99 8:49	10/21/99 9:07	4.00	10/21/99 13:07	5.00	10/21/99 18:07	2.05	10/21/99 20:10	2.56				
13.52	10/21/99 22:10	10/21/99 22:18	10/21/99 22:26	10/21/99 22:44	4.00	10/22/99 2:44	5.00	10/22/99 7:44	1.96	10/22/99 9:41	2.45				
13.30	10/22/99 11:35	10/22/99 11:43	10/22/99 11:50	10/22/99 12:08	4.00	10/22/99 16:08	5.00	10/22/99 21:08	1.85	10/22/99 22:59	2.31				
13.06	10/23/99 0:44	10/23/99 0:52	10/23/99 1:00	10/23/99 1:18	4.00	10/23/99 5:18	5.00	10/23/99 10:18	1.76	10/23/99 12:03	2.20				
12.85	10/23/99 13:42	10/23/99 13:49	10/23/99 13:57	10/23/99 14:15	4.00	10/23/99 18:15	5.00	10/23/99 23:15	1.65	10/24/99 0:54	2.07				
12.64	10/24/99 2:25	10/24/99 2:33	10/24/99 2:40	10/24/99 2:58	4.00	10/24/99 6:58	5.00	10/24/99 11:58	1.58	10/24/99 13:33	1.97				
12.44	10/24/99 14:58	10/24/99 15:06	10/24/99 15:14	10/24/99 15:32	4.00	10/24/99 19:32	5.00	10/25/99 0:32	1.46	10/25/99 1:59	1.83				
12.18	10/25/99 3:15	10/25/99 3:23	10/25/99 3:31	10/25/99 3:49	4.00	10/25/99 7:49	5.00	10/25/99 12:49	1.37	10/25/99 14:11	1.71				
11.98	10/25/99 15:20	10/25/99 15:27	10/25/99 15:35	10/25/99 15:53	4.00	10/25/99 19:53	5.00	10/26/99 0:53	1.27	10/26/99 2:09	1.59				
11.76	10/26/99 3:11	10/26/99 3:19	10/26/99 3:27	10/26/99 3:45	4.00	10/26/99 7:45	5.00	10/26/99 12:45	1.18	10/26/99 13:56	1.48				
11.58	10/26/99 14:51	10/26/99 14:59	10/26/99 15:06	10/26/99 15:24	4.00	10/26/99 19:24	5.00	10/27/99 0:24	1.11	10/27/99 1:31	1.39				
11.39	10/27/99 2:21	10/27/99 2:28	10/27/99 2:36	10/27/99 2:54	4.00	10/27/99 6:54	5.00	10/27/99 11:54	1.02	10/27/99 12:56	1.28				
11.18	10/27/99 13:39	10/27/99 13:47	10/27/99 13:54	10/27/99 14:12	4.00	10/27/99 18:12	5.00	10/27/99 23:12	0.93	10/28/99 0:08	1.16				
11.01	10/28/99 0:44	10/28/99 0:52	10/28/99 1:00	10/28/99 1:18	4.00	10/28/99 5:18	5.00	10/28/99 10:18	0.84	10/28/99 11:08	1.05				
10.82	10/28/99 11:38	10/28/99 11:46	10/28/99 11:53	10/28/99 12:11	4.00	10/28/99 16:11	5.00	10/28/99 21:11	0.77	10/28/99 21:58	0.96				
10.64	10/28/99 22:21	10/28/99 22:29	10/28/99 22:37	10/28/99 22:55	4.00	10/29/99 2:55	5.00	10/29/99 7:55	0.50	10/29/99 8:25	0.63				
10.47	10/29/99 8:52	10/29/99 9:00	10/29/99 9:08	10/29/99 9:26	4.00	10/29/99 13:26	5.00								
10.32	10/29/99 19:16	10/29/99 19:24	10/29/99 19:31	10/29/99 19:49	4.00	10/29/99 23:49	5.00								
10.15	10/30/99 5:29	10/30/99 5:37	10/30/99 5:45	10/30/99 6:03	4.00	10/30/99 10:03	5.00								
10.00	10/30/99 15:34	10/30/99 15:42	10/30/99 15:50	10/30/99 16:08	4.00	10/30/99 20:08	5.00								
9.87	10/31/99 1:30	10/31/99 1:38	10/31/99 1:46	10/31/99 2:04	4.00	10/31/99 6:04	5.00								
9.74	10/31/99 11:18	10/31/99 11:25	10/31/99 11:33	10/31/99 11:51	4.00	10/31/99 15:51	5.00								

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Tracking Schedule - open LP

period	Start	Periapase	End	Start	Track 1 duration	End	Off 1 duration	Start	Track 2 duration	End	Off 2 duration	Start	Track3 duration	End	Off 3 duration
h	Aeropass		Aeropass	Track 1 [post peri]	h	Track 1	h	Track 2	h	Track 2	h	Track 3	h	Track 3	h
9.58	10/31/99 20:56	10/31/99 21:04	10/31/99 21:12	10/31/99 21:30	4.00	11/1/99 1:30	5.00								
9.43	11/1/99 6:25	11/1/99 6:33	11/1/99 6:41	11/1/99 6:59	4.00	11/1/99 10:59	5.00								
9.29	11/1/99 15:48	11/1/99 15:56	11/1/99 16:04	11/1/99 16:22	4.00	11/1/99 20:22	5.00								
9.16	11/2/99 1:03	11/2/99 1:11	11/2/99 1:19	11/2/99 1:37	4.00	11/2/99 5:36	4.99								
9.00	11/2/99 10:06	11/2/99 10:13	11/2/99 10:21	11/2/99 10:39	3.94	11/2/99 14:36	4.92								
8.87	11/2/99 19:03	11/2/99 19:11	11/2/99 19:19	11/2/99 19:37	3.89	11/2/99 23:30	4.86								
8.76	11/3/99 3:51	11/3/99 3:59	11/3/99 4:07	11/3/99 4:25	3.83	11/3/99 8:15	4.79								
8.63	11/3/99 12:32	11/3/99 12:40	11/3/99 12:48	11/3/99 13:06	3.77	11/3/99 16:52	4.71								
8.49	11/3/99 21:06	11/3/99 21:14	11/3/99 21:22	11/3/99 21:40	3.72	11/4/99 1:24	4.65								
8.38	11/4/99 5:32	11/4/99 5:40	11/4/99 5:48	11/4/99 6:06	3.68	11/4/99 9:46	4.59								
8.28	11/4/99 13:52	11/4/99 14:00	11/4/99 14:08	11/4/99 14:26	3.62	11/4/99 18:03	4.52								
8.15	11/4/99 22:04	11/4/99 22:12	11/4/99 22:20	11/4/99 22:38	3.57	11/5/99 2:12	4.47								
8.05	11/5/99 6:11	11/5/99 6:19	11/5/99 6:27	11/5/99 6:45	3.53	11/5/99 10:17	4.41								
7.95	11/5/99 14:10	11/5/99 14:18	11/5/99 14:26	11/5/99 14:44	3.47	11/5/99 18:13	4.34								
7.82	11/5/99 22:03	11/5/99 22:11	11/5/99 22:19	11/5/99 22:37	3.43	11/6/99 2:03	4.29								
7.73	11/6/99 5:51	11/6/99 5:59	11/6/99 6:07	11/6/99 6:25	3.39	11/6/99 9:48	4.24								
7.64	11/6/99 13:31	11/6/99 13:39	11/6/99 13:47	11/6/99 14:05	3.34	11/6/99 17:26	4.18								
7.53	11/6/99 21:06	11/6/99 21:14	11/6/99 21:22	11/6/99 21:40	3.30	11/7/99 0:59	4.13								
7.44	11/7/99 4:36	11/7/99 4:44	11/7/99 4:52	11/7/99 5:10	3.25	11/7/99 8:25	4.06								
7.32	11/7/99 11:59	11/7/99 12:07	11/7/99 12:15	11/7/99 12:33	3.21	11/7/99 15:46	4.01								
7.23	11/7/99 19:17	11/7/99 19:25	11/7/99 19:33	11/7/99 19:51	3.18	11/7/99 23:02	3.97								
7.16	11/8/99 2:29	11/8/99 2:37	11/8/99 2:45	11/8/99 3:03	3.13	11/8/99 6:11	3.92								
7.06	11/8/99 9:35	11/8/99 9:43	11/8/99 9:51	11/8/99 10:09	3.10	11/8/99 13:15	3.87								
6.98	11/8/99 16:37	11/8/99 16:45	11/8/99 16:53	11/8/99 17:11	3.05	11/8/99 20:14	3.82								
6.88	11/8/99 23:33	11/8/99 23:41	11/8/99 23:49	11/9/99 0:07	3.02	11/9/99 3:09	3.78								
6.81	11/9/99 6:24	11/9/99 6:32	11/9/99 6:40	11/9/99 6:58	2.98	11/9/99 9:57	3.73								
6.71	11/9/99 13:10	11/9/99 13:18	11/9/99 13:26	11/9/99 13:44	2.94	11/9/99 16:41	3.68								
6.63	11/9/99 19:51	11/9/99 20:00	11/9/99 20:08	11/9/99 20:26	2.91	11/9/99 23:20	3.64								
6.56	11/10/99 2:27	11/10/99 2:36	11/10/99 2:44	11/10/99 3:02	2.87	11/10/99 5:54	3.59								
6.47	11/10/99 8:59	11/10/99 9:07	11/10/99 9:15	11/10/99 9:33	2.84	11/10/99 12:24	3.55								
6.40	11/10/99 15:25	11/10/99 15:33	11/10/99 15:41	11/10/99 15:59	2.81	11/10/99 18:48	3.51								
6.32	11/10/99 21:48	11/10/99 21:56	11/10/99 22:04	11/10/99 22:22	2.78	11/11/99 1:09	3.48								
6.26	11/11/99 4:05	11/11/99 4:13	11/11/99 4:22	11/11/99 4:40	2.75	11/11/99 7:24	3.43								
6.18	11/11/99 10:20	11/11/99 10:28	11/11/99 10:36	11/11/99 10:54	2.72	11/11/99 13:37	3.39								
6.12	11/11/99 16:30	11/11/99 16:38	11/11/99 16:46	11/11/99 17:04	2.68	11/11/99 19:45	3.35								
6.03	11/11/99 22:34	11/11/99 22:42	11/11/99 22:51	11/11/99 23:09	2.65	11/12/99 1:48	3.32								
5.97	11/12/99 4:35	11/12/99 4:44	11/12/99 4:52	11/12/99 5:10	2.62	11/12/99 7:47	3.27								
5.89	11/12/99 10:31	11/12/99 10:39	11/12/99 10:48	11/12/99 11:06	2.59	11/12/99 13:41	3.24								
5.83	11/12/99 16:24	11/12/99 16:32	11/12/99 16:41	11/12/99 16:59	2.56	11/12/99 19:32	3.20								
5.76	11/12/99 22:12	11/12/99 22:21	11/12/99 22:29	11/12/99 22:47	2.53	11/13/99 1:19	3.16								
5.69	11/13/99 3:56	11/13/99 4:05	11/13/99 4:13	11/13/99 4:31	2.50	11/13/99 7:01	3.12								
5.62	11/13/99 9:36	11/13/99 9:45	11/13/99 9:53	11/13/99 10:11	2.47	11/13/99 12:39	3.08								
5.55	11/13/99 15:12	11/13/99 15:20	11/13/99 15:29	11/13/99 15:47	2.44	11/13/99 18:13	3.05								
5.50	11/13/99 20:44	11/13/99 20:53	11/13/99 21:01	11/13/99 21:19	2.41	11/13/99 23:44	3.01								
5.43	11/14/99 2:13	11/14/99 2:21	11/14/99 2:30	11/14/99 2:48	2.39	11/14/99 5:11	2.99								
5.38	11/14/99 7:38	11/14/99 7:47	11/14/99 7:55	11/14/99 8:13	2.36	11/14/99 10:35	2.95								
5.32	11/14/99 12:59	11/14/99 13:08	11/14/99 13:16	11/14/99 13:34	2.34	11/14/99 15:54	2.92								
5.26	11/14/99 18:17	11/14/99 18:26	11/14/99 18:34	11/14/99 18:52	2.31	11/14/99 21:11	2.88								
5.19	11/14/99 23:31	11/14/99 23:40	11/14/99 23:48	11/15/99 0:06	2.28	11/15/99 2:23	2.85								
5.14	11/15/99 4:42	11/15/99 4:51	11/15/99 4:59	11/15/99 5:17	2.25	11/15/99 7:33	2.82								

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Tracking Schedule - open LP

period	Start	Periapse	End	Start	Track 1 duration	End	Off 1 duration	Start	Track 2 duration	End	Off 2 duration	Start	Track3 duration	End	Off 3 duration
h	Aeropass		Aeropass	Track 1 [post peri]	h	Track 1	h	Track 2	h	Track 2	h	Track 3	h	Track 3	h
5.08	11/15/99 9:49	11/15/99 9:58	11/15/99 10:06	11/15/99 10:24	2.22	11/15/99 12:38	2.78								
5.01	11/15/99 14:53	11/15/99 15:01	11/15/99 15:10	11/15/99 15:28	2.20	11/15/99 17:40	2.75								
4.96	11/15/99 19:52	11/15/99 20:01	11/15/99 20:10	11/15/99 20:28	2.17	11/15/99 22:38	2.72								
4.89	11/16/99 0:49	11/16/99 0:58	11/16/99 1:06	11/16/99 1:24	2.15	11/16/99 3:33	2.69								
4.85	11/16/99 5:41	11/16/99 5:50	11/16/99 5:59	11/16/99 6:17	2.13	11/16/99 8:24	2.66								
4.79	11/16/99 10:31	11/16/99 10:39	11/16/99 10:48	11/16/99 11:06	2.10	11/16/99 13:12	2.63								
4.74	11/16/99 15:17	11/16/99 15:26	11/16/99 15:35	11/16/99 15:53	2.08	11/16/99 17:58	2.60								
4.69	11/16/99 20:01	11/16/99 20:10	11/16/99 20:18	11/16/99 20:36	2.06	11/16/99 22:40	2.58								
4.64	11/17/99 0:42	11/17/99 0:50	11/17/99 0:59	11/17/99 1:17	2.04	11/17/99 3:20	2.55								
4.60	11/17/99 5:20	11/17/99 5:28	11/17/99 5:37	11/17/99 5:55	2.02	11/17/99 7:56	2.53								
4.55	11/17/99 9:56	11/17/99 10:05	11/17/99 10:13	11/17/99 10:31	2.00	11/17/99 12:31	2.50								
4.50	11/17/99 14:27	11/17/99 14:36	11/17/99 14:44	11/17/99 15:02	1.98	11/17/99 17:01	2.47								
4.45	11/17/99 18:56	11/17/99 19:05	11/17/99 19:14	11/17/99 19:32	1.95	11/17/99 21:29	2.44								
4.40	11/17/99 23:23	11/17/99 23:31	11/17/99 23:40	11/17/99 23:58	1.93	11/18/99 1:54	2.41								
4.35	11/18/99 3:46	11/18/99 3:55	11/18/99 4:03	11/18/99 4:21	1.91	11/18/99 6:16	2.39								
4.31	11/18/99 8:07	11/18/99 8:15	11/18/99 8:24	11/18/99 8:42	1.89	11/18/99 10:36	2.36								
4.26	11/18/99 12:24	11/18/99 12:33	11/18/99 12:42	11/18/99 13:00	1.87	11/18/99 14:52	2.34								
4.21	11/18/99 16:39	11/18/99 16:48	11/18/99 16:57	11/18/99 17:15	1.85	11/18/99 19:06	2.31								
4.17	11/18/99 20:51	11/18/99 21:00	11/18/99 21:09	11/18/99 21:27	1.83	11/18/99 23:17	2.29								
4.12	11/19/99 1:00	11/19/99 1:09	11/19/99 1:18	11/19/99 1:36	1.81	11/19/99 3:25	2.26								
4.08	11/19/99 5:07	11/19/99 5:15	11/19/99 5:24	11/19/99 5:42	1.79	11/19/99 7:30	2.24								
4.04	11/19/99 9:11	11/19/99 9:20	11/19/99 9:29	11/19/99 9:47	1.77	11/19/99 11:33	2.22								
3.99	11/19/99 13:13	11/19/99 13:22	11/19/99 13:31	11/19/99 13:49	1.75	11/19/99 15:34	2.19								
3.95	11/19/99 17:12	11/19/99 17:21	11/19/99 17:30	11/19/99 17:48	1.73	11/19/99 19:32	2.17								
3.91	11/19/99 21:08	11/19/99 21:17	11/19/99 21:26	11/19/99 21:44	1.71	11/19/99 23:27	2.14								
3.86	11/20/99 1:01	11/20/99 1:11	11/20/99 1:20	11/20/99 1:38	1.70	11/20/99 3:19	2.12								
3.82	11/20/99 4:53	11/20/99 5:02	11/20/99 5:12	11/20/99 5:30	1.68	11/20/99 7:10	2.10								
3.79	11/20/99 8:42	11/20/99 8:51	11/20/99 9:01	11/20/99 9:19	1.66	11/20/99 10:58	2.08								
3.75	11/20/99 12:28	11/20/99 12:37	11/20/99 12:47	11/20/99 13:05	1.65	11/20/99 14:43	2.06								
3.71	11/20/99 16:13	11/20/99 16:22	11/20/99 16:31	11/20/99 16:49	1.63	11/20/99 18:27	2.04								
3.67	11/20/99 19:55	11/20/99 20:04	11/20/99 20:13	11/20/99 20:31	1.61	11/20/99 22:08	2.02								
3.63	11/20/99 23:35	11/20/99 23:44	11/20/99 23:53	11/21/99 0:11	1.59	11/21/99 1:47	1.99								
3.59	11/21/99 3:12	11/21/99 3:22	11/21/99 3:31	11/21/99 3:49	1.58	11/21/99 5:24	1.97								
3.55	11/21/99 6:47	11/21/99 6:56	11/21/99 7:06	11/21/99 7:24	1.56	11/21/99 8:57	1.95								
3.52	11/21/99 10:20	11/21/99 10:29	11/21/99 10:39	11/21/99 10:57	1.55	11/21/99 12:30	1.93								
3.48	11/21/99 13:50	11/21/99 14:00	11/21/99 14:09	11/21/99 14:27	1.53	11/21/99 15:59	1.91								
3.45	11/21/99 17:19	11/21/99 17:28	11/21/99 17:38	11/21/99 17:56	1.52	11/21/99 19:27	1.90								
3.41	11/21/99 20:46	11/21/99 20:56	11/21/99 21:05	11/21/99 21:23	1.50	11/21/99 22:53	1.87								
3.38	11/22/99 0:11	11/22/99 0:20	11/22/99 0:30	11/22/99 0:48	1.49	11/22/99 2:17	1.86								
3.35	11/22/99 3:32	11/22/99 3:42	11/22/99 3:51	11/22/99 4:09	1.48	11/22/99 5:38	1.85								
3.33	11/22/99 6:54	11/22/99 7:03	11/22/99 7:13	11/22/99 7:31	1.47	11/22/99 8:59	1.84								
3.31	11/22/99 10:13	11/22/99 10:22	11/22/99 10:32	11/22/99 10:50	1.46	11/22/99 12:17	1.83								
3.29	11/22/99 13:33	11/22/99 13:42	11/22/99 13:52	11/22/99 14:10	1.45	11/22/99 15:37	1.82								
3.28	11/22/99 16:50	11/22/99 17:00	11/22/99 17:09	11/22/99 17:27	1.45	11/22/99 18:54	1.81								
3.26	11/22/99 20:07	11/22/99 20:17	11/22/99 20:26	11/22/99 20:44	1.44	11/22/99 22:11	1.80								
3.24	11/22/99 23:23	11/22/99 23:33	11/22/99 23:42	11/23/99 0:00	1.43	11/23/99 1:26	1.78								
3.21	11/23/99 2:37	11/23/99 2:47	11/23/99 2:57	11/23/99 3:15	1.42	11/23/99 4:40	1.77								
3.20	11/23/99 5:50	11/23/99 6:00	11/23/99 6:10	11/23/99 6:28	1.41	11/23/99 7:52	1.76								
3.18	11/23/99 9:02	11/23/99 9:12	11/23/99 9:21	11/23/99 9:39	1.40	11/23/99 11:03	1.75								
3.15	11/23/99 12:13	11/23/99 12:23	11/23/99 12:33	11/23/99 12:51	1.39	11/23/99 14:14	1.74								

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Tracking Schedule - open LP

period	Start	Periapse	End	Start	Track 1 duration	End	Off 1 duration	Start	Track 2 duration	End	Off 2 duration	Start	Track3 duration	End	Off 3 duration
h	Aeropass		Aeropass	Track 1 [post peri]	h	Track 1	h	Track 2	h	Track 2	h	Track 3	h	Track 3	h
3.13	11/23/99 15:22	11/23/99 15:32	11/23/99 15:42	11/23/99 16:00	1.38	11/23/99 17:22	1.72								
3.10	11/23/99 18:29	11/23/99 18:39	11/23/99 18:49	11/23/99 19:07	1.37	11/23/99 20:29	1.71								
3.08	11/23/99 21:36	11/23/99 21:46	11/23/99 21:56	11/23/99 22:14	1.36	11/23/99 23:35	1.70								
3.06	11/24/99 0:41	11/24/99 0:50	11/24/99 1:00	11/24/99 1:18	1.35	11/24/99 2:39	1.68								
3.03	11/24/99 3:45	11/24/99 3:55	11/24/99 4:05	11/24/99 4:23	1.34	11/24/99 5:43	1.67								
3.01	11/24/99 6:46	11/24/99 6:56	11/24/99 7:06	11/24/99 7:24	1.33	11/24/99 8:44	1.66								
2.99	11/24/99 9:48	11/24/99 9:58	11/24/99 10:08	11/24/99 10:26	1.32	11/24/99 11:45	1.65								
2.97	11/24/99 12:48	11/24/99 12:58	11/24/99 13:08	11/24/99 13:26	1.31	11/24/99 14:44	1.64								
2.95	11/24/99 15:46	11/24/99 15:56	11/24/99 16:06	11/24/99 16:24	1.30	11/24/99 17:42	1.63								
2.94	11/24/99 18:43	11/24/99 18:53	11/24/99 19:03	11/24/99 19:21	1.30	11/24/99 20:39	1.62								
2.92	11/24/99 21:39	11/24/99 21:49	11/24/99 21:59	11/24/99 22:17	1.29	11/24/99 23:34	1.61								
2.90	11/25/99 0:35	11/25/99 0:45	11/25/99 0:55	11/25/99 1:13	1.28	11/25/99 2:30	1.60								
2.88	11/25/99 3:29	11/25/99 3:39	11/25/99 3:49	11/25/99 4:07	1.27	11/25/99 5:23	1.59								
2.86	11/25/99 6:23	11/25/99 6:33	11/25/99 6:43	11/25/99 7:01	1.27	11/25/99 8:17	1.58								
2.85	11/25/99 9:14	11/25/99 9:25	11/25/99 9:35	11/25/99 9:53	1.26	11/25/99 11:08	1.57								
2.83	11/25/99 12:06	11/25/99 12:16	11/25/99 12:26	11/25/99 12:44	1.25	11/25/99 13:59	1.56								
2.82	11/25/99 14:57	11/25/99 15:07	11/25/99 15:17	11/25/99 15:35	1.24	11/25/99 16:50	1.56								
2.80	11/25/99 17:45	11/25/99 17:56	11/25/99 18:06	11/25/99 18:24	1.24	11/25/99 19:38	1.55								
2.79	11/25/99 20:34	11/25/99 20:44	11/25/99 20:54	11/25/99 21:12	1.23	11/25/99 22:26	1.54								
2.77	11/25/99 23:22	11/25/99 23:33	11/25/99 23:43	11/26/99 0:01	1.22	11/26/99 1:14	1.52								
2.75	11/26/99 2:08	11/26/99 2:18	11/26/99 2:29	11/26/99 2:47	1.21	11/26/99 3:59	1.51								
2.72	11/26/99 4:53	11/26/99 5:04	11/26/99 5:14	11/26/99 5:32	1.20	11/26/99 6:44	1.50								
2.70	11/26/99 7:36	11/26/99 7:47	11/26/99 7:57	11/26/99 8:15	1.19	11/26/99 9:27	1.49								
2.68	11/26/99 10:19	11/26/99 10:29	11/26/99 10:40	11/26/99 10:58	1.18	11/26/99 12:09	1.48								
2.66	11/26/99 13:00	11/26/99 13:11	11/26/99 13:21	11/26/99 13:39	1.17	11/26/99 14:50	1.47								
2.64	11/26/99 15:40	11/26/99 15:50	11/26/99 16:01	11/26/99 16:19	1.16	11/26/99 17:29	1.46								
2.62	11/26/99 18:18	11/26/99 18:29	11/26/99 18:39	11/26/99 18:57	1.16	11/26/99 20:07	1.45								
2.61	11/26/99 20:57	11/26/99 21:07	11/26/99 21:18	11/26/99 21:36	1.15	11/26/99 22:45	1.44								
2.59	11/26/99 23:32	11/26/99 23:43	11/26/99 23:53	11/27/99 0:11	1.14	11/27/99 1:20	1.43								
2.57	11/27/99 2:08	11/27/99 2:18	11/27/99 2:29	11/27/99 2:47	1.13	11/27/99 3:55	1.42								
2.55	11/27/99 4:43	11/27/99 4:54	11/27/99 5:05	11/27/99 5:23	1.13	11/27/99 6:30	1.41								
2.54	11/27/99 7:16	11/27/99 7:26	11/27/99 7:37	11/27/99 7:55	1.12	11/27/99 9:02	1.40								
2.52	11/27/99 9:48	11/27/99 9:59	11/27/99 10:10	11/27/99 10:28	1.11	11/27/99 11:35	1.39								
2.51	11/27/99 12:21	11/27/99 12:32	11/27/99 12:43	11/27/99 13:01	1.11	11/27/99 14:07	1.38								
2.49	11/27/99 14:50	11/27/99 15:01	11/27/99 15:13	11/27/99 15:31	1.10	11/27/99 16:37	1.38								
2.48	11/27/99 17:20	11/27/99 17:31	11/27/99 17:43	11/27/99 18:01	1.09	11/27/99 19:06	1.37								
2.46	11/27/99 19:50	11/27/99 20:01	11/27/99 20:12	11/27/99 20:30	1.09	11/27/99 21:36	1.36								
2.45	11/27/99 22:18	11/27/99 22:29	11/27/99 22:41	11/27/99 22:59	1.08	11/28/99 0:03	1.35								
2.43	11/28/99 0:45	11/28/99 0:56	11/28/99 1:08	11/28/99 1:26	1.07	11/28/99 2:30	1.33								
2.40	11/28/99 3:10	11/28/99 3:22	11/28/99 3:33	11/28/99 3:51	1.06	11/28/99 4:55	1.32								
2.38	11/28/99 5:34	11/28/99 5:46	11/28/99 5:57	11/28/99 6:15	1.05	11/28/99 7:18	1.31								
2.36	11/28/99 7:56	11/28/99 8:08	11/28/99 8:20	11/28/99 8:38	1.04	11/28/99 9:40	1.30								
2.34	11/28/99 10:19	11/28/99 10:31	11/28/99 10:43	11/28/99 11:01	1.03	11/28/99 12:03	1.29								
2.33	11/28/99 12:40	11/28/99 12:52	11/28/99 13:04	11/28/99 13:22	1.02	11/28/99 14:23	1.28								
2.31	11/28/99 14:59	11/28/99 15:12	11/28/99 15:24	11/28/99 15:42	1.02	11/28/99 16:43	1.27								
2.29	11/28/99 17:18	11/28/99 17:30	11/28/99 17:42	11/28/99 18:00	1.01	11/28/99 19:00	1.26								
2.27	11/28/99 19:34	11/28/99 19:47	11/28/99 19:59	11/28/99 20:17	1.00	11/28/99 21:17	1.25								
2.25	11/28/99 21:51	11/28/99 22:03	11/28/99 22:16	11/28/99 22:34	0.99	11/28/99 23:33	1.24								
2.24	11/29/99 0:06	11/29/99 0:19	11/29/99 0:31	11/29/99 0:49	0.99	11/29/99 1:49	1.23								
2.22	11/29/99 2:20	11/29/99 2:33	11/29/99 2:45	11/29/99 3:03	0.98	11/29/99 4:02	1.22								

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Tracking Schedule - open LP

period	Start	Periapse	End	Start	Track 1 duration	End	Off 1 duration	Start Track 2	Track 2 duration	End Track 2	Off 2 duration	Start Track 3	Track3 duration	End Track 3	Off 3 duration
h	Aeropass		Aeropass	Track 1 [post peri]	h	Track 1	h		h						
2.20	11/29/99 4:34	11/29/99 4:47	11/29/99 4:59	11/29/99 5:17	0.97	11/29/99 6:16	1.21								
2.19	11/29/99 6:46	11/29/99 6:59	11/29/99 7:12	11/29/99 7:30	0.96	11/29/99 8:28	1.21								
2.17	11/29/99 8:57	11/29/99 9:10	11/29/99 9:23	11/29/99 9:41	0.50	11/29/99 10:11	0.63								
2.16	11/29/99 11:08	11/29/99 11:21	11/29/99 11:34	11/29/99 11:52	0.50	11/29/99 12:22	0.63								
2.14	11/29/99 13:17	11/29/99 13:31	11/29/99 13:44	11/29/99 14:02	0.50	11/29/99 14:32	0.63								
2.12	11/29/99 15:25	11/29/99 15:39	11/29/99 15:52	11/29/99 16:10	0.50	11/29/99 16:40	0.63								
2.10	11/29/99 17:32	11/29/99 17:46	11/29/99 17:59	11/29/99 18:17	0.50	11/29/99 18:47	0.63								
2.07	11/29/99 19:38	11/29/99 19:52	11/29/99 20:06	11/29/99 20:24	0.50	11/29/99 20:54	0.63								
2.05	11/29/99 21:42	11/29/99 21:56	11/29/99 22:10	11/29/99 22:28	0.50	11/29/99 22:58	0.63								
2.03	11/29/99 23:44	11/29/99 23:59	11/30/99 0:13	11/30/99 0:31	0.50	11/30/99 1:01	0.63								
2.01	11/30/99 1:46	11/30/99 2:01	11/30/99 2:16	11/30/99 2:34	0.50	11/30/99 3:04	0.63								
1.98	11/30/99 3:45	11/30/99 4:01	11/30/99 4:16	11/30/99 4:34	0.50	11/30/99 5:04	0.63								
1.96	11/30/99 5:43	11/30/99 5:59	11/30/99 6:14	11/30/99 6:32	0.50	11/30/99 7:02	0.63								
1.95	11/30/99 7:41	11/30/99 7:57	11/30/99 8:13	11/30/99 8:31	0.50	11/30/99 9:01	0.63								
1.94	11/30/99 9:38	11/30/99 9:55	11/30/99 10:11	11/30/99 10:29	0.50	11/30/99 10:59	0.63								
1.93	11/30/99 11:33	11/30/99 11:50	11/30/99 12:07	11/30/99 12:25	0.50	11/30/99 12:55	0.63								
1.92	11/30/99 13:30	11/30/99 13:47	11/30/99 14:03	11/30/99 14:21	0.50	11/30/99 14:51	0.63								
1.91	11/30/99 15:25	11/30/99 15:42	11/30/99 15:59	11/30/99 16:17	0.50	11/30/99 16:47	0.63								
1.91	11/30/99 17:21	11/30/99 17:38	11/30/99 17:56	11/30/99 18:14	0.50	11/30/99 18:44	0.63								
1.90	11/30/99 19:15	11/30/99 19:32	11/30/99 19:50	11/30/99 20:08	0.50	11/30/99 20:38	0.63								
1.89	11/30/99 21:10	11/30/99 21:27	11/30/99 21:45	11/30/99 22:03	0.50	11/30/99 22:33	0.63								
1.89	11/30/99 23:02	11/30/99 23:21	11/30/99 23:40	11/30/99 23:58	0.50	12/1/99 0:28	0.63								
1.88	12/1/99 0:55	12/1/99 1:15	12/1/99 1:35	12/1/99 1:53	0.50	12/1/99 2:23	0.63								
1.87	12/1/99 2:49	12/1/99 3:09	12/1/99 3:29	12/1/99 3:47	0.50	12/1/99 4:17	0.63								
1.86	12/1/99 4:39	12/1/99 5:01	12/1/99 5:23	12/1/99 5:41	0.50	12/1/99 6:11	0.63								
1.85	12/1/99 6:31	12/1/99 6:53	12/1/99 7:15	12/1/99 7:33	0.50	12/1/99 8:03	0.63								
1.84	12/1/99 8:22	12/1/99 8:44	12/1/99 9:06	12/1/99 9:24	0.50	12/1/99 9:54	0.63								

CLOSE LAUNCH PERIOD - AEROBRAKING TIMELINE

J2000.0

MSP Per View 11996, Oct 4, LWR, Min Conf, Data written at Watkins Point

Starting Time for Simulation: Oct 3, 1999, 06:30 ET (Apostasis, Last Perilun, Manuever)

(DO NOT USE)

DYNAMIC

SUN ECLIPSE

SUN ECLIPSE

EARTH OCCULT

EARTH OCCULT

Note: Earth & Sun positions use table lookup & data interpolation on 10 day intervals

ORBIT PERIOD

RAW

DRAGGAS

DRAGGAS

ORBIT PERIOD

DATE	TIME	DAY	REV	PERIAPSIS	APHELIUM	PERIAPSIS	APHELIUM	PERIAPSIS	APHELIUM	PERIAPSIS	APHELIUM	PERIAPSIS	APHELIUM	PERIAPSIS	APHELIUM	DATE	TIME	DAY	REV	PERIAPSIS	APHELIUM	PERIAPSIS	APHELIUM	PERIAPSIS	APHELIUM											
10/10/99	6:30	10/10/99	6:30	10/10/99	6:30	10/10/99	6:30	10/10/99	6:30	10/10/99	6:30	10/10/99	6:30	10/10/99	6:30	10/10/99	6:30	10/10/99	6:30	10/10/99	6:30	10/10/99	6:30	10/10/99	6:30											
10/10/99	20:58	10/10/99	20:58	10/10/99	20:58	10/10/99	20:58	10/10/99	20:58	10/10/99	20:58	10/10/99	20:58	10/10/99	20:58	10/10/99	20:58	10/10/99	20:58	10/10/99	20:58	10/10/99	20:58	10/10/99	20:58											
10/10/99	4:52	1.77	2	10.117	11.416	34672.00	1	0.51	0.25	92.96	355.66	153.17	286.52	34.26	75.95	-394.98	852.44	#####	-15.41	79.13	2.07E+08	1.20	41.10	27.870	#####	2739.6	806.0	5.07	0.926	-4.360	0.010	5:53:02 PM	306.6	-453.3	453.3	99459.0738
10/10/99	4:50	2.90	3	10.936	11.416	34672.00	1	0.55	0.26	92.96	355.66	153.17	310.76	-235.86	54.74	-394.57	837.98	#####	-15.64	79.83	2.07E+08	1.27	40.10	27.877	#####	2890.3	806.0	5.85	1.519	-4.340	0.030	5:53:03 PM	307.2	-453.3	453.6	96568.8441
10/10/99	4:50	4.00	4	11.420	11.416	34672.00	1	0.55	0.26	92.96	355.66	153.17	310.76	-235.86	54.74	-394.57	837.98	#####	-15.64	79.83	2.07E+08	1.27	40.10	27.877	#####	2890.3	806.0	5.85	1.519	-4.340	0.030	5:53:03 PM	307.2	-453.3	453.6	96568.8441
10/10/99	8:05	5.00	5	10.930	11.410	34808.00	1	0.56	0.27	92.96	355.72	152.85	315.57	-192.05	23.29	-395.18	811.80	#####	-16.08	81.16	2.09E+08	1.20	42.48	25.401	#####	2767.2	837.0	4.05	2.655	-4.330	0.040	5:46:32 PM	308.7	-454.4	454.4	90536.1143
10/10/99	8:00	6.10	6	10.928	11.394	34010.00	1	0.57	0.27	92.96	355.68	152.66	317.11	-170.15	5.92	-394.66	798.68	#####	-16.29	81.80	2.10E+08	0.87	43.14	24.676	#####	2612.3	788.0	4.07	1.998	-4.320	0.050	5:46:34 PM	308.4	-454.7	454.7	87923.1493
10/10/99	8:15	7.11	7	10.905	11.378	33226.00	1	0.60	0.28	92.97	355.69	152.48	272.21	-148.24	-17.34	-394.18	788.87	#####	-16.49	82.42	2.10E+08	0.54	43.78	23.970	#####	2561.8	784.0	4.16	3.728	-4.310	0.060	5:46:22 PM	310.1	-455.0	455.0	85380.5697
10/10/99	8:45	8.09	8	10.885	11.343	32477.00	1	0.64	0.30	92.96	355.71	152.29	304.08	-126.34	-53.46	-393.81	776.58	#####	-16.69	83.02	2.11E+08	0.22	44.40	23.971	#####	2405.8	784.0	4.01	4.242	-4.290	0.080	5:46:21 PM	310.7	-455.4	455.4	82724.165
10/10/99	8:50	9.00	9	10.865	11.344	32477.00	1	0.64	0.30	92.96	355.71	152.29	304.08	-126.34	-53.46	-393.81	776.58	#####	-16.69	83.02	2.11E+08	0.22	44.40	23.971	#####	2405.8	784.0	4.01	4.242	-4.290	0.080	5:46:21 PM	310.7	-455.4	455.4	82724.165
10/10/99	9:00	10.00	10	10.840	11.326	32032.00	1	0.65	0.31	92.96	355.72	152.10	298.33	-104.31	-60.31	-393.49	765.22	#####	-17.06	84.17	2.11E+08	-0.38	45.59	22.013	#####	2373.3	756.0	4.24	5.292	-4.270	0.100	5:36:31 PM	312.0	-456.0	456.0	78330.0143
10/10/99	9:10	11.00	11	10.848	11.310	31808.00	2	0.49	0.23	92.97	355.73	151.87	283.28	-90.00	0.00	-392.67	745.77	#####	-17.24	84.72	2.13E+08	-0.67	46.16	21.385	#####	2261.0	725.0	4.94	5.692	-4.260	0.110	5:34:34 PM	312.7	-456.4	456.4	76023.3378
10/10/99	9:14	11.74	12	10.811	11.288	31662.00	3	0.67	0.31	92.98	355.76	151.70	280.73	0.00	0.00	-392.69	734.40	#####	-17.42	85.26	2.14E+08	-0.95	46.72	20.848	#####	1933.6	623.0	2.43	6.152	-4.240	0.130	5:32:55 PM	313.8	-456.9	456.9	74137.6445
10/10/99	20:59	20:59	20:59	11.339	11.849	31441.00	4	0.54	0.26	92.98	355.77	151.55	258.76	0.00	0.00	-392.68	724.92	#####	-17.59	85.79	2.15E+08	-1.23	47.26	20.842	#####	1819.0	559.0	4.63	6.598	-4.230	0.140	5:31:10 PM	314.5	-457.2	457.2	72317.9543
10/10/99	16:36	13:42	14	11.028	12.065	30846.00	4	0.49	0.24	92.99	355.78	150.40	322.40	0.00	0.00	-392.69	714.68	#####	-17.76	86.30	2.16E+08	-1.50	47.79	19.911	#####	1681.6	608.0	4.63	7.033	-4.220	0.150	5:29:28 PM	315.2	-457.6	457.6	70417.6538
10/10/99	12:58	12:58	12:58	11.316	12.065	30783.00	5	0.70	0.33	92.99	355.81	151.23	270.83	0.00	0.00	-392.70	704.31	#####	-17.92	86.81	2.17E+08	-1.76	48.32	19.022	#####	1549.1	510.0	4.63	7.476	-4.210	0.170	5:27:49 PM	316.3	-458.2	458.2	68517.3542
10/10/99	7:03	15:02	16	10.933	11.510	30763.00	6	0.51	0.24	92.99	355.81	151.06	267.99	0.00	0.00	-392.70	694.43	#####	-18.08	87.28	2.17E+08	-2.01	48.81	18.831	#####	1387.0	600.0	6.01	7.833	-4.190	0.180	5:26:14 PM	316.6	-458.4	458.4	66875.5955
10/10/99	1:34	15:80	17	10.939	11.512	30670.00	6	0.51	0.24	93.00	355.83	150.90	199.26	0.00	0.00	-391.82	686.85	#####	-18.24	87.76	2.17E+08	-2.26	49.30	18.043	#####	1259.0	496.0	3.92	8.277	-4.170	0.200	5:24:01 PM	317.2	-458.6	458.6	65040.9361
10/10/99	14:52	16:55	18	11.004	11.511	26305.00	6	0.51	0.24	93.01	355.84	150.78	309.25	0.00	0.00	-391.51	678.09	#####	-18.39	88.27	2.18E+08	-2.51	49.78	18.425	#####	1079.2	466.0	3.87	8.773	-4.160	0.210	5:22:41 PM	317.8	-458.9	458.9	64044.5338
10/10/99	13:26	17:29	19	11.016	11.513	25825.00	6	0.53	0.25	93.00	355.86	150.61	241.27	0.00	0.00	-390.54	671.22	#####	-18.52	88.69	2.19E+08	-2.75	50.27	17.855	#####	1003.3	480.0	4.06	9.060	-4.140	0.230	5:21:41 PM	318.4	-459.2	459.2	62640.8512
10/10/99	13:29	18:01	20	11.021	11.514	25315.00	6	0.51	0.25	93.01	355.88	150.41	201.99	0.00	0.00	-391.37	660.93	#####	-18.67	89.21	2.19E+08	-3.01	51.21	18.889	#####	928.0	447.0	4.06	9.519	-4.130	0.240	5:20:41 PM	319.0	-459.4	459.4	61459.6126
10/10/99	23:49	18:22	21	10.754	11.927	24873.00	7	0.72	0.34	93.00	355.90	150.28	416.49	0.00	0.00	-390.42	653.74	#####	-18.77	89.61	2.20E+08	-3.21	51.11	18.889	#####	1280.8	442.0	1.98	9.811	-4.100	0.270	5:18:50 PM	320.4	-460.2	460.2	59875.5835
10/22/99	16:21	19:41	22	11.048	11.597	24275.00	8	0.48	0.23	92.98	355.91	150.11	316.76	0.00	0.00	-391.37	645.39	#####	-18.89	90.06	2.20E+08	-3.44	51.67	16.043	#####	1699.9	598.0	7.72	10.270	-4.090	0.280	5:17:26 PM	321.4	-460.7	460.7	58177.7263
10/22/99	8:35	20:09	23	10.780	11.335	23829.00	9	0.68	0.32	92.98	355.93	149.92	317.47	0.00	0.00	-389.59	637.60	#####	-19.00	90.49	2.21E+08	-3.66	52.12	16.063	#####	1271.1	460.0	3.20	10.526	-4.070	0.300	5:16:06 PM	322.1	-461.1	461.1	56905.9222
10/24/99	0:24	20:75	24	10.898	11.289	23406.00	10	0.53	0.25	92.99	355.95	149.75	279.31	0.00	0.00	-389.83	630.89	#####	-19.12	90.92	2.21E+08	-3.87	52.55	15.734	#####	1184.0	423.0	5.73	10.807	-4.050	0.320	5:14:48 PM	322.9	-461.4	461.4	55721.2153
10/25/99	7:04	22:02	25	10.898	11.289	22991.00	10	0.53	0.25	92.99	355.95	149.75	279.31	0.00	0.00	-389.83	630.89	#####	-19.12	90.92	2.21E+08	-3.87	52.55	15.734	#####	1184.0	423.0	5.73	10.807	-4.050	0.320	5:14:48 PM	322.9	-461.4	461.4	55721.2153
10/25/99	7:04	22:02	26	11.021	11.593	22581.00	10	0.49	0.23	92.96	355.89	149.43	263.88	0.00	0.00	-388.74	616.88	#####	-19.34	91.74	2.22E+08	-4.29	53.40	15.097	#####	1133.9	409.0	4.51	11.541	-4.010	0.360	5:12:16 PM	323.4	-462.2	462.2	53423.0104
10/25/99	22:00	22:65	27	10.866	11.383	22198.00	11	0.62	0.29	92.96	355.99	149.26	224.40	0.00	0.00	-388.59	608.09	#####	-19.44	92.14	2.23E+08	-4.49	53.81	14.803	#####	1058.6	382.0	2.52	11.617	-4.010	0.360	5:10:38 PM	325.8	-462.5	462.5	52364.843
10/25/99	12:34	23:25	28	10.863	11.386	21764.00	11	0.62	0.29	92.97	356.01	149.10	249.48	0.00	0.00	-388.66	602.47	#####	-19.55	92.53	2.23E+08	-4.69	54.21	14.472	#####	1019.0	435.0	4.80	12.186	-3.990	0.380	5:09:47 PM	325.8	-462.9	462.9	51173.724
10/27/99	2:49	23:85	29	11.021	11.593	21329.00	11	0.68	0.32	92.99	356.03	148.85	247.13	0.00	0.00	-388.72	597.31	#####	-19.65	92.91	2.24E+08	-4.88	54.61	14.144	#####	1182.2	435.0	4.74	12.497	-3.970	0.400	5:08:37 PM	326.8	-463.3	463.3	49999.1932
10/28/99	16:46	24:09	30	10.983	11.593	20831.00	12	0.68	0.32	92.99	356.03	148.85	247.13	0.00	0.00	-388.72	597.31	#####	-19.65	92.91	2.24E+08	-4.88	54.61	14.144	#####	1182.2	435.0	4.74	12.497	-3.970	0.400	5:08:37 PM	326.8	-463.3	463.3	49999.1932
10/28/99	6:22	25:05	31	10.993	11.597	20593.00	12	0.49	0.22	92.97	356.07	148.66	321.78	0.00	0.00	-388.04	582.34	#####	-19.88	93.65	2.25E+08	-5.26	55.37	13.590	#####	934.5	348.0	4.26	13.098	-3.930	0.440	5:06:22 PM	329.2	-464.0	464.	

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[illegible]

6/24/97

Tracking Schedule - close LP

period	Start	Periapse	End	Start	Track 1 duration	End	Off 1 duration	Start	Track 2 duration	End	Off 2 duration	Start	Track3 duration	End	Off 3 duration
h	Aeropass		Aeropass	Track 1 [post peri]	h	Track 1	h	Track 2	h	Track 2	h	Track 3	h	Track 3	h
28.64	10/3/99 20:50	10/3/99 20:58	10/3/99 21:06	10/3/99 21:24	4.00	10/4/99 1:24	5.00	10/4/99 6:24	4.00	10/4/99 10:24	5.00	10/4/99 15:24	4.00	10/4/99 19:24	5.00
27.88	10/5/99 0:46	10/5/99 0:54	10/5/99 1:01	10/5/99 1:19	4.00	10/5/99 5:19	5.00	10/5/99 10:19	4.00	10/5/99 14:19	5.00	10/5/99 19:19	4.00	10/5/99 23:19	5.00
27.08	10/6/99 3:55	10/6/99 4:02	10/6/99 4:10	10/6/99 4:28	4.00	10/6/99 8:28	5.00	10/6/99 13:28	4.00	10/6/99 17:28	5.00	10/6/99 22:28	3.73	10/7/99 2:11	4.66
26.17	10/7/99 6:18	10/7/99 6:25	10/7/99 6:33	10/7/99 6:51	4.00	10/7/99 10:51	5.00	10/7/99 15:51	4.00	10/7/99 19:51	5.00	10/8/99 0:51	3.40	10/8/99 4:15	4.25
25.40	10/8/99 7:57	10/8/99 8:05	10/8/99 8:12	10/8/99 8:30	4.00	10/8/99 12:30	5.00	10/8/99 17:30	4.00	10/8/99 21:30	5.00	10/9/99 2:30	3.08	10/9/99 5:35	3.85
24.68	10/9/99 8:53	10/9/99 9:00	10/9/99 9:08	10/9/99 9:26	4.00	10/9/99 13:26	5.00	10/9/99 18:26	4.00	10/9/99 22:26	5.00	10/10/99 3:26	2.76	10/10/99 6:12	3.45
23.97	10/10/99 9:06	10/10/99 9:13	10/10/99 9:21	10/10/99 9:39	4.00	10/10/99 13:39	5.00	10/10/99 18:39	4.00	10/10/99 22:39	5.00	10/11/99 3:39	2.45	10/11/99 6:06	3.07
23.30	10/11/99 8:37	10/11/99 8:45	10/11/99 8:52	10/11/99 9:10	4.00	10/11/99 13:10	5.00	10/11/99 18:10	4.00	10/11/99 22:10	5.00	10/12/99 3:10	2.14	10/12/99 5:19	2.68
22.67	10/12/99 7:26	10/12/99 7:34	10/12/99 7:41	10/12/99 7:59	4.00	10/12/99 11:59	5.00	10/12/99 16:59	4.00	10/12/99 20:59	5.00	10/13/99 1:59	1.81	10/13/99 3:48	2.26
22.01	10/13/99 5:31	10/13/99 5:38	10/13/99 5:46	10/13/99 6:04	4.00	10/13/99 10:04	5.00	10/13/99 15:04	4.00	10/13/99 19:04	5.00	10/14/99 0:04	1.57	10/14/99 1:38	1.97
21.38	10/14/99 3:03	10/14/99 3:11	10/14/99 3:18	10/14/99 3:36	4.00	10/14/99 7:36	5.00	10/14/99 12:36	4.00	10/14/99 16:36	5.00	10/14/99 21:36	1.35	10/14/99 22:58	1.69
20.85	10/15/99 0:06	10/15/99 0:14	10/15/99 0:21	10/15/99 0:39	4.00	10/15/99 4:39	5.00	10/15/99 9:39	4.00	10/15/99 13:39	5.00	10/15/99 18:39	1.08	10/15/99 19:44	1.35
20.34	10/15/99 20:31	10/15/99 20:39	10/15/99 20:47	10/15/99 21:05	4.00	10/16/99 1:05	5.00	10/16/99 6:05	4.00	10/16/99 10:05	5.00	10/16/99 15:05	0.86	10/16/99 15:57	1.08
19.83	10/16/99 16:28	10/16/99 16:36	10/16/99 16:43	10/16/99 17:01	4.00	10/16/99 21:01	5.00	10/17/99 2:01	4.00	10/17/99 6:01	5.00	10/17/99 11:01	0.50	10/17/99 11:31	0.63
19.33	10/17/99 11:59	10/17/99 12:06	10/17/99 12:14	10/17/99 12:32	4.00	10/17/99 16:32	5.00	10/17/99 21:32	4.00	10/18/99 1:32	5.00				
18.83	10/18/99 6:55	10/18/99 7:03	10/18/99 7:10	10/18/99 7:28	4.00	10/18/99 11:28	5.00	10/18/99 16:28	4.00	10/18/99 20:28	5.00				
18.42	10/19/99 1:27	10/19/99 1:34	10/19/99 1:42	10/19/99 2:00	4.00	10/19/99 6:00	5.00	10/19/99 11:00	4.00	10/19/99 15:00	5.00				
18.05	10/19/99 19:34	10/19/99 19:42	10/19/99 19:49	10/19/99 20:07	4.00	10/20/99 0:07	5.00	10/20/99 5:07	3.88	10/20/99 9:00	4.85				
17.66	10/20/99 13:18	10/20/99 13:26	10/20/99 13:33	10/20/99 13:51	4.00	10/20/99 17:51	5.00	10/20/99 22:51	3.72	10/21/99 2:35	4.65				
17.24	10/21/99 6:41	10/21/99 6:48	10/21/99 6:56	10/21/99 7:14	4.00	10/21/99 11:14	5.00	10/21/99 16:14	3.56	10/21/99 19:48	4.45				
16.89	10/21/99 23:42	10/21/99 23:49	10/21/99 23:57	10/22/99 0:15	4.00	10/22/99 4:15	5.00	10/22/99 9:15	3.35	10/22/99 12:36	4.19				
16.42	10/22/99 16:14	10/22/99 16:21	10/22/99 16:29	10/22/99 16:47	4.00	10/22/99 20:47	5.00	10/23/99 1:47	3.21	10/23/99 5:00	4.01				
16.06	10/23/99 8:27	10/23/99 8:35	10/23/99 8:42	10/23/99 9:00	4.00	10/23/99 13:00	5.00	10/23/99 18:00	3.03	10/23/99 21:02	3.79				
15.73	10/24/99 0:16	10/24/99 0:24	10/24/99 0:31	10/24/99 0:49	4.00	10/24/99 4:49	5.00	10/24/99 9:49	2.88	10/24/99 12:42	3.60				
15.41	10/24/99 15:45	10/24/99 15:53	10/24/99 16:00	10/24/99 16:18	4.00	10/24/99 20:18	5.00	10/25/99 1:18	2.75	10/25/99 4:03	3.44				
15.10	10/25/99 6:56	10/25/99 7:04	10/25/99 7:12	10/25/99 7:30	4.00	10/25/99 11:30	5.00	10/25/99 16:30	2.63	10/25/99 19:08	3.29				
14.80	10/25/99 21:52	10/25/99 22:00	10/25/99 22:07	10/25/99 22:25	4.00	10/26/99 2:25	5.00	10/26/99 7:25	2.47	10/26/99 9:54	3.09				
14.47	10/26/99 12:26	10/26/99 12:34	10/26/99 12:42	10/26/99 13:00	4.00	10/26/99 17:00	5.00	10/26/99 22:00	2.34	10/27/99 0:20	2.92				
14.14	10/27/99 2:41	10/27/99 2:49	10/27/99 2:57	10/27/99 3:15	4.00	10/27/99 7:15	5.00	10/27/99 12:15	2.18	10/27/99 14:25	2.72				
13.85	10/27/99 16:35	10/27/99 16:43	10/27/99 16:51	10/27/99 17:09	4.00	10/27/99 21:09	5.00	10/28/99 2:09	2.07	10/28/99 4:13	2.59				
13.59	10/28/99 6:15	10/28/99 6:22	10/28/99 6:30	10/28/99 6:48	4.00	10/28/99 10:48	5.00	10/28/99 15:48	1.96	10/28/99 17:46	2.45				
13.30	10/28/99 19:40	10/28/99 19:47	10/28/99 19:55	10/28/99 20:13	4.00	10/29/99 0:13	5.00	10/29/99 5:13	1.83	10/29/99 7:03	2.29				
13.05	10/29/99 8:47	10/29/99 8:55	10/29/99 9:03	10/29/99 9:21	4.00	10/29/99 13:21	5.00	10/29/99 18:21	1.74	10/29/99 20:05	2.17				
12.80	10/29/99 21:42	10/29/99 21:50	10/29/99 21:57	10/29/99 22:15	4.00	10/30/99 2:15	5.00	10/30/99 7:15	1.63	10/30/99 8:53	2.04				
12.56	10/30/99 10:22	10/30/99 10:30	10/30/99 10:38	10/30/99 10:56	4.00	10/30/99 14:56	5.00	10/30/99 19:56	1.51	10/30/99 21:27	1.89				
12.32	10/30/99 22:47	10/30/99 22:54	10/30/99 23:02	10/30/99 23:20	4.00	10/31/99 3:20	5.00	10/31/99 8:20	1.43	10/31/99 9:46	1.79				
12.11	10/31/99 11:00	10/31/99 11:07	10/31/99 11:15	10/31/99 11:33	4.00	10/31/99 15:33	5.00	10/31/99 20:33	1.32	10/31/99 21:53	1.65				
11.90	10/31/99 22:58	10/31/99 23:06	10/31/99 23:14	10/31/99 23:32	4.00	11/1/99 3:32	5.00	11/1/99 8:32	1.25	11/1/99 9:47	1.56				
11.71	11/1/99 10:47	11/1/99 10:54	11/1/99 11:02	11/1/99 11:20	4.00	11/1/99 15:20	5.00	11/1/99 20:20	1.14	11/1/99 21:29	1.43				
11.47	11/1/99 22:21	11/1/99 22:29	11/1/99 22:36	11/1/99 22:54	4.00	11/2/99 2:54	5.00	11/2/99 7:54	1.05	11/2/99 8:57	1.31				
11.26	11/2/99 9:42	11/2/99 9:50	11/2/99 9:57	11/2/99 10:15	4.00	11/2/99 14:15	5.00	11/2/99 19:15	0.94	11/2/99 20:12	1.17				
11.05	11/2/99 20:49	11/2/99 20:56	11/2/99 21:04	11/2/99 21:22	4.00	11/3/99 1:22	5.00	11/3/99 6:22	0.84	11/3/99 7:13	1.05				
10.85	11/3/99 7:42	11/3/99 7:50	11/3/99 7:58	11/3/99 8:16	4.00	11/3/99 12:16	5.00	11/3/99 17:16	0.77	11/3/99 18:02	0.96				
10.67	11/3/99 18:26	11/3/99 18:34	11/3/99 18:42	11/3/99 19:00	4.00	11/3/99 23:00	5.00	11/4/99 4:00	0.69	11/4/99 4:41	0.87				
10.50	11/4/99 5:00	11/4/99 5:07	11/4/99 5:15	11/4/99 5:33	4.00	11/4/99 9:33	5.00	11/4/99 14:33	0.50	11/4/99 15:03	0.63				
10.31	11/4/99 15:23	11/4/99 15:31	11/4/99 15:39	11/4/99 15:57	4.00	11/4/99 19:57	5.00								
10.12	11/5/99 1:35	11/5/99 1:43	11/5/99 1:51	11/5/99 2:09	4.00	11/5/99 6:09	5.00								
9.97	11/5/99 11:37	11/5/99 11:45	11/5/99 11:53	11/5/99 12:11	4.00	11/5/99 16:11	5.00								
9.82	11/5/99 21:30	11/5/99 21:38	11/5/99 21:46	11/5/99 22:04	4.00	11/6/99 2:04	5.00								
9.65	11/6/99 7:12	11/6/99 7:20	11/6/99 7:28	11/6/99 7:46	4.00	11/6/99 11:46	5.00								

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Tracking Schedule - close LP

period	Start	Periapse	End	Start	Track 1 duration	End	Off 1 duration	Start	Track 2 duration	End	Off 2 duration	Start	Track3 duration	End	Off 3 duration
h	Aeropass		Aeropass	Track 1 [post peri]	h	Track 1	h	Track 2	h	Track 2	h	Track 3	h	Track 3	h
9.47	11/6/99 16:44	11/6/99 16:52	11/6/99 17:00	11/6/99 17:00	4.00	11/6/99 21:18	5.00								
9.33	11/7/99 2:08	11/7/99 2:16	11/7/99 2:24	11/7/99 2:42	4.00	11/7/99 6:42	5.00								
9.21	11/7/99 11:24	11/7/99 11:32	11/7/99 11:40	11/7/99 11:58	4.00	11/7/99 15:58	5.00								
9.06	11/7/99 20:31	11/7/99 20:39	11/7/99 20:47	11/7/99 21:05	3.96	11/8/99 1:03	4.95								
8.91	11/8/99 5:30	11/8/99 5:38	11/8/99 5:46	11/8/99 6:04	3.90	11/8/99 9:58	4.87								
8.78	11/8/99 14:20	11/8/99 14:28	11/8/99 14:36	11/8/99 14:54	3.84	11/8/99 18:44	4.80								
8.66	11/8/99 23:02	11/8/99 23:10	11/8/99 23:18	11/8/99 23:36	3.77	11/9/99 3:23	4.72								
8.50	11/9/99 7:35	11/9/99 7:43	11/9/99 7:51	11/9/99 8:09	3.71	11/9/99 11:52	4.64								
8.37	11/9/99 16:00	11/9/99 16:08	11/9/99 16:16	11/9/99 16:34	3.67	11/9/99 20:14	4.58								
8.26	11/10/99 0:19	11/10/99 0:27	11/10/99 0:35	11/10/99 0:53	3.61	11/10/99 4:29	4.51								
8.12	11/10/99 8:30	11/10/99 8:38	11/10/99 8:46	11/10/99 9:04	3.55	11/10/99 12:37	4.44								
8.00	11/10/99 16:33	11/10/99 16:42	11/10/99 16:50	11/10/99 17:08	3.51	11/10/99 20:38	4.39								
7.91	11/11/99 0:30	11/11/99 0:38	11/11/99 0:46	11/11/99 1:04	3.46	11/11/99 4:32	4.32								
7.79	11/11/99 8:20	11/11/99 8:28	11/11/99 8:36	11/11/99 8:54	3.41	11/11/99 12:18	4.26								
7.68	11/11/99 16:03	11/11/99 16:11	11/11/99 16:19	11/11/99 16:37	3.36	11/11/99 19:59	4.20								
7.58	11/11/99 23:41	11/11/99 23:49	11/11/99 23:57	11/12/99 0:15	3.31	11/12/99 3:34	4.14								
7.45	11/12/99 7:10	11/12/99 7:18	11/12/99 7:27	11/12/99 7:45	3.27	11/12/99 11:00	4.08								
7.35	11/12/99 14:35	11/12/99 14:43	11/12/99 14:51	11/12/99 15:09	3.21	11/12/99 18:22	4.01								
7.22	11/12/99 21:52	11/12/99 22:00	11/12/99 22:08	11/12/99 22:26	3.15	11/13/99 1:35	3.94								
7.10	11/13/99 5:02	11/13/99 5:10	11/13/99 5:18	11/13/99 5:36	3.11	11/13/99 8:43	3.88								
7.00	11/13/99 12:06	11/13/99 12:14	11/13/99 12:22	11/13/99 12:40	3.05	11/13/99 15:43	3.82								
6.88	11/13/99 19:00	11/13/99 19:08	11/13/99 19:16	11/13/99 19:34	3.02	11/13/99 22:36	3.77								
6.80	11/14/99 1:51	11/14/99 1:59	11/14/99 2:07	11/14/99 2:25	2.97	11/14/99 5:23	3.71								
6.68	11/14/99 8:35	11/14/99 8:43	11/14/99 8:52	11/14/99 9:10	2.93	11/14/99 12:05	3.66								
6.60	11/14/99 15:14	11/14/99 15:22	11/14/99 15:30	11/14/99 15:48	2.88	11/14/99 18:42	3.61								
6.50	11/14/99 21:46	11/14/99 21:54	11/14/99 22:02	11/14/99 22:20	2.85	11/15/99 1:11	3.56								
6.42	11/15/99 4:15	11/15/99 4:23	11/15/99 4:31	11/15/99 4:49	2.81	11/15/99 7:38	3.51								
6.33	11/15/99 10:36	11/15/99 10:44	11/15/99 10:53	11/15/99 11:11	2.78	11/15/99 13:57	3.47								
6.25	11/15/99 16:53	11/15/99 17:02	11/15/99 17:10	11/15/99 17:28	2.74	11/15/99 20:12	3.42								
6.17	11/15/99 23:06	11/15/99 23:15	11/15/99 23:23	11/15/99 23:41	2.71	11/16/99 2:23	3.38								
6.10	11/16/99 5:14	11/16/99 5:22	11/16/99 5:30	11/16/99 5:48	2.67	11/16/99 8:29	3.34								
6.02	11/16/99 11:18	11/16/99 11:26	11/16/99 11:34	11/16/99 11:52	2.64	11/16/99 14:31	3.30								
5.95	11/16/99 17:16	11/16/99 17:25	11/16/99 17:33	11/16/99 17:51	2.61	11/16/99 20:28	3.26								
5.88	11/16/99 23:12	11/16/99 23:20	11/16/99 23:29	11/16/99 23:47	2.58	11/17/99 2:22	3.23								
5.82	11/17/99 5:03	11/17/99 5:12	11/17/99 5:20	11/17/99 5:38	2.55	11/17/99 8:11	3.19								
5.75	11/17/99 10:50	11/17/99 10:59	11/17/99 11:07	11/17/99 11:25	2.52	11/17/99 13:57	3.15								
5.68	11/17/99 16:35	11/17/99 16:43	11/17/99 16:51	11/17/99 17:09	2.49	11/17/99 19:38	3.11								
5.60	11/17/99 22:13	11/17/99 22:21	11/17/99 22:30	11/17/99 22:48	2.46	11/18/99 1:15	3.07								
5.53	11/18/99 3:47	11/18/99 3:55	11/18/99 4:04	11/18/99 4:22	2.42	11/18/99 6:47	3.02								
5.45	11/18/99 9:17	11/18/99 9:25	11/18/99 9:34	11/18/99 9:52	2.39	11/18/99 12:15	2.99								
5.39	11/18/99 14:42	11/18/99 14:51	11/18/99 14:59	11/18/99 15:17	2.36	11/18/99 17:39	2.95								
5.32	11/18/99 20:03	11/18/99 20:12	11/18/99 20:20	11/18/99 20:38	2.34	11/18/99 22:58	2.92								
5.26	11/19/99 1:22	11/19/99 1:30	11/19/99 1:38	11/19/99 1:56	2.31	11/19/99 4:15	2.89								
5.20	11/19/99 6:35	11/19/99 6:44	11/19/99 6:52	11/19/99 7:10	2.28	11/19/99 9:27	2.85								
5.14	11/19/99 11:46	11/19/99 11:55	11/19/99 12:03	11/19/99 12:21	2.26	11/19/99 14:37	2.82								
5.09	11/19/99 16:53	11/19/99 17:02	11/19/99 17:10	11/19/99 17:28	2.23	11/19/99 19:42	2.78								
5.02	11/19/99 21:57	11/19/99 22:06	11/19/99 22:14	11/19/99 22:32	2.20	11/20/99 0:44	2.75								
4.96	11/20/99 2:56	11/20/99 3:05	11/20/99 3:14	11/20/99 3:32	2.18	11/20/99 5:42	2.72								
4.90	11/20/99 7:53	11/20/99 8:02	11/20/99 8:10	11/20/99 8:28	2.15	11/20/99 10:37	2.68								
4.84	11/20/99 12:45	11/20/99 12:54	11/20/99 13:03	11/20/99 13:21	2.12	11/20/99 15:28	2.65								

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Tracking Schedule - close LP

period	Start	Periapse	End	Start	Track 1 duration	End	Off 1 duration	Start	Track 2 duration	End	Off 2 duration	Start	Track3 duration	End	Off 3 duration
h	Aeropass		Aeropass	Track 1 [post peri]	h	Track 1	h	Track 2	h	Track 2	h	Track 3	h	Track 3	h
4.78	11/20/99 17:33	11/20/99 17:42	11/20/99 17:51	11/20/99 17:09	2.10	11/20/99 20:14	2.62								
4.72	11/20/99 22:20	11/20/99 22:29	11/20/99 22:37	11/20/99 22:55	2.07	11/21/99 1:00	2.59								
4.67	11/21/99 3:02	11/21/99 3:11	11/21/99 3:19	11/21/99 3:37	2.05	11/21/99 5:40	2.56								
4.62	11/21/99 7:40	11/21/99 7:49	11/21/99 7:57	11/21/99 8:15	2.03	11/21/99 10:17	2.53								
4.56	11/21/99 12:17	11/21/99 12:25	11/21/99 12:34	11/21/99 12:52	2.01	11/21/99 14:52	2.51								
4.52	11/21/99 16:49	11/21/99 16:57	11/21/99 17:06	11/21/99 17:24	1.98	11/21/99 19:23	2.47								
4.45	11/21/99 21:18	11/21/99 21:27	11/21/99 21:35	11/21/99 21:53	1.95	11/21/99 23:50	2.44								
4.40	11/22/99 1:44	11/22/99 1:53	11/22/99 2:02	11/22/99 2:20	1.93	11/22/99 4:16	2.41								
4.35	11/22/99 6:06	11/22/99 6:15	11/22/99 6:24	11/22/99 6:42	1.90	11/22/99 8:36	2.38								
4.29	11/22/99 10:27	11/22/99 10:36	11/22/99 10:44	11/22/99 11:02	1.88	11/22/99 12:55	2.35								
4.24	11/22/99 14:43	11/22/99 14:52	11/22/99 15:01	11/22/99 15:19	1.86	11/22/99 17:11	2.33								
4.19	11/22/99 18:57	11/22/99 19:06	11/22/99 19:14	11/22/99 19:32	1.84	11/22/99 21:23	2.30								
4.14	11/22/99 23:06	11/22/99 23:15	11/22/99 23:23	11/22/99 23:41	1.82	11/23/99 1:31	2.27								
4.10	11/23/99 3:13	11/23/99 3:22	11/23/99 3:31	11/23/99 3:49	1.80	11/23/99 5:37	2.25								
4.06	11/23/99 7:20	11/23/99 7:29	11/23/99 7:37	11/23/99 7:55	1.78	11/23/99 9:42	2.23								
4.01	11/23/99 11:22	11/23/99 11:30	11/23/99 11:39	11/23/99 11:57	1.76	11/23/99 13:43	2.20								
3.97	11/23/99 15:22	11/23/99 15:31	11/23/99 15:40	11/23/99 15:58	1.74	11/23/99 17:42	2.18								
3.93	11/23/99 19:20	11/23/99 19:29	11/23/99 19:37	11/23/99 19:55	1.72	11/23/99 21:39	2.15								
3.88	11/23/99 23:13	11/23/99 23:22	11/23/99 23:31	11/23/99 23:49	1.70	11/24/99 1:31	2.13								
3.83	11/24/99 3:05	11/24/99 3:14	11/24/99 3:23	11/24/99 3:41	1.68	11/24/99 5:22	2.11								
3.79	11/24/99 6:55	11/24/99 7:04	11/24/99 7:13	11/24/99 7:31	1.66	11/24/99 9:11	2.08								
3.75	11/24/99 10:41	11/24/99 10:50	11/24/99 10:59	11/24/99 11:17	1.65	11/24/99 12:56	2.06								
3.71	11/24/99 14:26	11/24/99 14:35	11/24/99 14:44	11/24/99 15:02	1.63	11/24/99 16:40	2.04								
3.67	11/24/99 18:07	11/24/99 18:17	11/24/99 18:26	11/24/99 18:44	1.61	11/24/99 20:21	2.02								
3.63	11/24/99 21:46	11/24/99 21:55	11/24/99 22:05	11/24/99 22:23	1.60	11/24/99 23:59	2.00								
3.59	11/25/99 1:24	11/25/99 1:33	11/25/99 1:42	11/25/99 2:00	1.58	11/25/99 3:35	1.97								
3.56	11/25/99 4:59	11/25/99 5:09	11/25/99 5:18	11/25/99 5:36	1.56	11/25/99 7:10	1.95								
3.52	11/25/99 8:31	11/25/99 8:41	11/25/99 8:50	11/25/99 9:08	1.54	11/25/99 10:41	1.93								
3.47	11/25/99 12:01	11/25/99 12:11	11/25/99 12:20	11/25/99 12:38	1.53	11/25/99 14:10	1.91								
3.44	11/25/99 15:30	11/25/99 15:40	11/25/99 15:49	11/25/99 16:07	1.51	11/25/99 17:38	1.89								
3.40	11/25/99 18:56	11/25/99 19:06	11/25/99 19:15	11/25/99 19:33	1.50	11/25/99 21:03	1.87								
3.37	11/25/99 22:19	11/25/99 22:29	11/25/99 22:38	11/25/99 22:56	1.48	11/26/99 0:25	1.85								
3.34	11/26/99 1:41	11/26/99 1:50	11/26/99 2:00	11/26/99 2:18	1.47	11/26/99 3:46	1.84								
3.32	11/26/99 5:01	11/26/99 5:10	11/26/99 5:20	11/26/99 5:38	1.47	11/26/99 7:06	1.83								
3.30	11/26/99 8:21	11/26/99 8:30	11/26/99 8:40	11/26/99 8:58	1.46	11/26/99 10:26	1.82								
3.29	11/26/99 11:38	11/26/99 11:48	11/26/99 11:57	11/26/99 12:15	1.45	11/26/99 13:42	1.81								
3.27	11/26/99 14:55	11/26/99 15:05	11/26/99 15:15	11/26/99 15:33	1.44	11/26/99 16:59	1.80								
3.25	11/26/99 18:13	11/26/99 18:22	11/26/99 18:32	11/26/99 18:50	1.43	11/26/99 20:16	1.79								
3.22	11/26/99 21:27	11/26/99 21:37	11/26/99 21:46	11/26/99 22:04	1.42	11/26/99 23:29	1.77								
3.19	11/27/99 0:40	11/27/99 0:50	11/27/99 0:59	11/27/99 1:17	1.40	11/27/99 2:42	1.76								
3.16	11/27/99 3:50	11/27/99 4:00	11/27/99 4:10	11/27/99 4:28	1.39	11/27/99 5:51	1.74								
3.14	11/27/99 7:00	11/27/99 7:10	11/27/99 7:20	11/27/99 7:38	1.38	11/27/99 9:01	1.73								
3.12	11/27/99 10:09	11/27/99 10:18	11/27/99 10:28	11/27/99 10:46	1.37	11/27/99 12:09	1.71								
3.09	11/27/99 13:16	11/27/99 13:26	11/27/99 13:36	11/27/99 13:54	1.36	11/27/99 15:15	1.70								
3.07	11/27/99 16:20	11/27/99 16:30	11/27/99 16:40	11/27/99 16:58	1.35	11/27/99 18:19	1.69								
3.05	11/27/99 19:24	11/27/99 19:34	11/27/99 19:44	11/27/99 20:02	1.34	11/27/99 21:23	1.68								
3.02	11/27/99 22:27	11/27/99 22:37	11/27/99 22:47	11/27/99 23:05	1.33	11/28/99 0:25	1.67								
3.00	11/28/99 1:29	11/28/99 1:39	11/28/99 1:49	11/28/99 2:07	1.32	11/28/99 3:26	1.65								
2.98	11/28/99 4:29	11/28/99 4:39	11/28/99 4:49	11/28/99 5:07	1.32	11/28/99 6:26	1.64								
2.96	11/28/99 7:27	11/28/99 7:37	11/28/99 7:47	11/28/99 8:05	1.31	11/28/99 9:24	1.63								

6/24/97

Tracking Schedule - close LP

period	Start	Periapse	End	Start	Track 1 duration	End	Off 1 duration	Start	Track 2 duration	End	Off 2 duration	Start	Track3 duration	End	Off 3 duration
h	Aeropass		Aeropass	Track 1 [post peri]	h	Track 1	h	Track 2	h	Track 2	h	Track 3	h	Track 3	h
2.94	11/28/99 10:26	11/28/99 10:36	11/28/99 10:46	11/28/99 10:46	1.30	11/28/99 11:04	1.62								
2.92	11/28/99 13:21	11/28/99 13:31	11/28/99 13:42	11/28/99 14:00	1.29	11/28/99 15:17	1.61								
2.91	11/28/99 16:17	11/28/99 16:27	11/28/99 16:37	11/28/99 16:55	1.28	11/28/99 18:12	1.60								
2.89	11/28/99 19:11	11/28/99 19:21	11/28/99 19:31	11/28/99 19:49	1.28	11/28/99 21:06	1.59								
2.87	11/28/99 22:05	11/28/99 22:16	11/28/99 22:26	11/28/99 22:44	1.27	11/29/99 0:00	1.58								
2.86	11/29/99 0:58	11/29/99 1:08	11/29/99 1:19	11/29/99 1:37	1.26	11/29/99 2:52	1.58								
2.84	11/29/99 3:50	11/29/99 4:00	11/29/99 4:10	11/29/99 4:28	1.25	11/29/99 5:43	1.56								
2.82	11/29/99 6:39	11/29/99 6:50	11/29/99 7:00	11/29/99 7:18	1.24	11/29/99 8:32	1.55								
2.79	11/29/99 9:29	11/29/99 9:40	11/29/99 9:50	11/29/99 10:08	1.23	11/29/99 11:22	1.54								
2.77	11/29/99 12:16	11/29/99 12:27	11/29/99 12:37	11/29/99 12:55	1.22	11/29/99 14:08	1.52								
2.74	11/29/99 15:02	11/29/99 15:12	11/29/99 15:23	11/29/99 15:41	1.21	11/29/99 16:53	1.51								
2.72	11/29/99 17:46	11/29/99 17:56	11/29/99 18:07	11/29/99 18:25	1.20	11/29/99 19:37	1.50								
2.70	11/29/99 20:29	11/29/99 20:39	11/29/99 20:50	11/29/99 21:08	1.19	11/29/99 22:19	1.48								
2.67	11/29/99 23:11	11/29/99 23:22	11/29/99 23:32	11/29/99 23:50	1.18	11/30/99 1:01	1.47								
2.65	11/30/99 1:51	11/30/99 2:02	11/30/99 2:12	11/30/99 2:30	1.17	11/30/99 3:40	1.46								
2.63	11/30/99 4:29	11/30/99 4:40	11/30/99 4:51	11/30/99 5:09	1.16	11/30/99 6:18	1.45								
2.61	11/30/99 7:08	11/30/99 7:18	11/30/99 7:29	11/30/99 7:47	1.15	11/30/99 8:56	1.44								
2.59	11/30/99 9:45	11/30/99 9:55	11/30/99 10:06	11/30/99 10:24	1.14	11/30/99 11:33	1.43								
2.57	11/30/99 12:20	11/30/99 12:31	11/30/99 12:42	11/30/99 13:00	1.13	11/30/99 14:08	1.42								
2.55	11/30/99 14:54	11/30/99 15:05	11/30/99 15:16	11/30/99 15:34	1.13	11/30/99 16:41	1.41								
2.53	11/30/99 17:28	11/30/99 17:39	11/30/99 17:50	11/30/99 18:08	1.12	11/30/99 19:15	1.40								
2.52	11/30/99 19:59	11/30/99 20:10	11/30/99 20:21	11/30/99 20:39	1.11	11/30/99 21:46	1.39								
2.50	11/30/99 22:31	11/30/99 22:42	11/30/99 22:52	11/30/99 23:10	1.10	12/1/99 0:17	1.38								
2.48	12/1/99 1:00	12/1/99 1:11	12/1/99 1:23	12/1/99 1:41	1.09	12/1/99 2:46	1.37								
2.47	12/1/99 3:30	12/1/99 3:41	12/1/99 3:52	12/1/99 4:10	1.09	12/1/99 5:16	1.36								
2.45	12/1/99 5:58	12/1/99 6:09	12/1/99 6:21	12/1/99 6:39	1.08	12/1/99 7:44	1.35								
2.43	12/1/99 8:25	12/1/99 8:36	12/1/99 8:48	12/1/99 9:06	1.07	12/1/99 10:10	1.34								
2.41	12/1/99 10:50	12/1/99 11:02	12/1/99 11:13	12/1/99 11:31	1.06	12/1/99 12:35	1.32								
2.38	12/1/99 13:14	12/1/99 13:26	12/1/99 13:37	12/1/99 13:55	1.05	12/1/99 14:58	1.31								
2.36	12/1/99 15:36	12/1/99 15:48	12/1/99 16:00	12/1/99 16:18	1.04	12/1/99 17:20	1.30								
2.34	12/1/99 17:59	12/1/99 18:11	12/1/99 18:23	12/1/99 18:41	1.03	12/1/99 19:42	1.29								
2.32	12/1/99 20:18	12/1/99 20:30	12/1/99 20:43	12/1/99 21:01	1.02	12/1/99 22:02	1.27								
2.30	12/1/99 22:37	12/1/99 22:49	12/1/99 23:01	12/1/99 23:19	1.01	12/2/99 0:20	1.26								
2.28	12/2/99 0:55	12/2/99 1:07	12/2/99 1:19	12/2/99 1:37	1.00	12/2/99 2:37	1.25								
2.25	12/2/99 3:11	12/2/99 3:24	12/2/99 3:36	12/2/99 3:54	0.99	12/2/99 4:54	1.24								
2.23	12/2/99 5:25	12/2/99 5:38	12/2/99 5:50	12/2/99 6:08	0.98	12/2/99 7:07	1.23								
2.22	12/2/99 7:39	12/2/99 7:52	12/2/99 8:04	12/2/99 8:22	0.98	12/2/99 9:21	1.22								
2.20	12/2/99 9:53	12/2/99 10:06	12/2/99 10:18	12/2/99 10:36	0.97	12/2/99 11:34	1.21								
2.18	12/2/99 12:04	12/2/99 12:17	12/2/99 12:30	12/2/99 12:48	0.96	12/2/99 13:45	1.20								
2.16	12/2/99 14:14	12/2/99 14:28	12/2/99 14:41	12/2/99 14:59	0.95	12/2/99 15:56	1.19								
2.14	12/2/99 16:24	12/2/99 16:37	12/2/99 16:51	12/2/99 17:09	0.94	12/2/99 18:05	1.18								
2.12	12/2/99 18:32	12/2/99 18:45	12/2/99 18:59	12/2/99 19:17	0.50	12/2/99 19:47	0.63								
2.10	12/2/99 20:38	12/2/99 20:52	12/2/99 21:06	12/2/99 21:24	0.50	12/2/99 21:54	0.63								
2.09	12/2/99 22:45	12/2/99 22:59	12/2/99 23:13	12/2/99 23:31	0.50	12/3/99 0:01	0.63								
2.07	12/3/99 0:50	12/3/99 1:04	12/3/99 1:18	12/3/99 1:36	0.50	12/3/99 2:06	0.63								
2.05	12/3/99 2:54	12/3/99 3:08	12/3/99 3:22	12/3/99 3:40	0.50	12/3/99 4:10	0.63								
2.03	12/3/99 4:56	12/3/99 5:10	12/3/99 5:25	12/3/99 5:43	0.50	12/3/99 6:13	0.63								
2.01	12/3/99 6:58	12/3/99 7:13	12/3/99 7:28	12/3/99 7:46	0.50	12/3/99 8:16	0.63								
1.99	12/3/99 8:57	12/3/99 9:12	12/3/99 9:28	12/3/99 9:46	0.50	12/3/99 10:16	0.63								
1.97	12/3/99 10:56	12/3/99 11:12	12/3/99 11:27	12/3/99 11:45	0.50	12/3/99 12:15	0.63								

6/24/97

Tracking Schedule - close LP

period	Start	Periapse	End	Start	Track 1 duration	End	Off 1 duration	Start	Track 2 duration	End	Off 2 duration	Start	Track3 duration	End	Off 3 duration
h	Aeropass		Aeropass	Track 1 [post peri]	h	Track 1	h	Track 2	h	Track 2	h	Track 3	h	Track 3	h
1.95	12/3/99 12:54	12/3/99 13:10	12/3/99 13:26	12/3/99 13:44	0.50	12/3/99 14:14	0.63								
1.95	12/3/99 14:50	12/3/99 15:06	12/3/99 15:23	12/3/99 15:41	0.50	12/3/99 16:11	0.63								
1.94	12/3/99 16:47	12/3/99 17:03	12/3/99 17:20	12/3/99 17:38	0.50	12/3/99 18:08	0.63								
1.94	12/3/99 18:45	12/3/99 19:01	12/3/99 19:18	12/3/99 19:36	0.50	12/3/99 20:06	0.63								
1.93	12/3/99 20:41	12/3/99 20:58	12/3/99 21:15	12/3/99 21:33	0.50	12/3/99 22:03	0.63								
1.92	12/3/99 22:36	12/3/99 22:53	12/3/99 23:10	12/3/99 23:28	0.50	12/3/99 23:58	0.63								
1.92	12/4/99 0:33	12/4/99 0:50	12/4/99 1:07	12/4/99 1:25	0.50	12/4/99 1:55	0.63								
1.91	12/4/99 2:28	12/4/99 2:45	12/4/99 3:02	12/4/99 3:20	0.50	12/4/99 3:50	0.63								
1.90	12/4/99 4:23	12/4/99 4:40	12/4/99 4:58	12/4/99 5:16	0.50	12/4/99 5:46	0.63								
1.90	12/4/99 6:16	12/4/99 6:34	12/4/99 6:52	12/4/99 7:10	0.50	12/4/99 7:40	0.63								
1.89	12/4/99 8:08	12/4/99 8:28	12/4/99 8:47	12/4/99 9:05	0.50	12/4/99 9:35	0.63								
1.88	12/4/99 10:02	12/4/99 10:21	12/4/99 10:41	12/4/99 10:59	0.50	12/4/99 11:29	0.63								
1.87	12/4/99 11:55	12/4/99 12:15	12/4/99 12:35	12/4/99 12:53	0.50	12/4/99 13:23	0.63								
1.87	12/4/99 13:45	12/4/99 14:07	12/4/99 14:30	12/4/99 14:48	0.50	12/4/99 15:18	0.63								
1.86	12/4/99 15:38	12/4/99 16:00	12/4/99 16:22	12/4/99 16:40	0.50	12/4/99 17:10	0.63								
1.85	12/4/99 17:30	12/4/99 17:52	12/4/99 18:14	12/4/99 18:32	0.50	12/4/99 19:02	0.63								

A.6 Orbiter Post-Arrival Trajectory Characteristics

A.6.1 Solar Time and Eclipse Durations During Mission

Shown are solar time variations and eclipse durations during the mission, for three different cases.

Case 1: No Post-Aerobraking Inclination Trim: assumes that approximately $\pm 0.05^\circ$ in inclination dispersion remains after aerobraking. This is consistent with the currently baselined ΔV budget. The combined effect of this inclination error and the ± 20 minute aerobraking end node uncertainty, leads to the “worst case” profiles of solar times and eclipse durations illustrated. As shown, an early final node [Nominal - 20 minutes] combined with a final inclination 0.05° less than the targeted 92.93° leads to an orbit which drifts later in local mean solar time. The illustrated sun-drifter to early solar times occurs for a late final node [Nominal + 20 minutes], combined with a final inclination 0.05° higher than targeted.

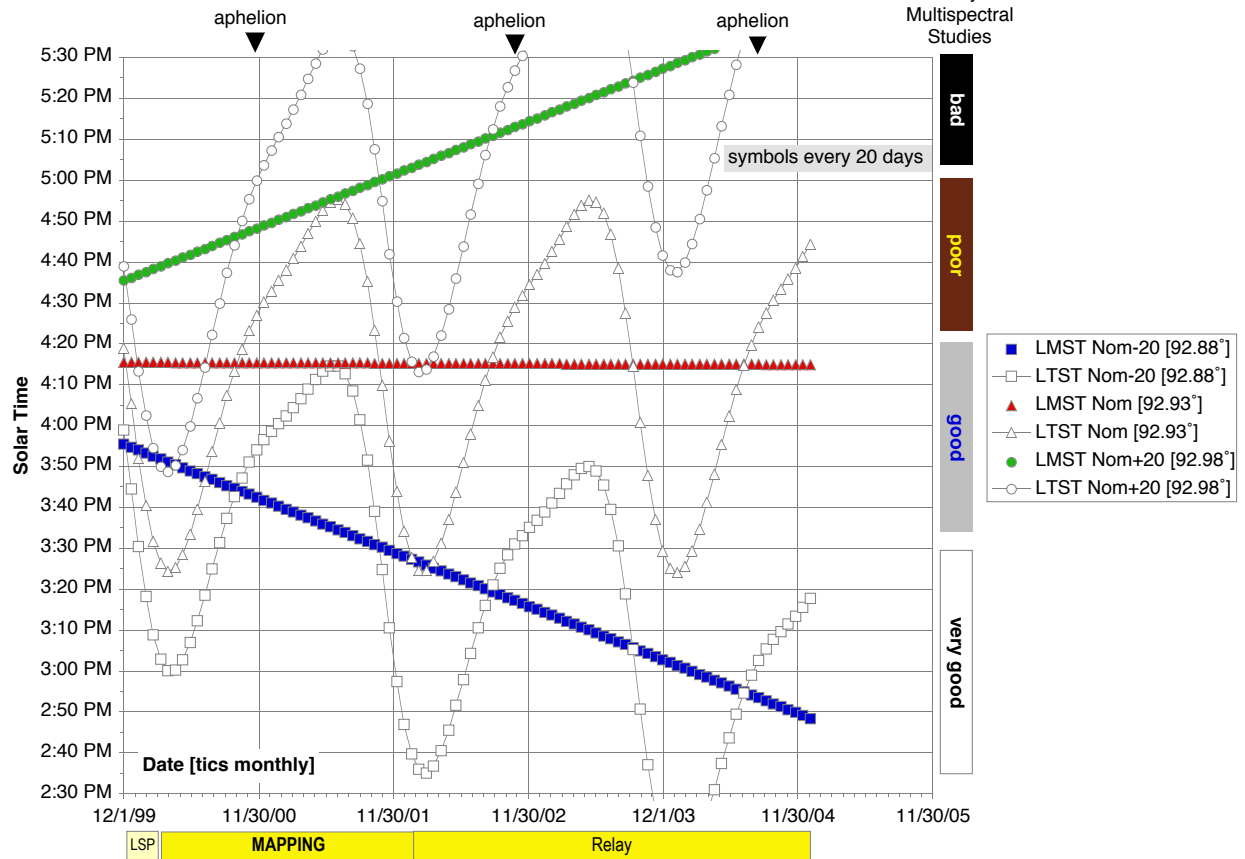
Case 2: Max Post-Aerobraking Inclination Trim of 0.05° : assumes that additional ΔV has been allocated to adjust the final inclination by as much as 0.05° . In this case, the orbit is always sun-synchronous, but at different local mean solar times, depending on the aerobraking end node. Maximum ΔV required for this adjustment is approximately 5-7 m/s if done as part of TMO-1, or 3 m/s if done as a separate maneuver at the node.

Case 3: Max Post-Aerobraking Inclination Trim of 0.1° : assumes that additional ΔV has been allocated to adjust the final inclination by as much as 0.1° . This allows the mapping orbit initial state to be adjusted to prevent very late solar times [bad for science] and very early solar times [bad for energy balance] during the mapping mission. Maximum ΔV required for this adjustment is approximately 6 m/s if done as a separate maneuver at the node.

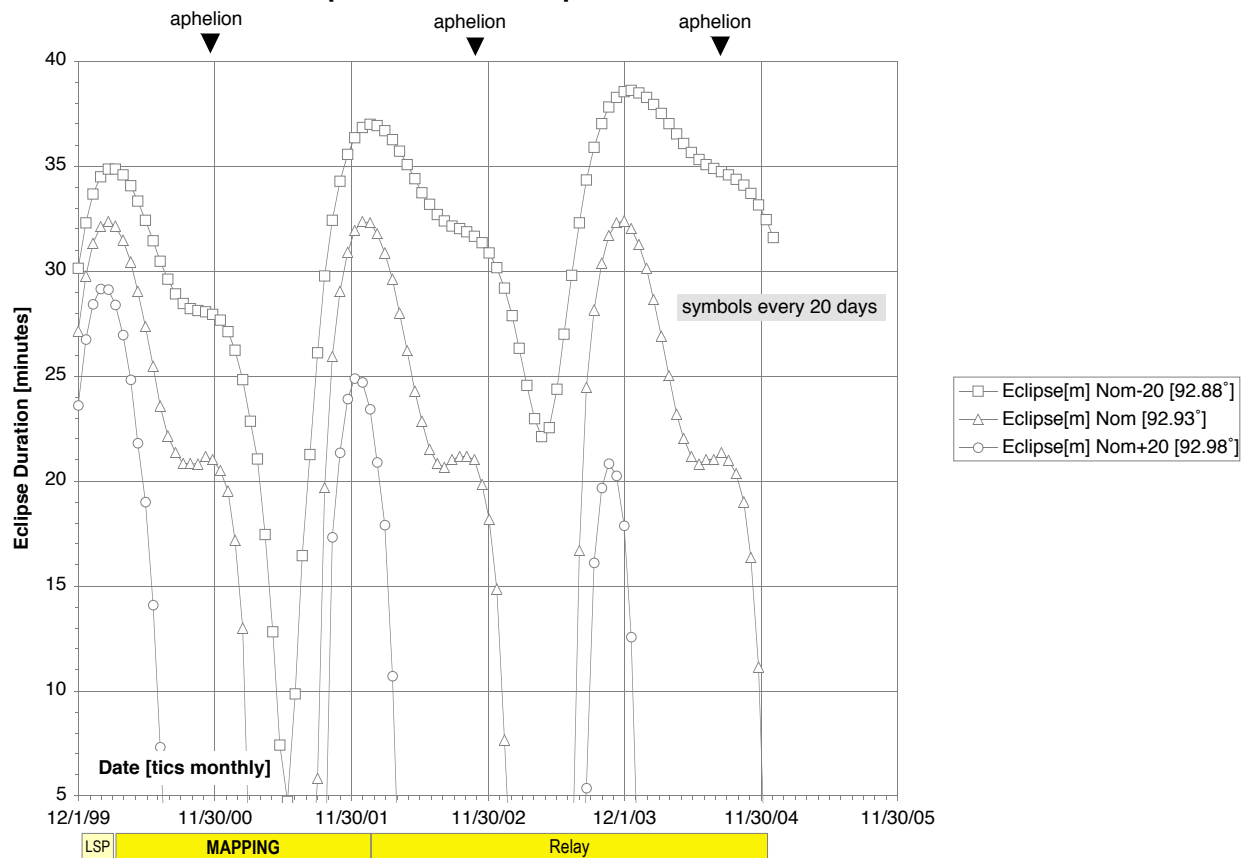
A.6.2 Frozen Orbit Characteristics

A.6.3 Post-Arrival Planetary Geometry

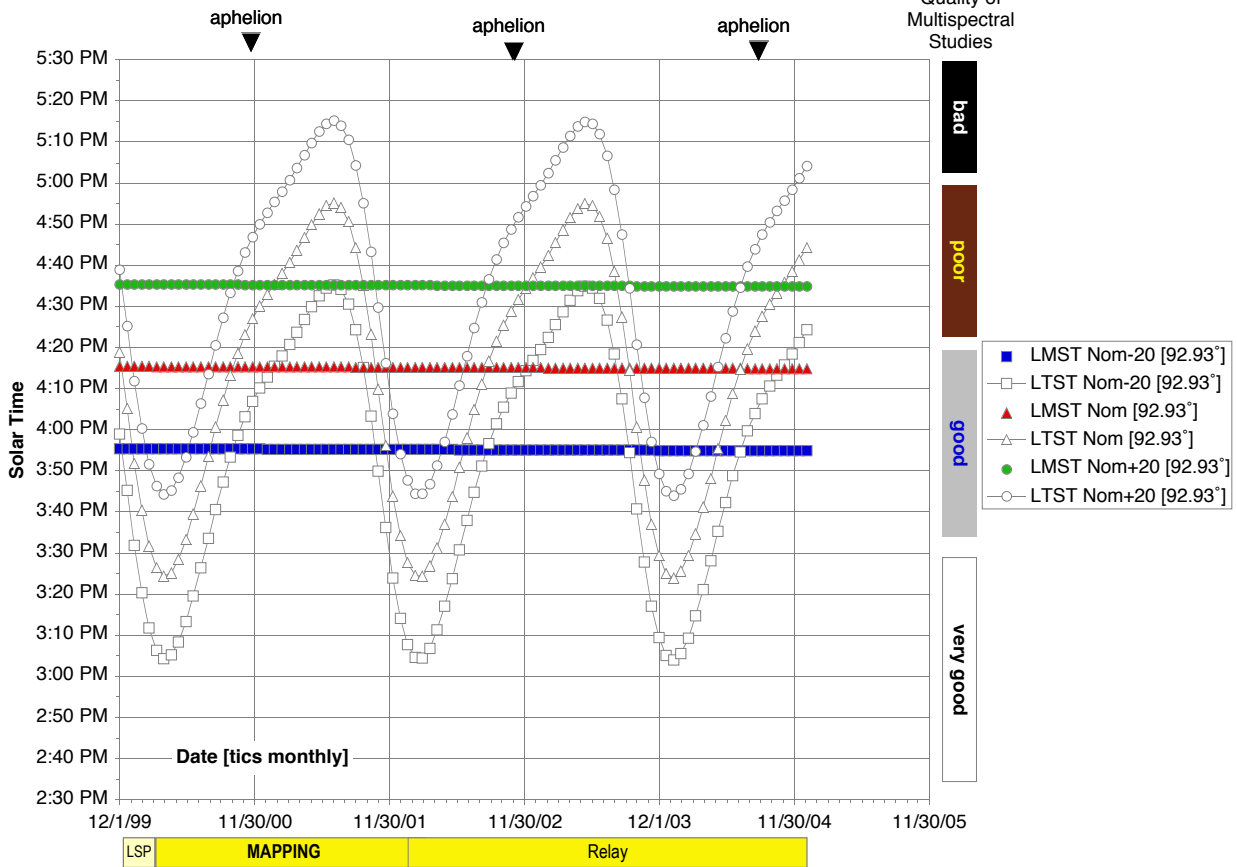
Solar Time - Open LP - No Post-AB Incl Trim



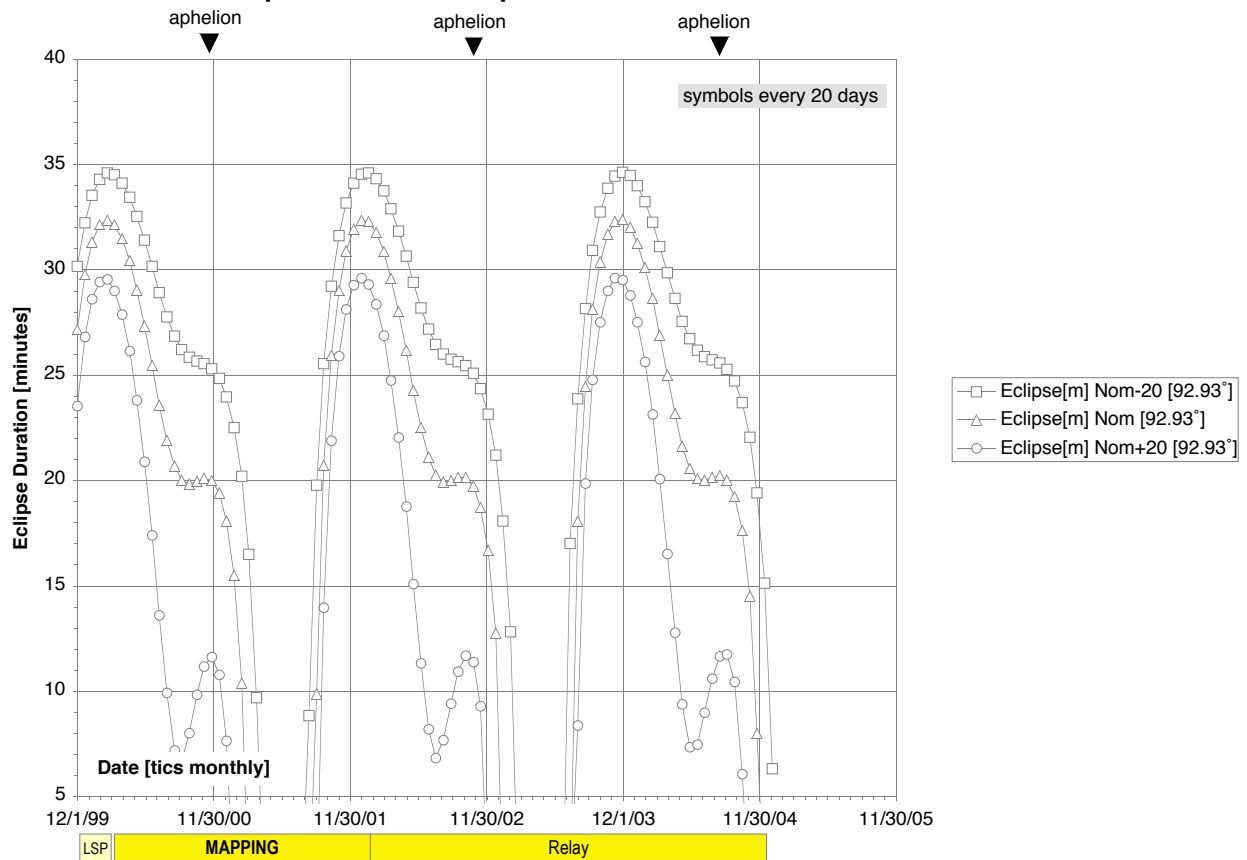
Eclipse Durations - Open LP - No Post-AB Incl Trim



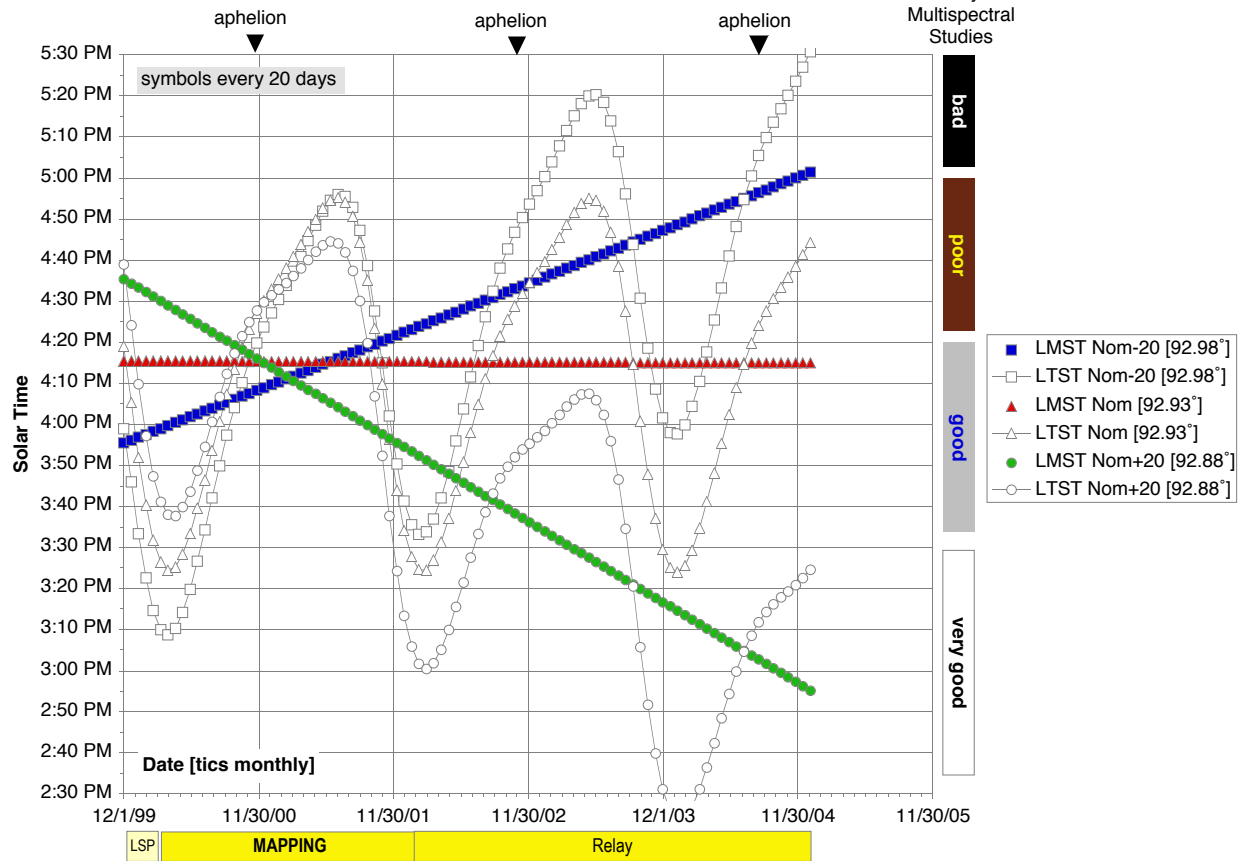
Solar Time - Open LP - Max Post-AB Incl Trim of 0.05°



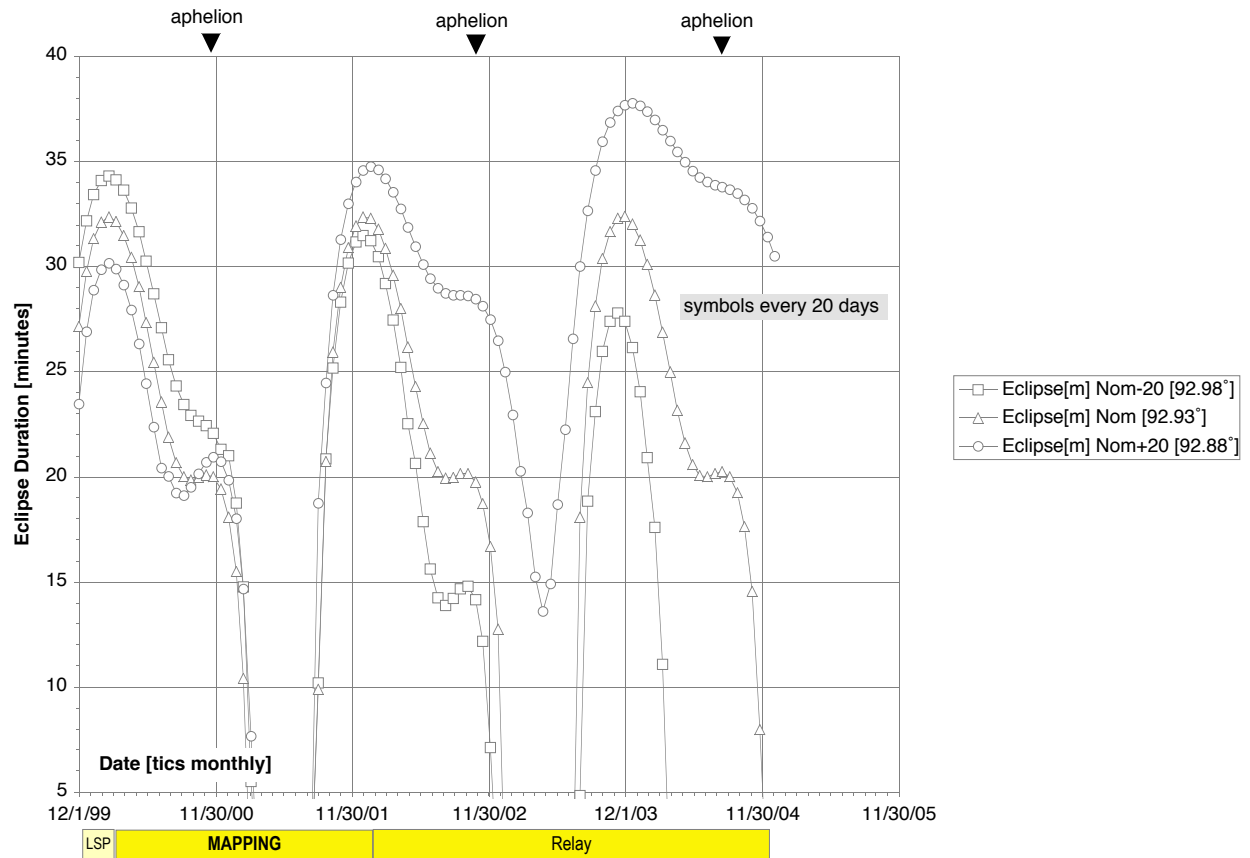
Eclipse Durations - Open LP - Max Post-AB Incl Trim of 0.05°

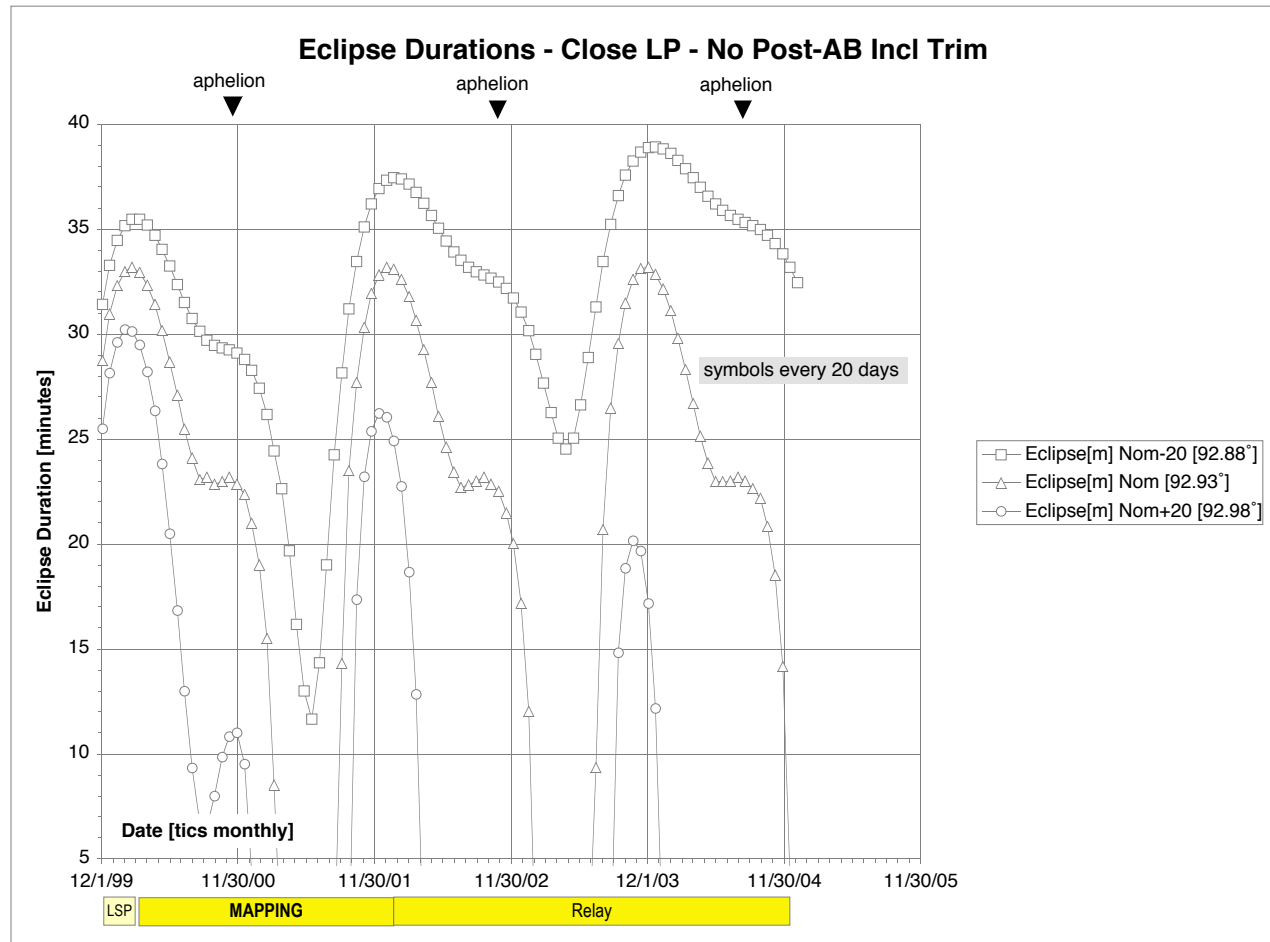
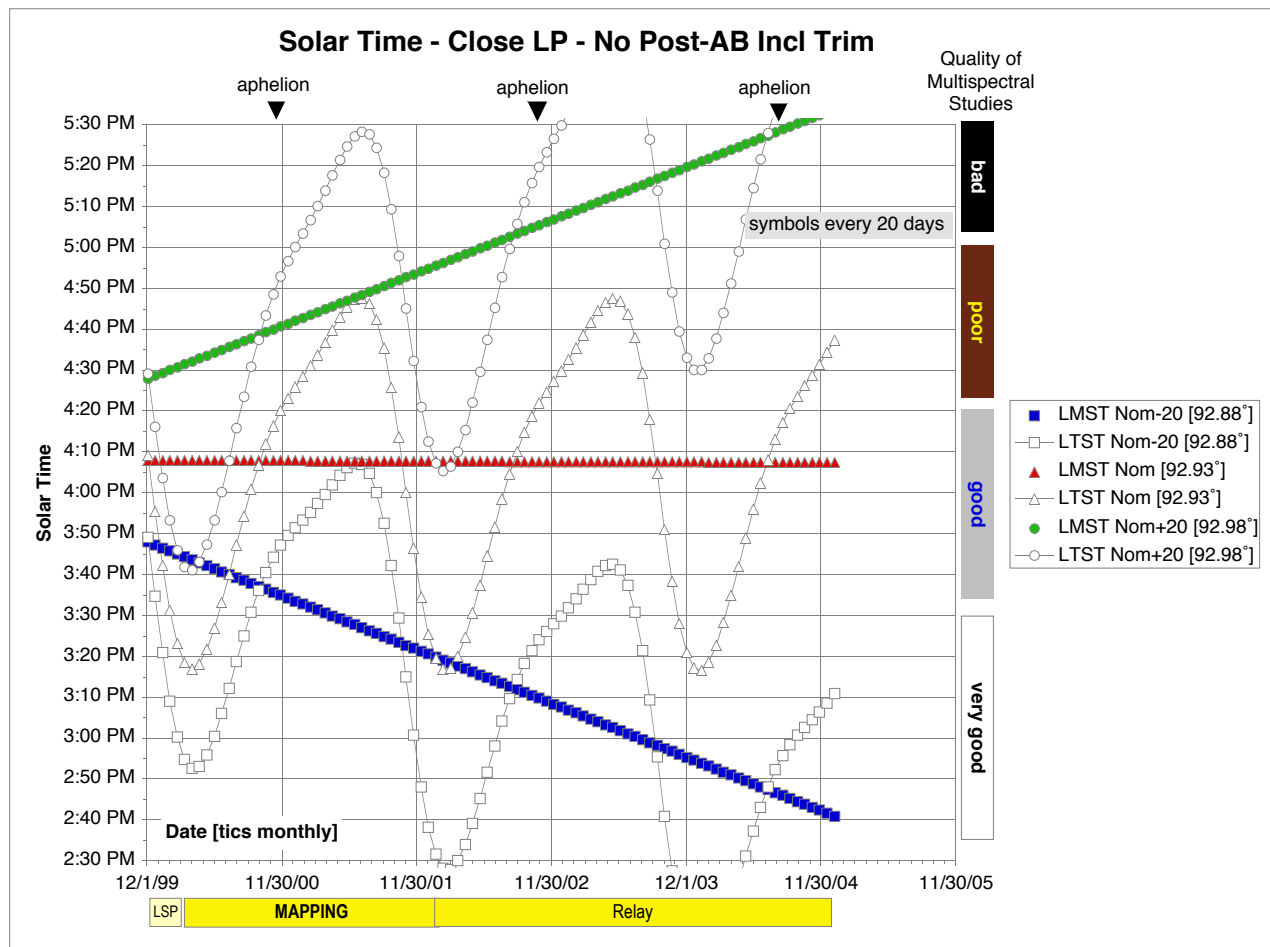


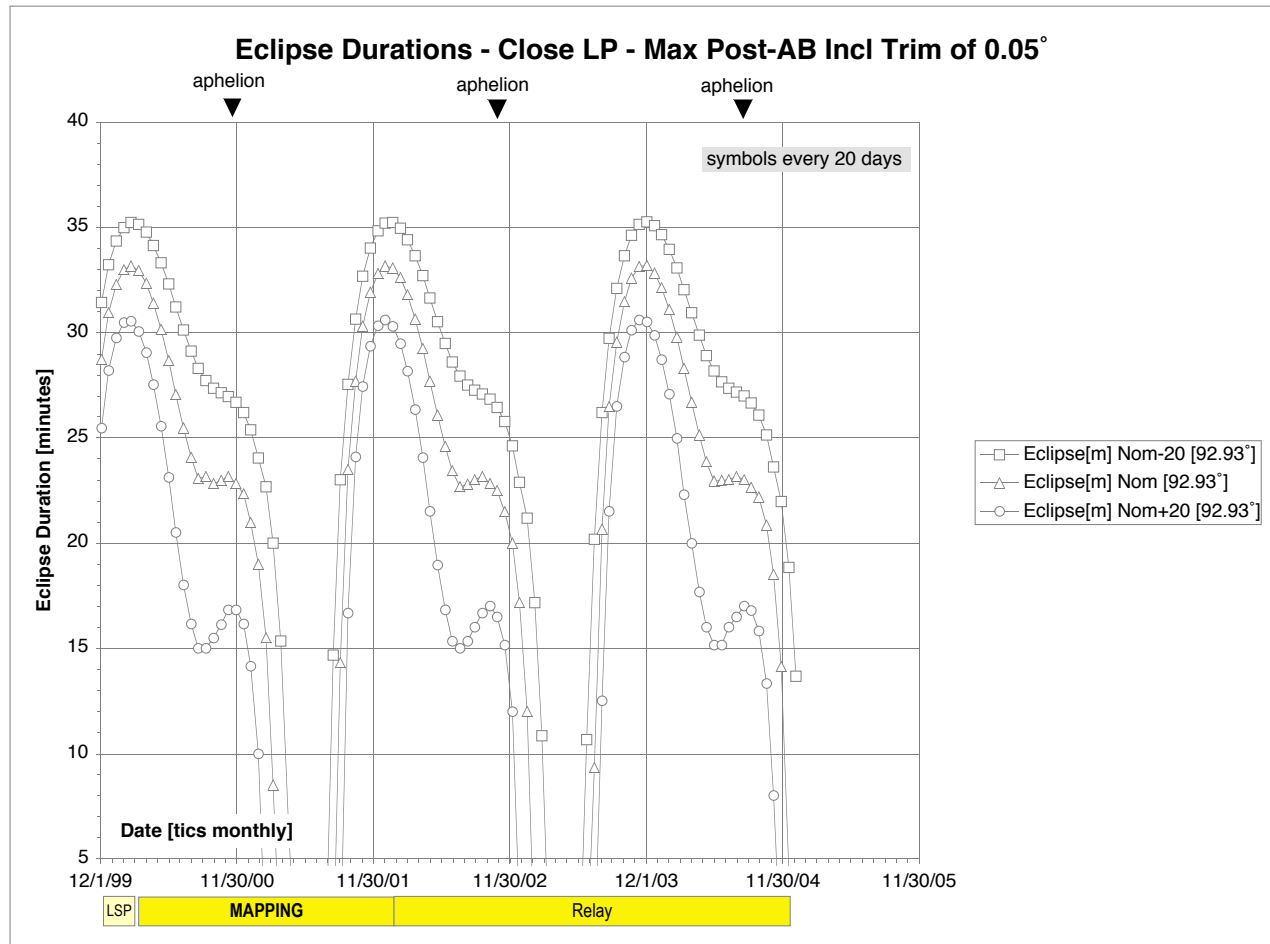
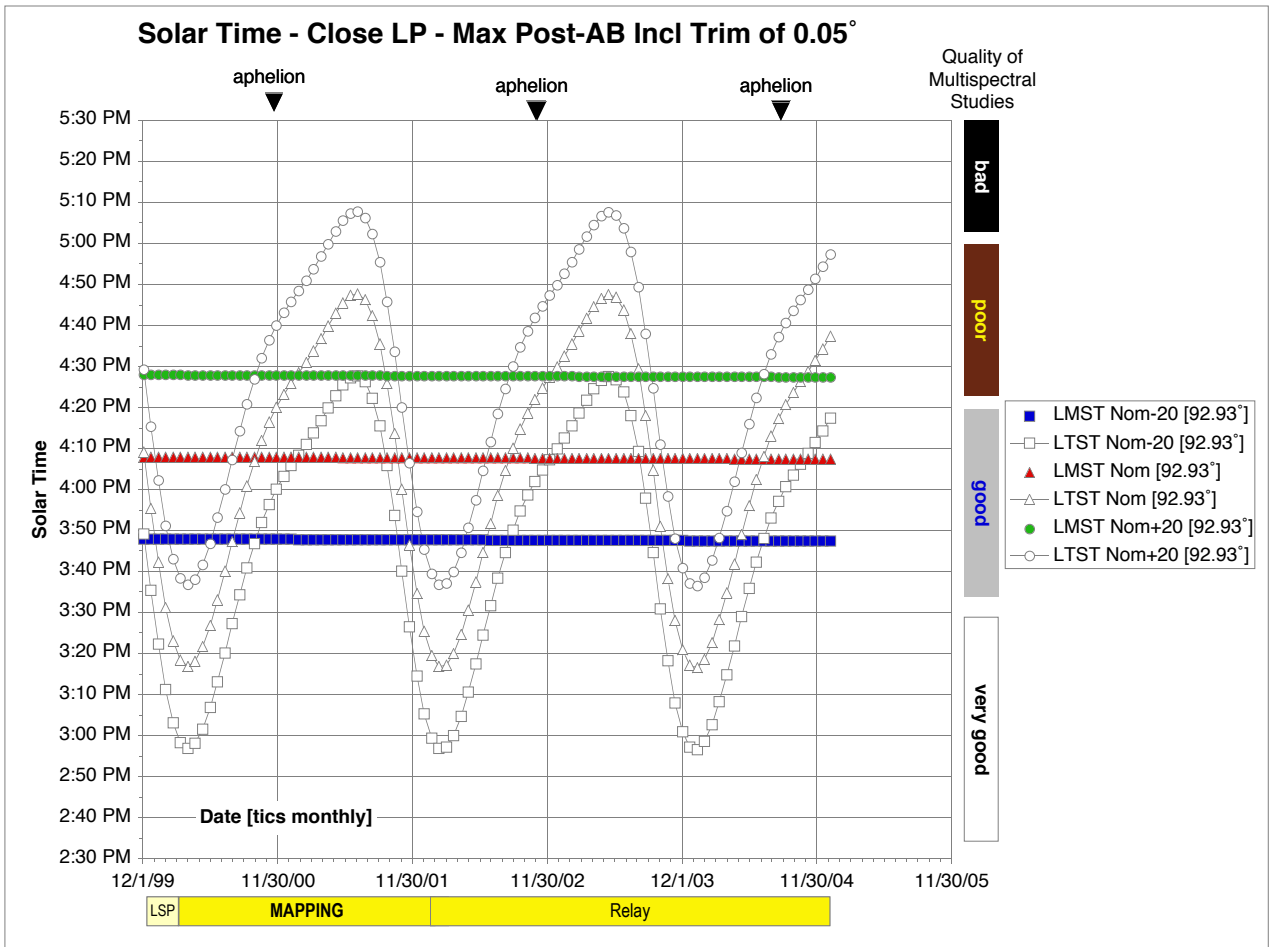
Solar Time - Open LP - Max Post-AB Incl Trim of 0.1°

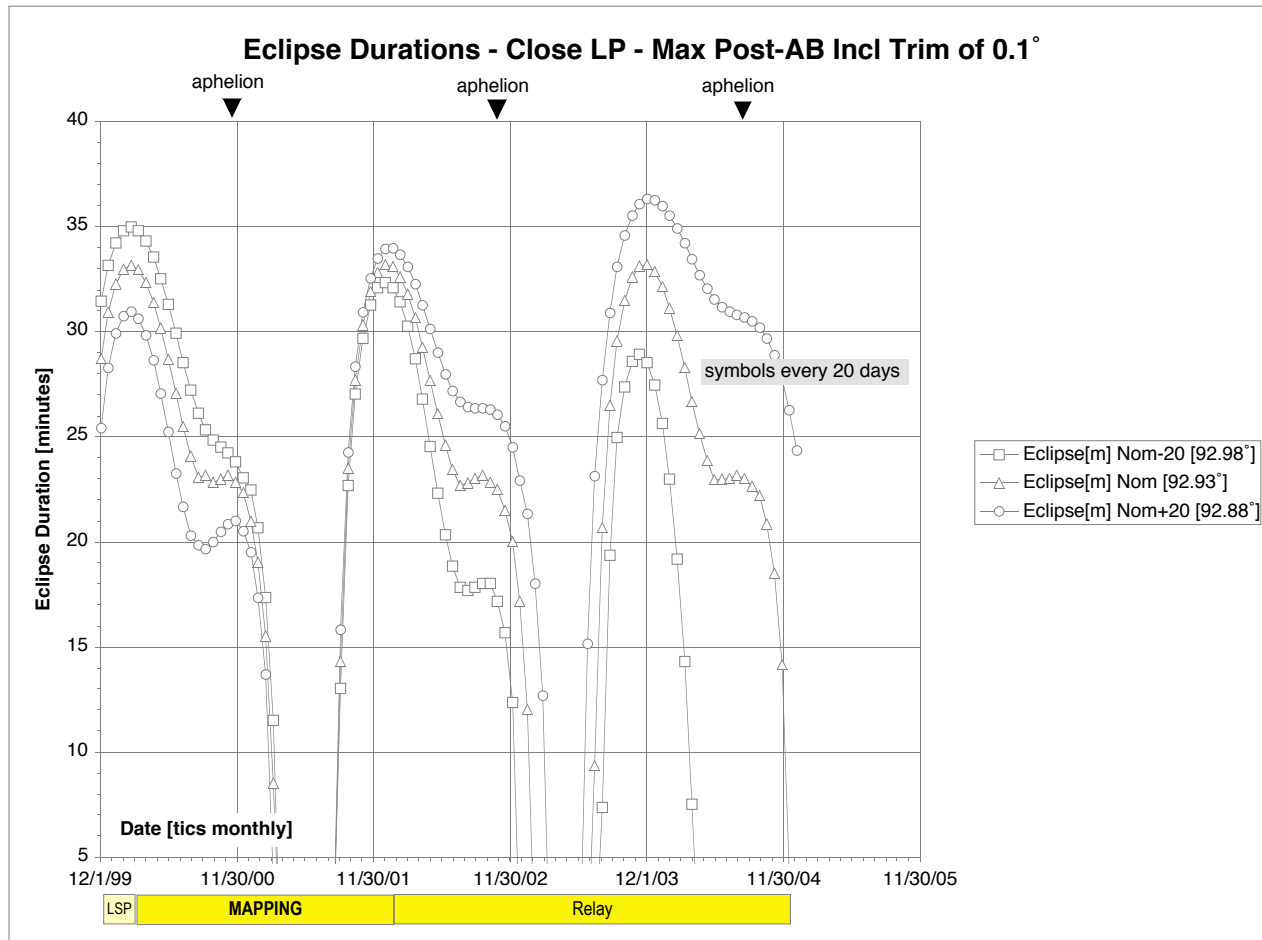
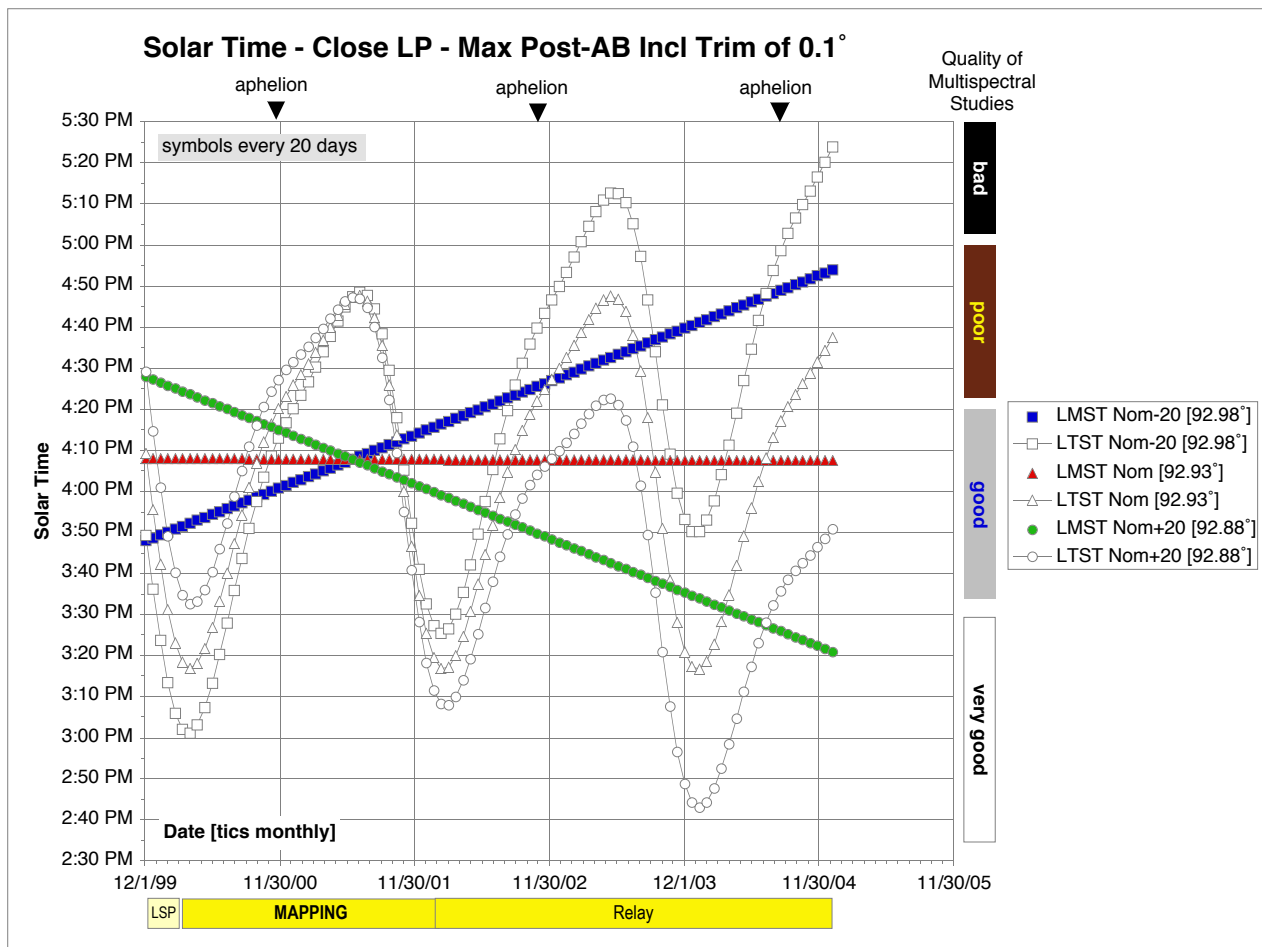


Eclipse Durations - Open LP - Max Post-AB Incl Trim of 0.1°

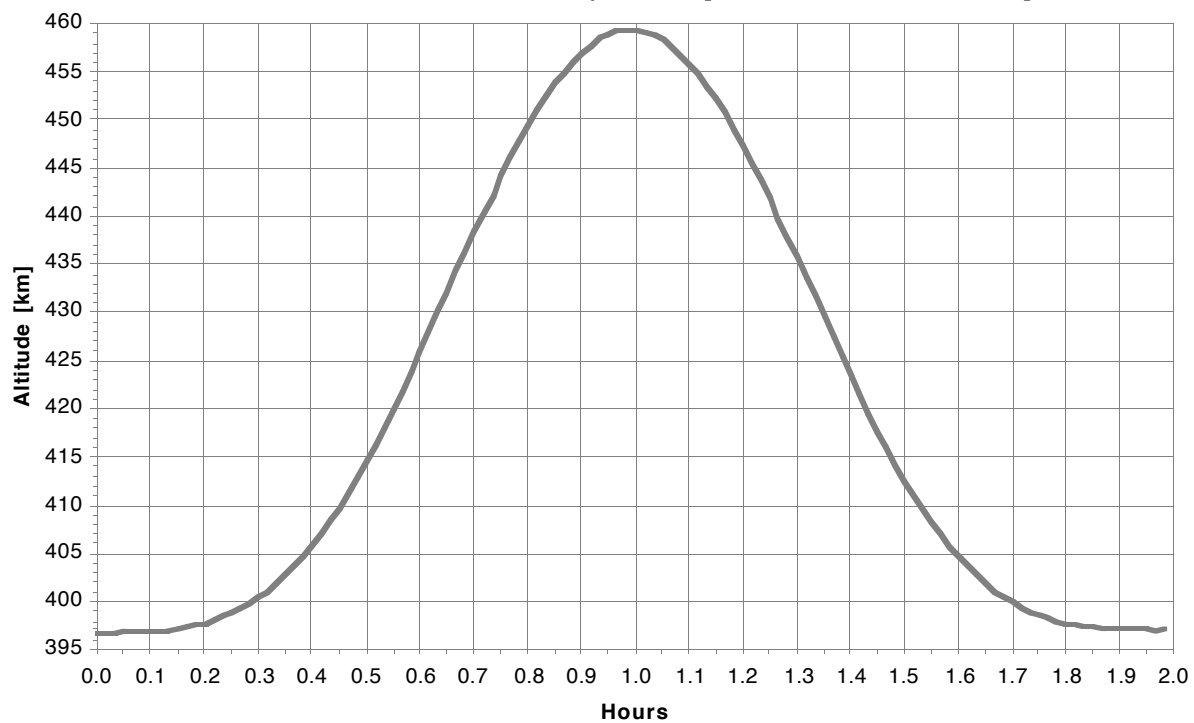








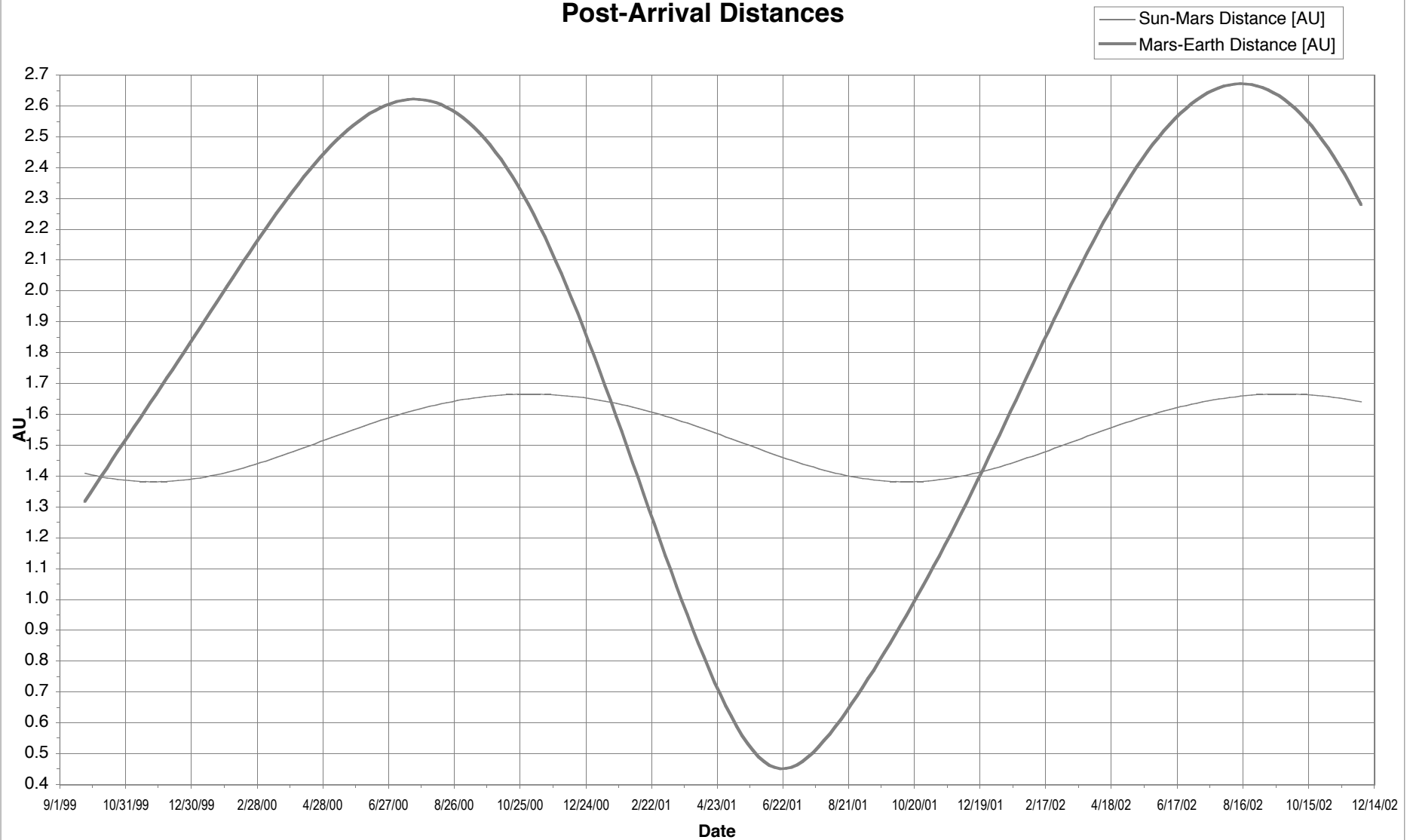
Planetodetic Altitude Variations over and Orbit wrt
MarsGRAM-based Oblate Spheroid [3393.94 x 3376.78 km]



Ranges		Δ from Mean	
Minimum Alt.	397	-24	km
Mean Alt.	421	0	km
Maximum Alt.	459	38	km

FROZEN ORBIT PLANETODETIC ALTITUDE VARIATIONS

Post-Arrival Distances



Date	Days from Earliest MOI	Days from Start of Mapping	Sun-Mars Distance [AU]	Mars-Earth Distance [AU]	ESM [deg.]	SEM [deg.]	SME [deg.]	Events
9/24/99	1		1.4085	1.3173	63.6326	73.3347	43.0327	Orbiter MOI
9/29/99	6		1.4045	1.3447	65.4709	71.8521	42.6770	
10/4/99	11		1.4008	1.3718	67.3062	70.4061	42.2877	
10/9/99	16		1.3974	1.3988	69.1398	68.9929	41.8673	
10/14/99	21		1.3943	1.4256	70.9729	67.6092	41.4179	
10/19/99	26		1.3915	1.4523	72.8070	66.2519	40.9411	
10/24/99	31		1.3891	1.4789	74.6431	64.9181	40.4389	
10/29/99	36		1.3869	1.5055	76.4825	63.6049	39.9126	
11/3/99	41		1.3852	1.5320	78.3264	62.3100	39.3636	
11/8/99	46		1.3837	1.5584	80.1758	61.0309	38.7933	
11/13/99	51		1.3826	1.5849	82.0318	59.7654	38.2027	Perihelion Lander Arrival
11/18/99	56		1.3819	1.6114	83.8954	58.5115	37.5930	
11/23/99	61		1.3815	1.6379	85.7674	57.2674	36.9652	
11/28/99	66		1.3815	1.6644	87.6486	56.0312	36.3202	
12/3/99	71		1.3819	1.6910	89.5398	54.8014	35.6588	
12/8/99	76		1.3826	1.7177	91.4416	53.5765	34.9819	
12/13/99	81		1.3837	1.7445	93.3545	52.3552	34.2903	
12/18/99	86		1.3851	1.7713	95.2790	51.1363	33.5847	
12/23/99	91		1.3869	1.7983	97.2155	49.9187	32.8658	
12/28/99	96		1.3890	1.8253	99.1642	48.7015	32.1343	
1/2/00	101		1.3915	1.8523	101.1254	47.4837	31.3909	
1/7/00	106		1.3942	1.8794	103.0992	46.2647	30.6361	
1/12/00	111		1.3973	1.9066	105.0855	45.0438	29.8707	
1/17/00	116		1.4008	1.9338	107.0845	43.8204	29.0951	
1/22/00	121		1.4045	1.9609	109.0960	42.5941	28.3099	
1/27/00	126		1.4084	1.9881	111.1198	41.3644	27.5157	
2/1/00	131		1.4127	2.0152	113.1559	40.1311	26.7130	
2/6/00	136		1.4172	2.0422	115.2039	38.8938	25.9023	
2/11/00	141		1.4220	2.0692	117.2637	37.6524	25.0840	
2/16/00	146		1.4269	2.0959	119.3349	36.4066	24.2585	
2/21/00	151		1.4321	2.1225	121.4174	35.1562	23.4264	End Lander Mission; Start Mapping
2/26/00	156		1.4375	2.1489	123.5107	33.9013	22.5880	
3/2/00	161	1	1.4431	2.1750	125.6148	32.6415	21.7437	
3/7/00	166	6	1.4488	2.2008	127.7293	31.3770	20.8938	
3/12/00	171	11	1.4547	2.2263	129.8539	30.1074	20.0387	
3/17/00	176	16	1.4607	2.2514	131.9885	28.8328	19.1787	
3/22/00	181	21	1.4669	2.2760	134.1328	27.5531	18.3141	
3/27/00	186	26	1.4731	2.3002	136.2868	26.2680	17.4451	
4/1/00	191	31	1.4795	2.3239	138.4503	24.9776	16.5721	
4/6/00	196	36	1.4859	2.3469	140.6233	23.6816	15.6951	
4/11/00	201	41	1.4923	2.3694	142.8056	22.3798	14.8145	
4/16/00	206	46	1.4988	2.3912	144.9974	21.0721	13.9305	
4/21/00	211	51	1.5054	2.4123	147.1986	19.7583	13.0431	
4/26/00	216	56	1.5119	2.4327	149.4093	18.4381	12.1526	
5/1/00	221	61	1.5184	2.4522	151.6296	17.1112	11.2592	
5/6/00	226	66	1.5249	2.4709	153.8596	15.7775	10.3629	
5/11/00	231	71	1.5314	2.4887	156.0994	14.4366	9.4640	
5/16/00	236	76	1.5379	2.5056	158.3493	13.0882	8.5625	
5/21/00	241	81	1.5443	2.5215	160.6091	11.7322	7.6587	
5/26/00	246	86	1.5506	2.5364	162.8788	10.3683	6.7529	
5/31/00	251	91	1.5568	2.5502	165.1582	8.9965	5.8453	Max Earth Dist
6/5/00	256	96	1.5630	2.5629	167.4464	7.6172	4.9365	
6/10/00	261	101	1.5690	2.5744	169.7415	6.2311	4.0274	
6/15/00	266	106	1.5750	2.5848	172.0389	4.8410	3.1201	
6/20/00	271	111	1.5808	2.5939	174.3257	3.4544	2.2199	
6/25/00	276	116	1.5864	2.6018	176.5531	2.1010	1.3460	
6/30/00	281	121	1.5920	2.6084	178.3783	0.9897	0.6320	
7/5/00	286	126	1.5974	2.6137	177.8429	1.3181	0.8389	
7/10/00	291	131	1.6026	2.6175	175.7372	2.6084	1.6544	
7/15/00	296	136	1.6077	2.6200	173.4108	4.0377	2.5516	
7/20/00	301	141	1.6126	2.6211	171.0203	5.5105	3.4692	Max Earth Dist
7/25/00	306	146	1.6173	2.6207	168.5950	7.0094	4.3956	
7/30/00	311	151	1.6218	2.6188	166.1434	8.5294	5.3271	

Date	Days from Earliest MOI	Days from Start of Mapping	Sun-Mars Distance [AU]	Mars-Earth Distance [AU]	ESM [deg.]	SEM [deg.]	SME [deg.]	Events
8/4/00	316	156	1.6261	2.6154	163.6692	10.0687	6.2621	
8/9/00	321	161	1.6303	2.6104	161.1737	11.6267	7.1996	
8/14/00	326	166	1.6342	2.6039	158.6576	13.2033	8.1392	
8/19/00	331	171	1.6379	2.5959	156.1211	14.7986	9.0803	
8/24/00	336	176	1.6414	2.5862	153.5645	16.4130	10.0225	
8/29/00	341	181	1.6447	2.5749	150.9877	18.0468	10.9655	
9/3/00	346	186	1.6478	2.5620	148.3908	19.7002	11.9090	
9/8/00	351	191	1.6506	2.5474	145.7738	21.3737	12.8525	
9/13/00	356	196	1.6532	2.5312	143.1369	23.0675	13.7956	
9/18/00	361	201	1.6556	2.5134	140.4802	24.7819	14.7379	
9/23/00	366	206	1.6577	2.4939	137.8040	26.5172	15.6788	
9/28/00	371	211	1.6596	2.4727	135.1085	28.2736	16.6179	
10/3/00	376	216	1.6613	2.4499	132.3942	30.0513	17.5545	
10/8/00	381	221	1.6627	2.4255	129.6616	31.8505	18.4880	
10/13/00	386	226	1.6638	2.3995	126.9112	33.6711	19.4177	
10/18/00	391	231	1.6647	2.3718	124.1437	35.5134	20.3429	
10/23/00	396	236	1.6654	2.3426	121.3600	37.3773	21.2627	
10/28/00	401	241	1.6658	2.3118	118.5610	39.2628	22.1762	
11/2/00	406	246	1.6660	2.2795	115.7476	41.1699	23.0826	Aphelion
11/7/00	411	251	1.6659	2.2457	112.9210	43.0984	23.9806	
11/12/00	416	256	1.6656	2.2104	110.0824	45.0483	24.8693	
11/17/00	421	261	1.6650	2.1737	107.2331	47.0194	25.7475	
11/22/00	426	266	1.6642	2.1356	104.3747	49.0116	26.6137	
11/27/00	431	271	1.6631	2.0963	101.5086	51.0247	27.4667	
12/2/00	436	276	1.6618	2.0556	98.6364	53.0587	28.3049	
12/7/00	441	281	1.6602	2.0137	95.7598	55.1135	29.1268	
12/12/00	446	286	1.6584	1.9707	92.8806	57.1889	29.9305	
12/17/00	451	291	1.6564	1.9266	90.0006	59.2852	30.7142	
12/22/00	456	296	1.6541	1.8815	87.1218	61.4023	31.4759	
12/27/00	461	301	1.6516	1.8355	84.2460	63.5405	32.2135	
1/1/01	466	306	1.6488	1.7886	81.3751	65.7003	32.9246	
1/6/01	471	311	1.6458	1.7410	78.5113	67.8820	33.6067	
1/11/01	476	316	1.6426	1.6926	75.6565	70.0866	34.2570	
1/16/01	481	321	1.6392	1.6437	72.8125	72.3149	34.8726	
1/21/01	486	326	1.6356	1.5942	69.9815	74.5683	35.4502	
1/26/01	491	331	1.6317	1.5443	67.1653	76.8484	35.9863	
1/31/01	496	336	1.6277	1.4941	64.3658	79.1571	36.4771	
2/5/01	501	341	1.6234	1.4437	61.5849	81.4969	36.9182	
2/10/01	506	346	1.6189	1.3931	58.8242	83.8707	37.3051	
2/15/01	511	351	1.6143	1.3425	56.0855	86.2820	37.6324	
2/20/01	516	356	1.6095	1.2919	53.3705	88.7350	37.8945	
2/25/01	521	361	1.6045	1.2415	50.6805	91.2346	38.0849	
3/2/01	526	366	1.5993	1.1914	48.0171	93.7865	38.1964	
3/7/01	531	371	1.5940	1.1417	45.3816	96.3974	38.2211	
3/12/01	536	376	1.5885	1.0924	42.7751	99.0751	38.1498	
3/17/01	541	381	1.5828	1.0438	40.1987	101.8287	37.9726	
3/22/01	546	386	1.5771	0.9959	37.6535	104.6687	37.6778	
3/27/01	551	391	1.5712	0.9488	35.1403	107.6069	37.2529	
4/1/01	556	396	1.5652	0.9027	32.6598	110.6570	36.6832	
4/6/01	561	401	1.5591	0.8577	30.2126	113.8346	35.9528	
4/11/01	566	406	1.5529	0.8140	27.7994	117.1570	35.0436	
4/16/01	571	411	1.5466	0.7716	25.4205	120.6437	33.9358	
4/21/01	576	416	1.5402	0.7309	23.0761	124.3157	32.6081	
4/26/01	581	421	1.5338	0.6920	20.7666	128.1958	31.0376	
5/1/01	586	426	1.5273	0.6550	18.4921	132.3072	29.2008	
5/6/01	591	431	1.5208	0.6203	16.2526	136.6728	27.0746	
5/11/01	596	436	1.5143	0.5881	14.0484	141.3130	24.6386	
5/16/01	601	441	1.5077	0.5586	11.8796	146.2428	21.8775	
5/21/01	606	446	1.5012	0.5321	9.7470	151.4678	18.7852	
5/26/01	611	451	1.4947	0.5089	7.6521	156.9777	15.3702	
5/31/01	616	456	1.4882	0.4893	5.5998	162.7358	11.6644	
6/5/01	621	461	1.4818	0.4736	3.6065	168.6480	7.7455	
6/10/01	626	466	1.4754	0.4618	1.7651	174.3519	3.8830	

Date	Days from Earliest MOI	Days from Start of Mapping	Sun-Mars Distance [AU]	Mars-Earth Distance [AU]	ESM [deg.]	SEM [deg.]	SME [deg.]	Events
6/15/01	631	471	1.4692	0.4541	1.1472	176.2861	2.5667	Min Earth Dist
6/20/01	636	476	1.4630	0.4505	2.6948	171.2176	6.0876	
6/25/01	641	481	1.4569	0.4509	4.5420	165.1750	10.2830	
6/30/01	646	486	1.4510	0.4551	6.4124	159.1408	14.4468	
7/5/01	651	491	1.4452	0.4628	8.2737	153.2982	18.4281	
7/10/01	656	496	1.4395	0.4737	10.1186	147.7305	22.1508	
7/15/01	661	501	1.4341	0.4874	11.9454	142.4828	25.5719	
7/20/01	666	506	1.4288	0.5035	13.7541	137.5749	28.6711	
7/25/01	671	511	1.4237	0.5218	15.5457	133.0090	31.4454	
7/30/01	676	516	1.4189	0.5419	17.3215	128.7747	33.9038	
8/4/01	681	521	1.4143	0.5635	19.0830	124.8539	36.0631	
8/9/01	686	526	1.4099	0.5863	20.8319	121.2235	37.9446	
8/14/01	691	531	1.4058	0.6103	22.5702	117.8586	39.5712	
8/19/01	696	536	1.4020	0.6352	24.2995	114.7341	40.9663	
8/24/01	701	541	1.3985	0.6609	26.0221	111.8257	42.1522	
8/29/01	706	546	1.3953	0.6873	27.7397	109.1104	43.1499	Perihelion
9/3/01	711	551	1.3924	0.7143	29.4545	106.5671	43.9784	
9/8/01	716	556	1.3898	0.7419	31.1686	104.1763	44.6551	
9/13/01	721	561	1.3876	0.7700	32.8839	101.9207	45.1953	
9/18/01	726	566	1.3857	0.7985	34.6026	99.7845	45.6129	
9/23/01	731	571	1.3841	0.8275	36.3266	97.7533	45.9200	
9/28/01	736	576	1.3829	0.8569	38.0580	95.8146	46.1274	
10/3/01	741	581	1.3820	0.8867	39.7986	93.9568	46.2446	
10/8/01	746	586	1.3815	0.9170	41.5502	92.1698	46.2800	
10/13/01	751	591	1.3814	0.9477	43.3148	90.4442	46.2410	
10/18/01	756	596	1.3816	0.9788	45.0939	88.7719	46.1343	
10/23/01	761	601	1.3822	1.0103	46.8890	87.1454	45.9656	
10/28/01	766	606	1.3832	1.0423	48.7017	85.5580	45.7403	Orbiter end of Mapping
11/2/01	771	611	1.3845	1.0747	50.5332	84.0039	45.4629	
11/7/01	776	616	1.3862	1.1075	52.3847	82.4776	45.1376	
11/12/01	781	621	1.3882	1.1408	54.2572	80.9745	44.7682	
11/17/01	786	626	1.3905	1.1745	56.1516	79.4903	44.3581	
11/22/01	791	631	1.3932	1.2087	58.0685	78.0212	43.9103	
11/27/01	796	636	1.3962	1.2432	60.0085	76.5640	43.4275	
12/2/01	801	641	1.3995	1.2782	61.9720	75.1158	42.9122	
12/7/01	806	646	1.4031	1.3136	63.9591	73.6741	42.3668	
12/12/01	811	651	1.4069	1.3493	65.9699	72.2368	41.7933	
12/17/01	816	656	1.4111	1.3854	68.0043	70.8020	41.1937	
12/22/01	821	661	1.4155	1.4219	70.0621	69.3682	40.5697	
12/27/01	826	666	1.4202	1.4586	72.1429	67.9342	39.9230	
1/1/02	831	671	1.4251	1.4956	74.2461	66.4989	39.2550	
1/6/02	836	676	1.4302	1.5329	76.3712	65.0616	38.5672	
1/11/02	841	681	1.4355	1.5703	78.5175	63.6216	37.8608	
1/16/02	846	686	1.4410	1.6079	80.6842	62.1786	37.1371	
1/21/02	851	691	1.4467	1.6456	82.8704	60.7323	36.3973	
1/26/02	856	696	1.4526	1.6834	85.0752	59.2825	35.6423	
1/31/02	861	701	1.4585	1.7212	87.2977	57.8292	34.8732	
2/5/02	866	706	1.4646	1.7589	89.5368	56.3724	34.0908	
2/10/02	871	711	1.4709	1.7966	91.7916	54.9123	33.2961	
2/15/02	876	716	1.4771	1.8342	94.0611	53.4491	32.4898	
2/20/02	881	721	1.4835	1.8715	96.3443	51.9830	31.6727	
2/25/02	886	726	1.4900	1.9086	98.6403	50.5141	30.8456	
3/2/02	891	731	1.4964	1.9455	100.9482	49.0428	30.0090	
3/7/02	896	736	1.5030	1.9819	103.2670	47.5694	29.1636	
3/12/02	901	741	1.5095	2.0180	105.5960	46.0940	28.3100	
3/17/02	906	746	1.5160	2.0536	107.9345	44.6169	27.4486	
3/22/02	911	751	1.5225	2.0887	110.2817	43.1382	26.5801	
3/27/02	916	756	1.5290	2.1232	112.6370	41.6582	25.7047	
4/1/02	921	761	1.5355	2.1571	114.9999	40.1770	24.8230	
4/6/02	926	766	1.5419	2.1903	117.3700	38.6947	23.9354	
4/11/02	931	771	1.5482	2.2228	119.7467	37.2112	23.0421	
4/16/02	936	776	1.5545	2.2545	122.1298	35.7266	22.1436	
4/21/02	941	781	1.5607	2.2853	124.5190	34.2410	21.2400	

Date	Days from Earliest MOI	Days from Start of Mapping	Sun-Mars Distance [AU]	Mars-Earth Distance [AU]	ESM [deg.]	SEM [deg.]	SME [deg.]	Events
4/26/02	946	786	1.5668	2.3154	126.9143	32.7541	20.3317	
5/1/02	951	791	1.5727	2.3444	129.3153	31.2658	19.4189	
5/6/02	956	796	1.5786	2.3726	131.7222	29.7760	18.5018	
5/11/02	961	801	1.5843	2.3997	134.1350	28.2844	17.5806	
5/16/02	966	806	1.5899	2.4257	136.5536	26.7909	16.6555	
5/21/02	971	811	1.5954	2.4506	138.9783	25.2950	15.7266	
5/26/02	976	816	1.6007	2.4744	141.4093	23.7966	14.7941	
5/31/02	981	821	1.6058	2.4971	143.8466	22.2952	13.8582	
6/5/02	986	826	1.6107	2.5185	146.2906	20.7905	12.9189	
6/10/02	991	831	1.6155	2.5386	148.7416	19.2821	11.9763	
6/15/02	996	836	1.6201	2.5574	151.1997	17.7696	11.0307	
6/20/02	1001	841	1.6245	2.5750	153.6651	16.2528	10.0821	
6/25/02	1006	846	1.6287	2.5911	156.1381	14.7312	9.1307	
6/30/02	1011	851	1.6328	2.6059	158.6187	13.2046	8.1768	
7/5/02	1016	856	1.6366	2.6192	161.1066	11.6729	7.2205	
7/10/02	1021	861	1.6401	2.6311	163.6013	10.1362	6.2625	
7/15/02	1026	866	1.6435	2.6415	166.1015	8.5951	5.3033	
7/20/02	1031	871	1.6467	2.6504	168.6043	7.0512	4.3445	
7/25/02	1036	876	1.6496	2.6578	171.1028	5.5086	3.3887	
7/30/02	1041	881	1.6523	2.6636	173.5787	3.9782	2.4431	
8/4/02	1046	886	1.6548	2.6678	175.9677	2.4998	1.5324	
8/9/02	1051	891	1.6570	2.6704	177.8957	1.3055	0.7988	
8/14/02	1056	896	1.6590	2.6714	177.5634	1.5129	0.9237	Max Earth Distance
8/19/02	1061	901	1.6607	2.6708	175.4183	2.8471	1.7346	
8/24/02	1066	906	1.6622	2.6685	172.9427	4.3892	2.6681	
8/29/02	1071	911	1.6635	2.6646	170.3774	5.9900	3.6326	
9/3/02	1076	916	1.6645	2.6590	167.7698	7.6204	4.6098	
9/8/02	1081	921	1.6653	2.6518	165.1345	9.2715	5.5940	
9/13/02	1086	926	1.6658	2.6428	162.4778	10.9396	6.5826	
9/18/02	1091	931	1.6661	2.6322	159.8026	12.6231	7.5744	
9/23/02	1096	936	1.6661	2.6199	157.1106	14.3211	8.5683	Aphelion
9/28/02	1101	941	1.6659	2.6059	154.4032	16.0330	9.5638	
10/3/02	1106	946	1.6654	2.5902	151.6811	17.7585	10.5603	
10/8/02	1111	951	1.6647	2.5729	148.9454	19.4973	11.5574	
10/13/02	1116	956	1.6637	2.5540	146.1967	21.2489	12.5544	
10/18/02	1121	961	1.6625	2.5334	143.4360	23.0130	13.5510	
10/23/02	1126	966	1.6611	2.5112	140.6641	24.7893	14.5465	
10/28/02	1131	971	1.6594	2.4874	137.8821	26.5773	15.5406	
11/2/02	1136	976	1.6574	2.4620	135.0910	28.3764	16.5326	
11/7/02	1141	981	1.6552	2.4351	132.2920	30.1861	17.5219	
11/12/02	1146	986	1.6528	2.4068	129.4863	32.0058	18.5079	
11/17/02	1151	991	1.6502	2.3770	126.6752	33.8348	19.4900	
11/22/02	1156	996	1.6473	2.3457	123.8603	35.6722	20.4674	
11/27/02	1161	1001	1.6442	2.3131	121.0431	37.5174	21.4395	
12/2/02	1166	1006	1.6408	2.2792	118.2251	39.3694	22.4055	

A.7 Orbiter Configuration Drawings

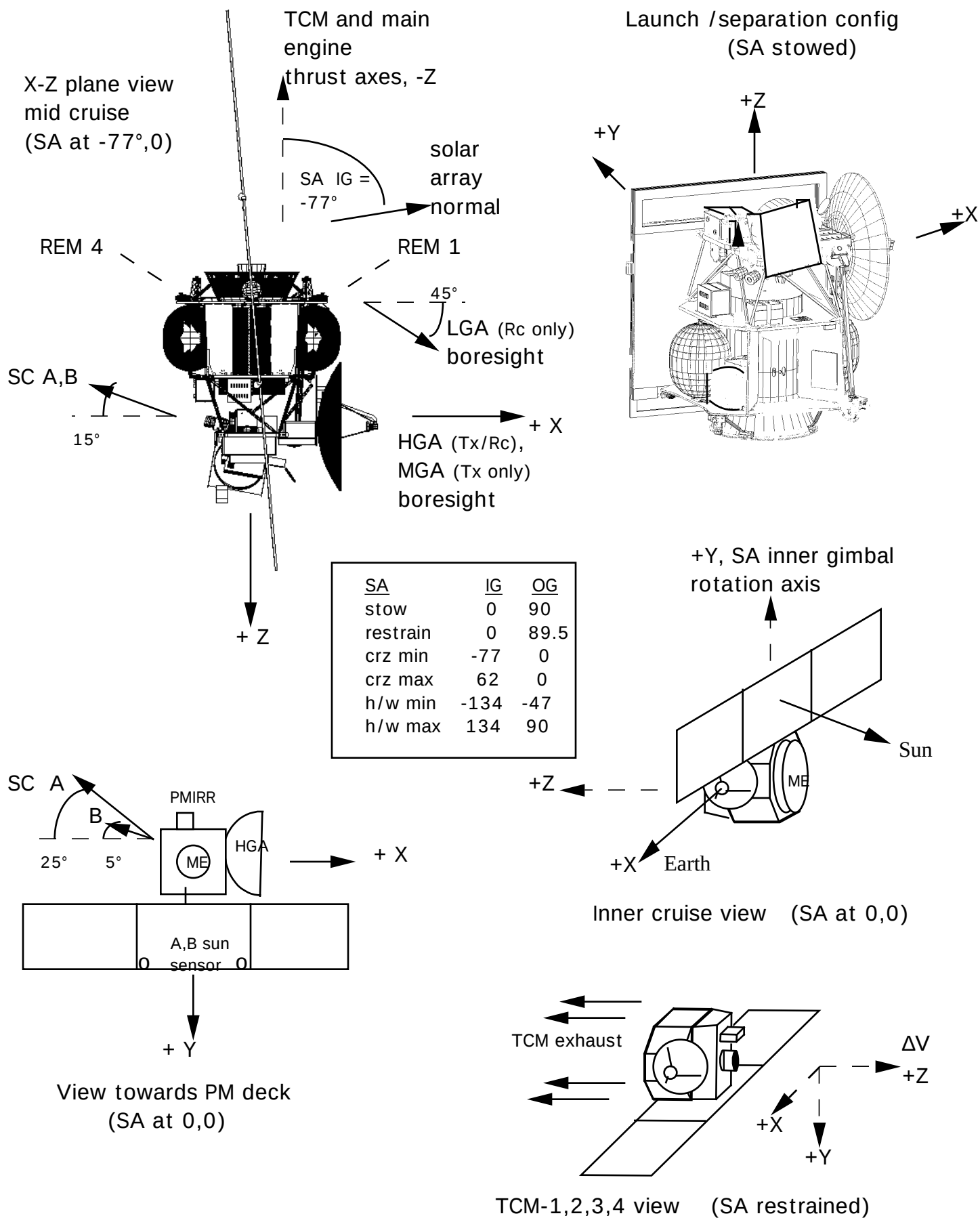


Figure 1.3.6.14.1-1 Orbiter Cruise Configurations

- HGA/MGA (+X) point to Earth (offset in early cruise)
- SA normal point to sun* using inner gimbal
- S-P-E plane same as X-Z plane
- Safe mode same as normal mode (no sun offset)

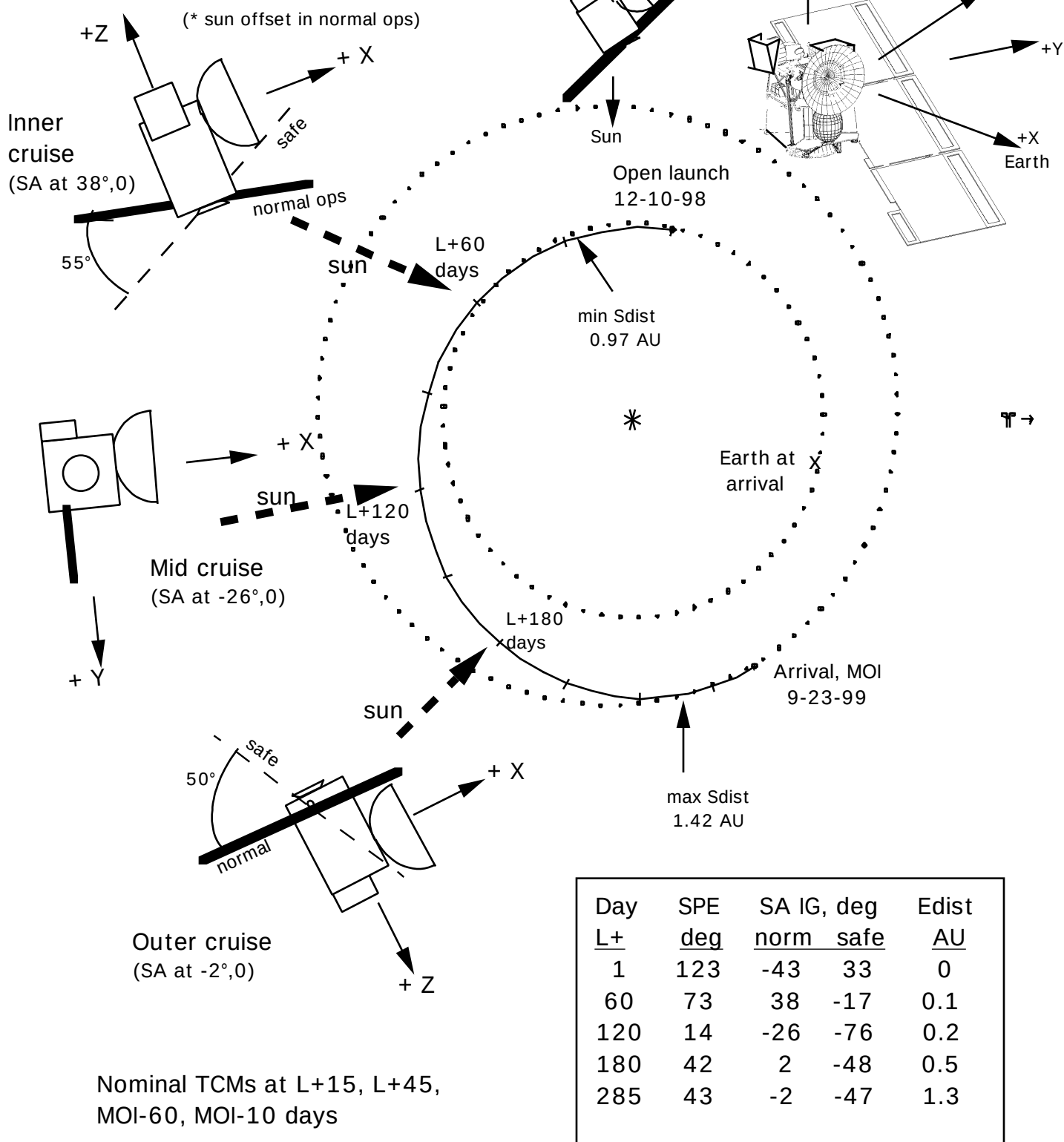


Figure 1.3.6.14.1-2 Orbiter Cruise Geometry

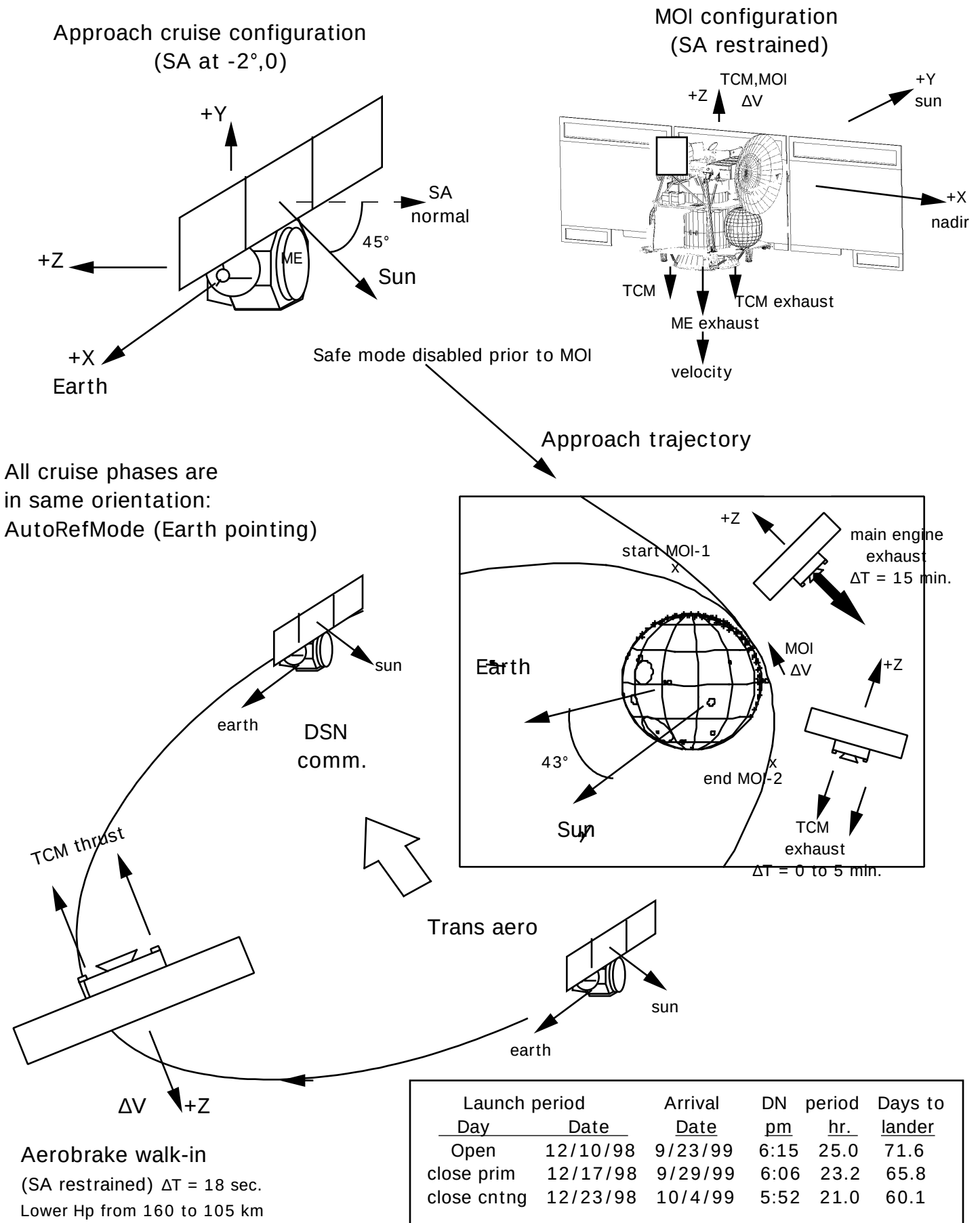
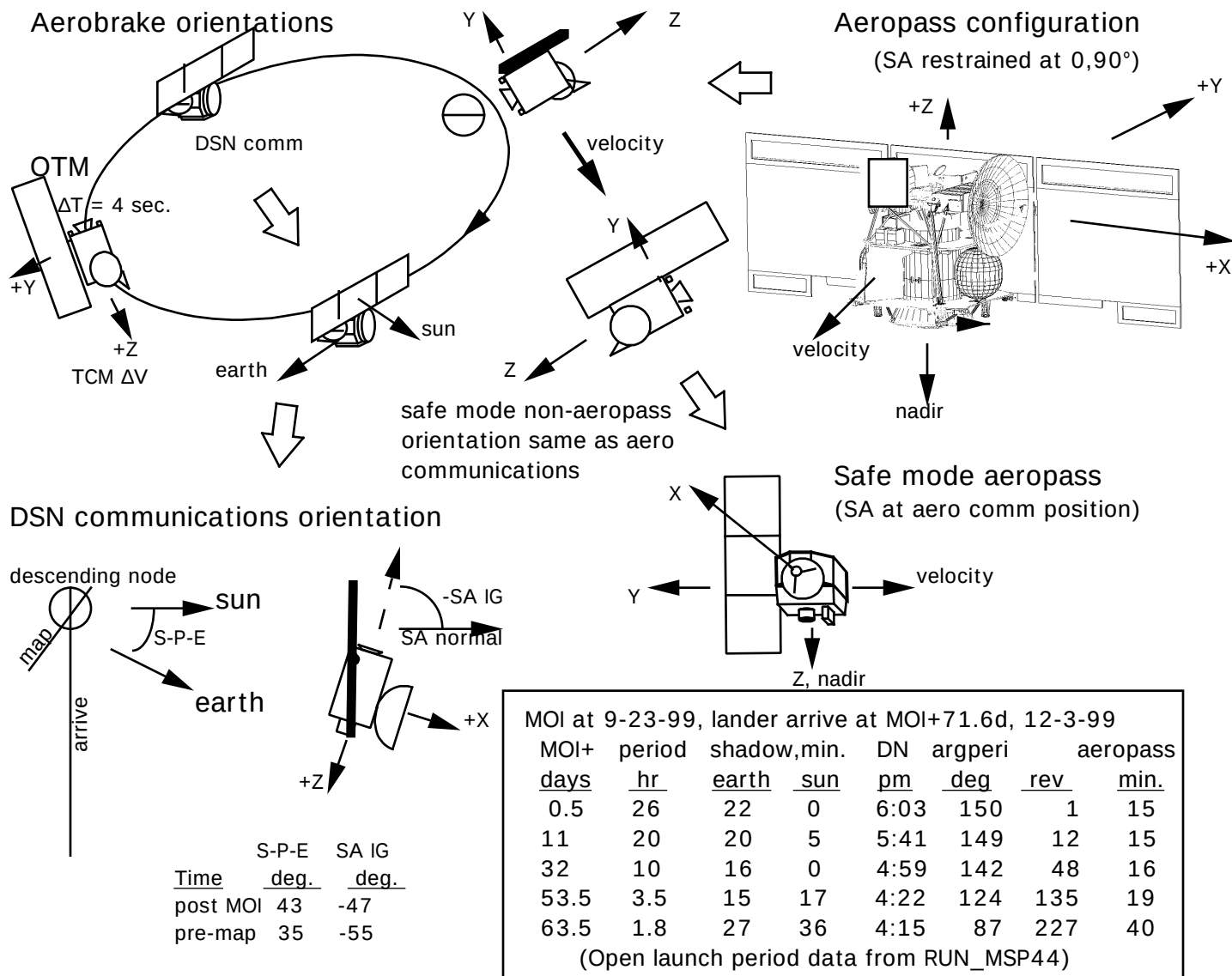


Figure 1.3.6.14.1-3 Mars Orbit Insertion Orientation



A/B termination (SA restrained) $\Delta T = 6$ min

Safe mode: Grnd cmd pop-up $\Delta T = 40$ s,
or Auto OTM $\Delta T = 7$ s

Map orbit transfer

(SA restrained) $\Delta T = 5$ to 40 sec

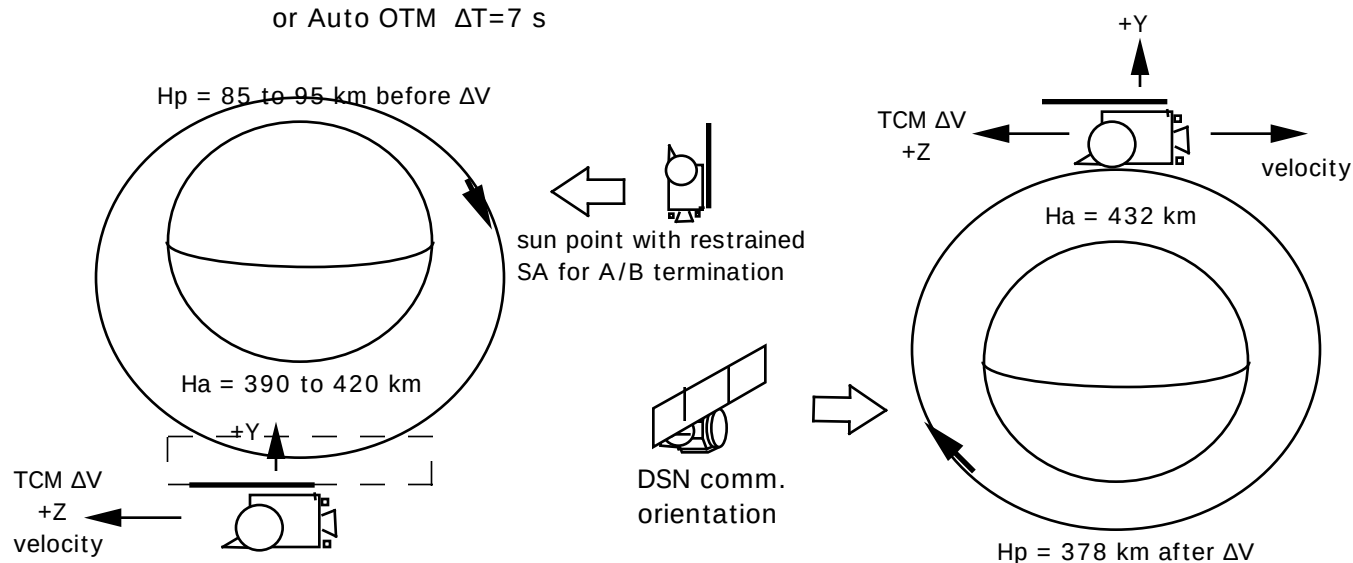


Figure 1.3.6.14.1-4 Aerobraking Configurations and Orientations

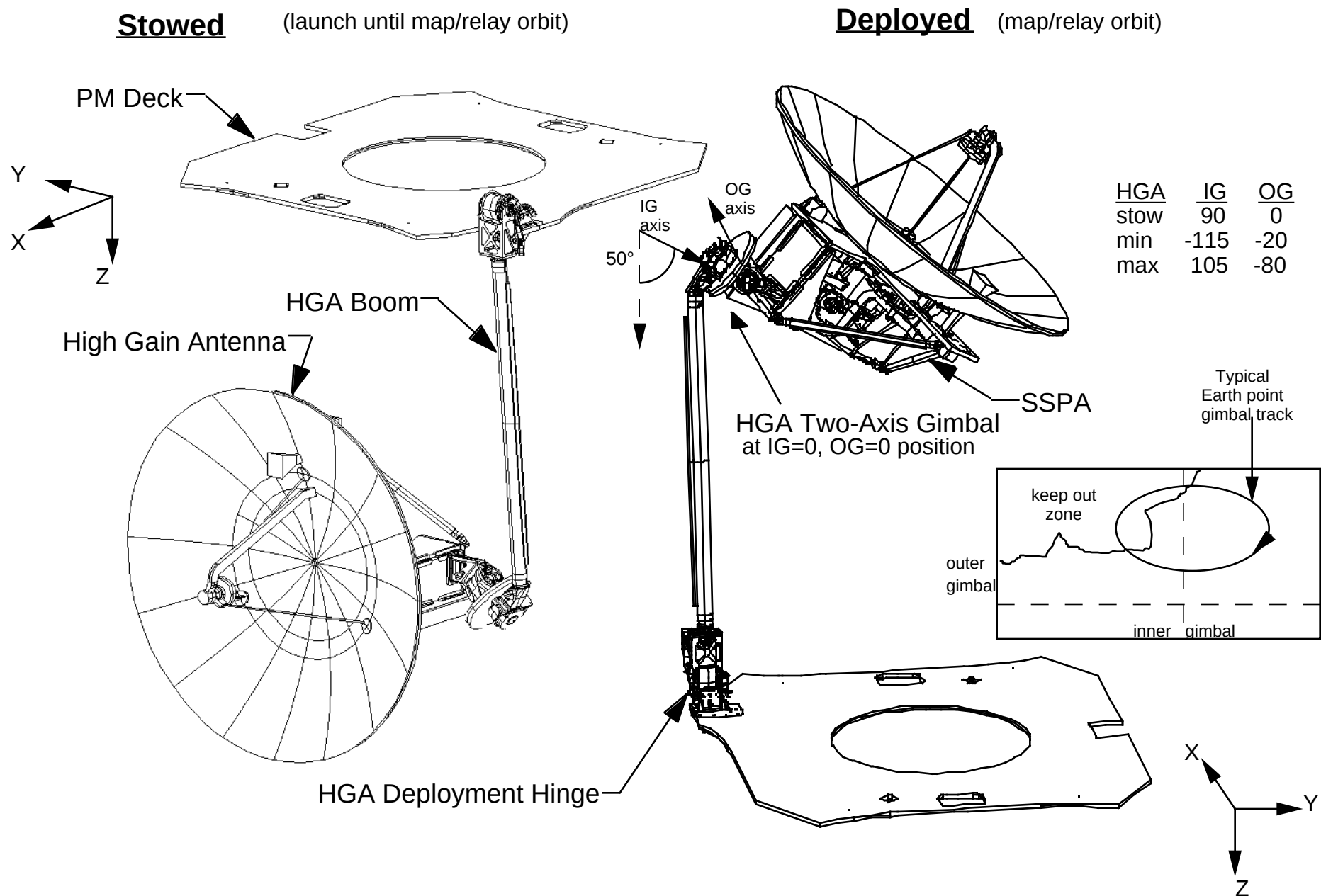


Figure 1.3.6.14.1-5 High Gain Antenna Orientation

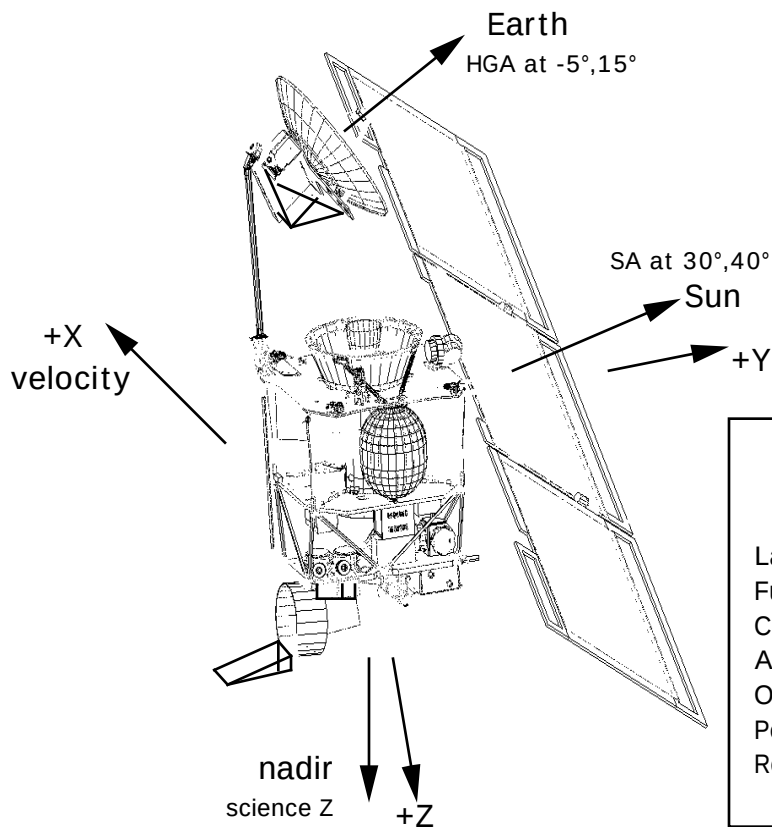
Mapping/relay configuration (at ~day 60, ~over south pole)

HGA constraints

- Gimbal travel & rate
- Earth occultation
- Avoid SA during Tx/Rc
- Mechanical keep out zone

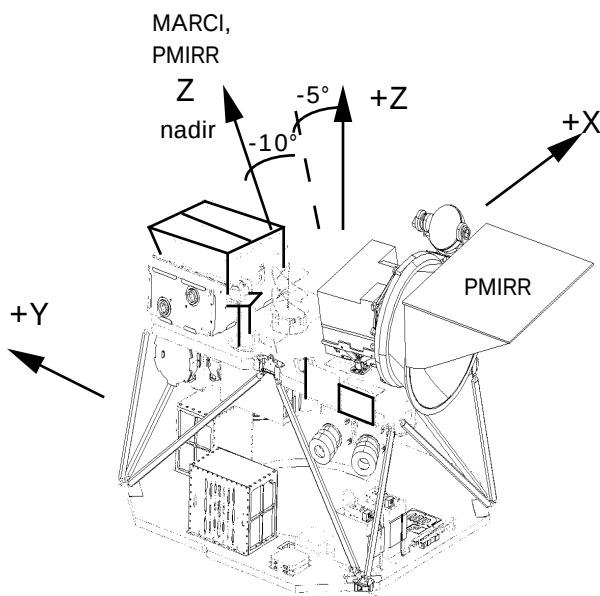
SA constraints

- Gimbal travel & rate
- Sun eclipse
- Avoid HGA beam during Tx/Rc
- Off-sun power
- Rewind
- Minimize MARCI intrusion



Event	Day	at sun side (PM) equator crossing		HGA gimbals		SA gimbals	
		inner	outer	inner	outer	inner	outer
Lander arrival	0	-35	52	-50	48		
Full science	71	-43	36	-49	42		
Conjunction	212	-7	8	-7	48		
Aphelion	336	5	-9	20	53		
Opposition	549	-7	29	-20	65		
Perihelion	680	-22	58	-55	50		
Relay begin	758	-44	50	-50	43		

Science deck



Mapping safe mode

(HGA at -90°, -20° and SA at -110° to -65°, 0°)

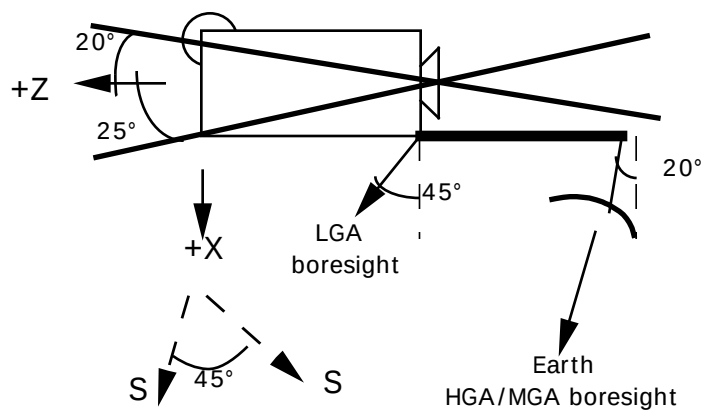
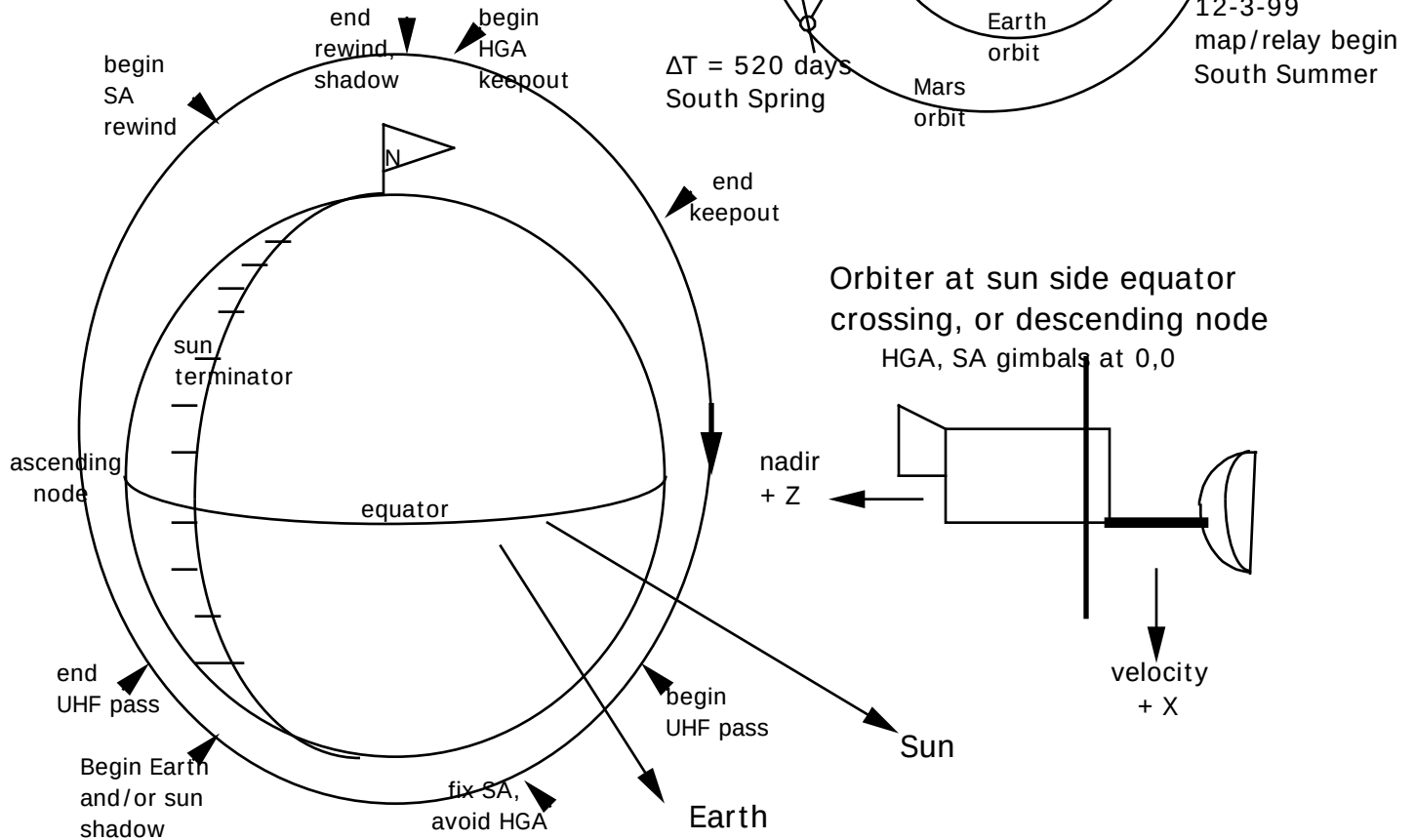


Figure 1.3.6.14.1-6 Mapping/Relay Configurations

Mapping/Relay Orbit

Sun synchronous
4:10 pm LMST descending node
inc = 93.9°
Frozen orbit
Hp = 378 km
Ha = 432 km
Periapsis over south pole



Date	Event	Day	shadow,min.		distance,AU		SPE deg.	DN pm	max Mb/day
			Earth	Sun	Earth	Sun			
12-3-99	Lander arrival	0	0	29	1.7	1.4	35	4:10	220
2-12-99	Full science	71	18	33	2.1	1.4	25	3:30	180
7-2-00	Conjunction	212	27	27	2.6	1.6	0	3:40	120
11-3-00	Aphelion	336	38	22	2.3	1.7	-23	4:20	100
6-11-01	Opposition	549	0	0	0.5	1.5	0	4:50	2300
10-13-01	Perihelion	680	0	27	0.9	1.4	46	4:10	500
12-30-01	Relay begin	758	9	33	1.5	1.4	40	3:30	230

Figure 1.3.6.14.1-7 Mapping / Relay Geometry

A.8 Orbiter Navigation Memo

This memo was last updated September 18, 1996, and should be used only as a general discussion of the navigation approach, and assumptions used in the navigation analysis. Since that time, the effects of 95% PCS have been added, and additional navigation analyses have been done for cruise, aerobraking, and mapping. Updated results [e.g. TCM ΔV estimates and tracking schedules] are indicated in the Mission Plan, and in the Databook Appendix A.11 [Orbiter Mapping Navigation].



Jet Propulsion Laboratory

INTEROFFICE MEMORANDUM

IOM 312.3-96-016, Rev. A

September 18, 1996

To: Distribution
From: Pieter Kallemeyn
Subject: Navigation analysis report for the Mars Surveyor '98 Orbiter

SUMMARY

This memo details the work to date in characterizing the navigation capability for the Mars Surveyor '98 Orbiter mission. This report supersedes those results that were first presented in Reference [1]. The interplanetary cruise phase is emphasized in this study. A preliminary orbit determination analysis of the aerobraking phase was performed and is summarized in this report.

Statistical information on the required ΔV for interplanetary TCM usage was calculated using the resulting OD error covariances, execution errors for the TCMs and an injection error covariance from McDonnell Douglas (received Sept. 5, 1996). The total interplanetary ΔV required for 95% confidence is 62 m/sec. The 1σ B-plane guidance error ellipse for the last midcourse maneuver is 12.8 km by 6.9 km with an uncertainty in the linearized time of flight of 1.84 seconds.

INTERPLANETARY PHASE NAVIGATION ANALYSIS

Reference Trajectory

The reference trajectory used for this orbit determination and guidance analysis is a Type 2 Earth-Mars transfer corresponding to the first day of the MSP '98 orbiter primary launch period. The trajectory is shown in Figure 1 and summarized in Table 1.

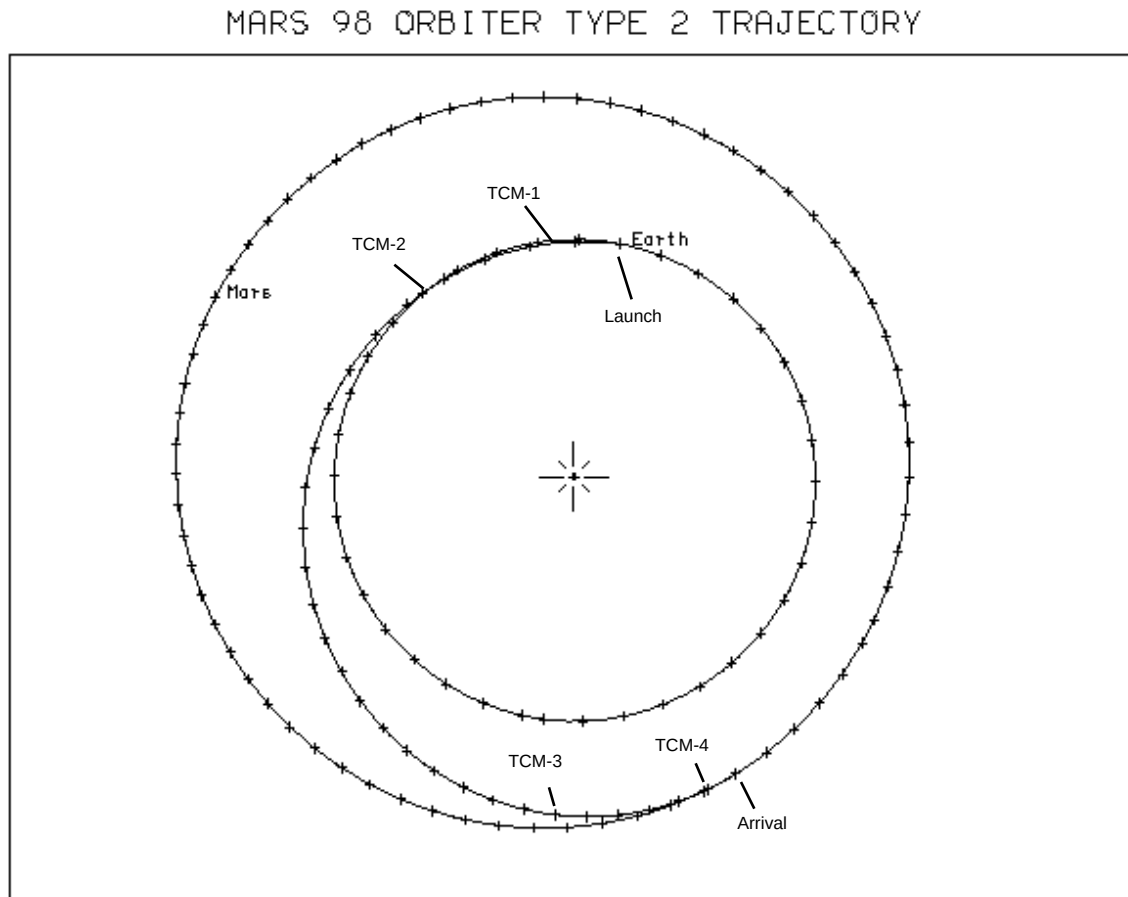


Table 1: Orbiter reference trajectory characteristics

Injection Date	Arrival Date	Length	Arrival V_{∞} (km/sec)
12/10/1998, 20:11	9/24/1999, 10:00	287 days 13.75 hours	3.34

Trajectory Correction Maneuvers

The four opportunities currently planned for interplanetary trajectory correction maneuvers (TCM's) are described in Table 2.

Table 2: Scheduled trajectory correction maneuvers

TCM #	Relative Date	Calendar Date	Comments
TCM-1	Launch+15 days	12/25/98	Corrects LV injection errors
TCM-2	Launch+45 days	1/24/99	Corrects NAV errors at TCM-1
TCM-3	Arrival-60 days	7/25/99	Targets to orbit insertion point
TCM-4	Arrival-10 days	9/14/99	Corrects errors from TCM-3

Orbit determination assumptions

Table 3 shows the tracking coverage assumed for the orbit determination analysis.

Table 3: Tracking Data schedule for orbiter OD analysis

Period	Tracking Schedule
Launch to Launch + 30 days	One 4-hour pass of Doppler and range per day
Launch +30 to Arrival -45 days	one 4-hour pass per complex per week (3 passes / week) of Doppler and range
Arrival - 45 days to Arrival	Three 4-hour passes of Doppler and range per day
<i>TCM coverage:</i>	
TCM -/+ 3 days	One 4-hour pass per day of Doppler and range
TCM -/+ 12 hours	Three 4-hour passes of Doppler and range

Table 4 gives a summary of the error sources included in the OD study, their nominal value, and level of assumed uncertainty. Many of the error sources (such as media, Earth motion, and non-gravitational accelerations) are assumed to be random in nature, and are therefore modeled as first-order Gauss-Markov processes. This model involves statistically correlated behavior, and is useful for describing these phenomena. Table 4 gives the steady-state uncertainty and the correlation time for the stochastic parameters. Parameters listed in Table 4 without these values, such as solar pressure, station locations, initial position and velocity, were assumed to be non-stochastic (bias) parameters. A complete description of these error source models can be found in References [2] through [6].

Table 4: Orbit Determination error assumptions for MSP '98 Orbiter interplanetary cruise

Error Source	Nominal value	Apriori uncertainty (1 σ)	Corr. Time (days)	Steady-State Unc.	Comments
2-way Doppler noise	-	3 mHz	-	-	
SRA range noise	-	1 meter	-	-	
Initial Position	variable	100 km	-	-	
Initial Velocity	variable	1.0 km/s	-	-	
Solar Radiation Model:					
orbiter bus: specular	0.15	0.15	-	-	2.4 m ² , Sun pointed
diffuse	0.09	0.09	-	-	
orb. solar panel: specular	0.1	0.1	-	-	2.4 m ² Sun pointed
diffuse	0.37	0.37	-	-	
orbiter antenna: specular	0.29	0.03	-	-	2.4 m ² , Earth pointed
diffuse	0.04	0.007	-	-	
S/C component area	100%	1%	-	-	error in sunlit area
ΔV from attitude turns (every 5 days)	0	2 mm/s in all directions	-	-	Models turns and momentum de-sat
anomalous self-induced accelerations	0	1.0E-12 km/s ² in all directions	1.5 d	1.0E-12 km/s ²	
TCM magnitude ¹	variable	0.33% (TCM1) 066% (TCM2-4)	-	-	from Exhibit 1
TCM pointing	variable	0.33% (TCM1) 066% (TCM2-4)	-	-	
Station-induced range bias	0	1 meter	0.0 d	1 meter	independent across all three stations
S/C-induced Doppler bias	0	0.02 mm/s	3 d	0.02 mm/s	
Troposphere calibrations	0	5 cm	0.1 d	5 cm	
Night Ionosphere calibrations	0	1 cm	1.0 d	1 cm	
Day Ionosphere calibrations	0	3 cm	0.2 d	3 cm	
Station locations	variable	10 cm	-	-	
Polar Motion calibrations	0	10 cm	2.0 d	10 cm	
UTC calibration	0	30 cm	1.0 d	30 cm	
Earth and Mars ephemeris	-	for Mars: Radial = 0.5 km Transverse = 5.0 km Normal = 5.0 km	-	-	Current knowledge. (This can be reduced with data from MGS)

¹ In addition to this proportional magnitude error, there is a fixed error of .033 m/s for TCM-1 and 0.0033 m/s for all other TCM's [from Exhibit 1, requirement 3.C.2].

Orbit Determination Analysis Results

The Orbit Determination Program (ODP) coupled with the MIRAGE OD filter was used for this analysis [7]. MIRAGE employs a batch-sequential filtering method to a set of simulated Doppler and range data (scheduled according to Table 3). For each maneuver, tracking data up to 5 days before each TCM was reduced and fit to the reference trajectory. The orbit determination error covariance was mapped to the Mars-centered, Mars-Mean-Equator of Date *B*-plane at a time 1 hour before closest approach to Mars (A description of this coordinate frame is provided in Appendix A). The important results are the size, shape and orientation of the error ellipse in the two-dimensional *B*-plane and the linearized time of flight uncertainty. The orbit determination knowledge uncertainties for each of the four TCM's are described in Table 5 and illustrated in Figure 2.

Table 5: Orbiter orbit determination knowledge uncertainty (1σ) at the time of TCM design (TCM-5 days).

[The reference frame is the Mars-Centered, Mars Mean Equator of Date *B*-plane while the reference time is 1 hour prior to closest approach to Mars]

	Ellipse Semi- Major Axis (km)	Ellipse Semi- Minor Axis (km)	Ellipse orientation relative to T-axis	Linearized time of flight (seconds)
TCM-1	430	96	32°	211.1
TCM-2	312	91	30°	135.9
TCM-3	19.6	13.6	106°	3.43
TCM-4	12.6	6.6	107°	1.75

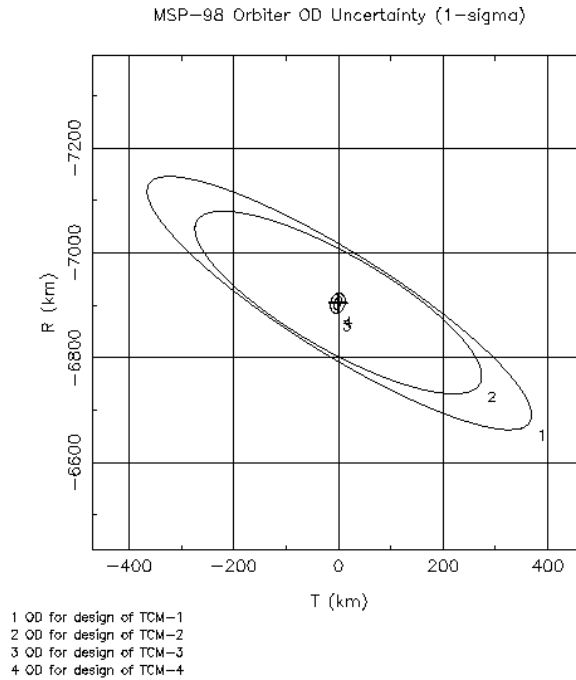


Figure 2a: Orbit determination results for the Orbiter mapped in the *B*-plane

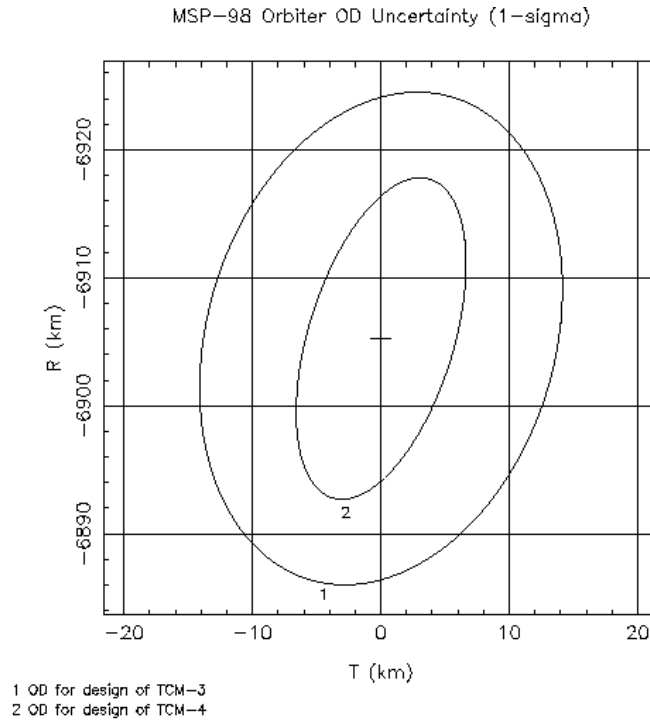


**Figure 2b: Orbit determination results for the Orbiter mapped in the B-plane
(for TCM3 and TCM4)**

Guidance Analysis Results

The OD results from Table 5 were combined with the maneuver execution assumptions described in Table 6 below to determine statistical data on the ΔV magnitude required for all four TCMs. The JPL programs INJCOV, LAMBIC, and PQ were used for this analysis [8].

Table 6: Trajectory correction maneuver assumptions for orbiter

Deterministic part of TCM-1	Fixed Magnitude Error (1- σ)	Proportional Magnitude Error (1- σ)	Proportional Pointing Error (1- σ)
17.3 m/s	0.033 m/s for TCM-1 0.0033 m/s for TCM 2-4	0.33% for TCM-1 0.66% for TCM 2-4	0.33% for TCM-1 0.66% for TCM 2-4

The launch vehicle injection errors were modeled with a covariance supplied by McDonnell-Douglas for the Delta-II 7425 launch vehicle received Sept. 5, 1996. (see Appendix B). Using K-matrices for the nominal trajectory, this injection covariance was mapped to the Mars B-plane at closest approach. The resulting uncertainty ellipse is shown in Figure 3 along with the B-plane contour for a $1.0E-4$ probability of impact. NASA planetary protection regulations requires the injection aimpoint to be outside this contour to minimize the chance the upper stage will impact on Mars. Therefore the launch vehicle aimpoint was targeted to $B \bullet R = 60,000$ km, $B \bullet T = -60,000$ km in a manner that minimizes the deterministic part of TCM-1.

To further reduce the interplanetary ΔV required, the minimum deterministic TCM-1 that satisfies planetary protection requirements was used in the LAMBIC computation [9]. This

minimum ΔV has the effect of moving the arrival time earlier (from Sept. 24, 1999 10:00 to Sept. 23, 1999 06:50), increases arrival V_∞ to 3.573 m/s and increases velocity at periapsis (V_p) by 0.173 m/s. Note that the effect of a 95% probability of command shutdown (PCS) of the launch vehicle has not yet been considered in this analysis.

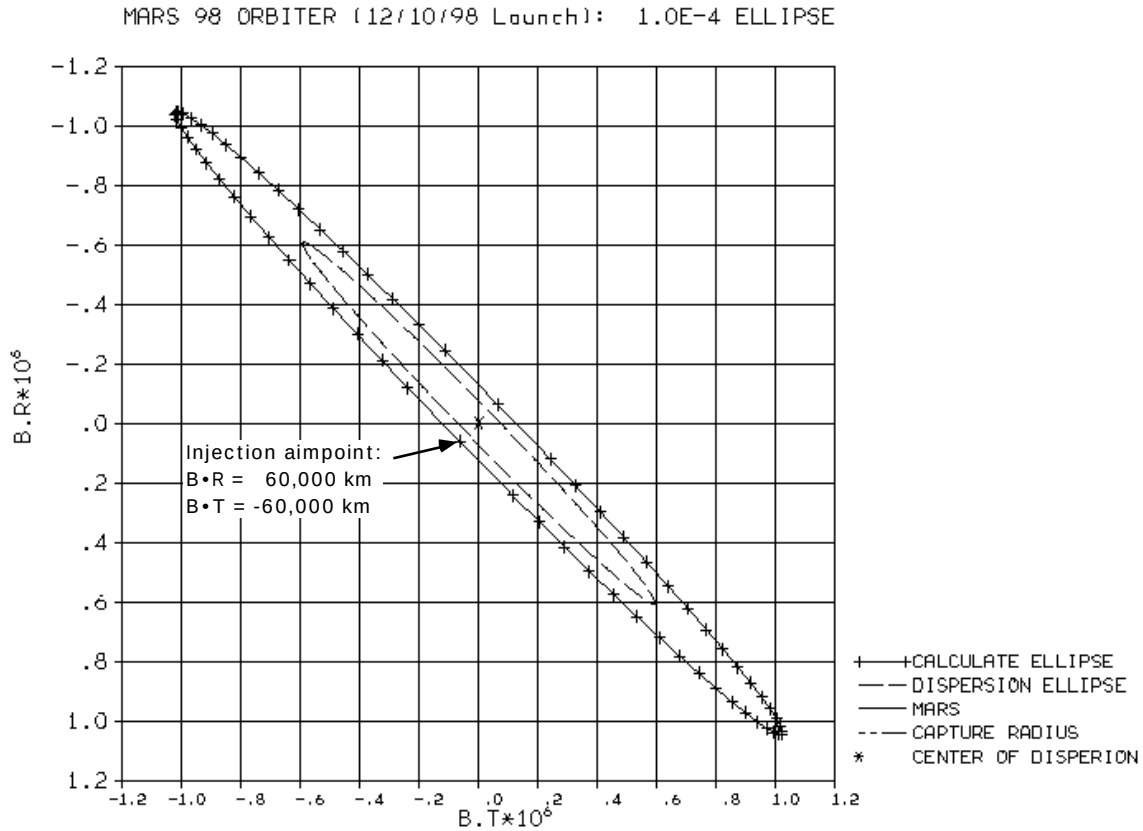


Figure 3: Injection error covariance mapped to the Mars B-plane, and injection aimpoint for $P(\text{impact}) < 1.0E-4$

Table 7 gives the ΔV results from LAMBIC. Figure 4 is a histogram illustrating the statistical spread of required ΔV for the orbiter.

Table 7: Results of maneuver analysis (m/s) for orbiter

Maneuver	Mean	1 σ	95%
TCM-1	31.68	15.49	61.0
TCM-2	0.27	0.18	0.63
TCM-3	0.18	0.15	0.50
TCM-4	0.04	0.02	0.08
Mission Total	32.18	15.62	61.93

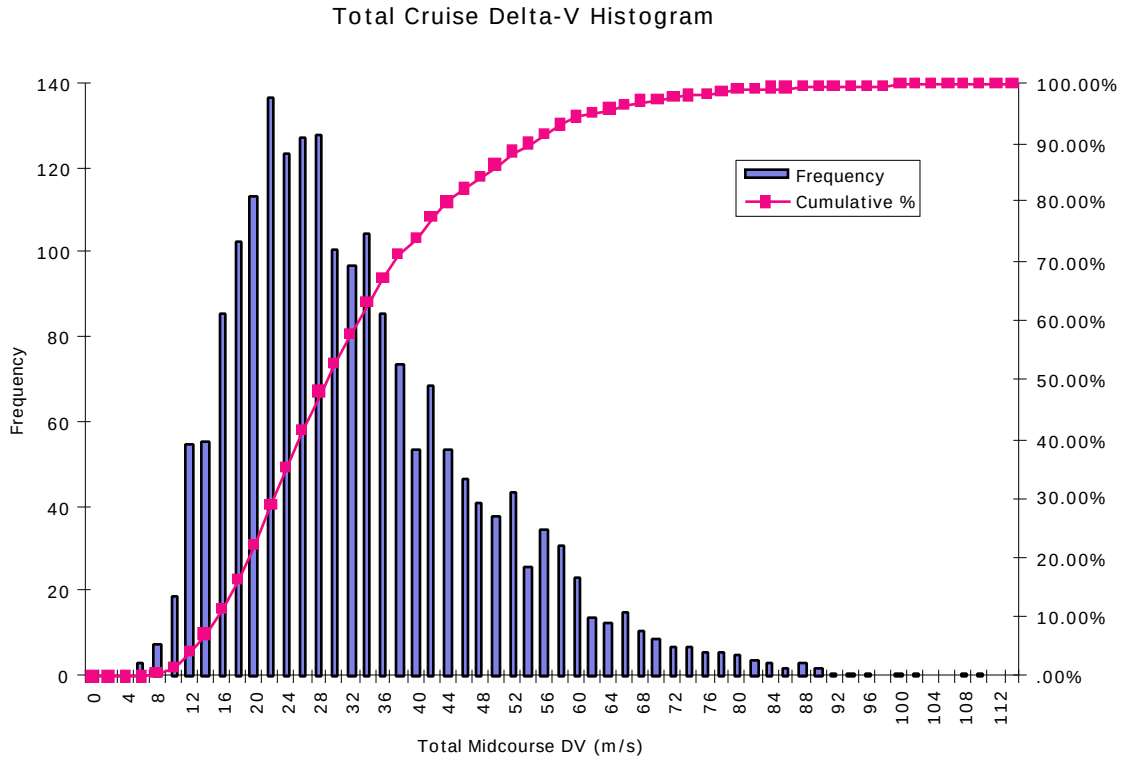


Figure 4: Histogram of maneuver ΔV (m/s) for interplanetary TCM usage

LAMBIC also provides the guidance error covariance, mapped to the Mars-Centered B-plane at closest approach (Table 8 and Figure 5). The guidance error is different than the OD error in that it includes maneuver execution errors. Guidance error from TCM-1 and TCM-2 are considerably larger than the corresponding OD error because these maneuvers are large and the resulting maneuver ΔV error is also large. Also, there is considerably more time between execution of these maneuvers and the arrival at Mars, so these errors propagate longer into a larger B-plane error. TCM-3 and TCM-4 are much smaller maneuvers and they occur closer to Mars, therefore their resulting guidance errors are not significantly larger than their corresponding OD errors.

Table 8: Maneuver Delivery Uncertainty Ellipses (1- σ) for orbiter mapped in the Mars-centered, Mars Mean Equator of Date B-plane

	Semi-Major Axis (km)	Semi-Minor Axis (km)	Ellipse Orientation to T-axis	Linearized Time of Flight
TCM-1	6070	830	40°	4085
TCM-2	580	120	35°	332
TCM-3	22.2	19.2	87°	6.1
TCM-4	12.8	6.9	107°	1.84

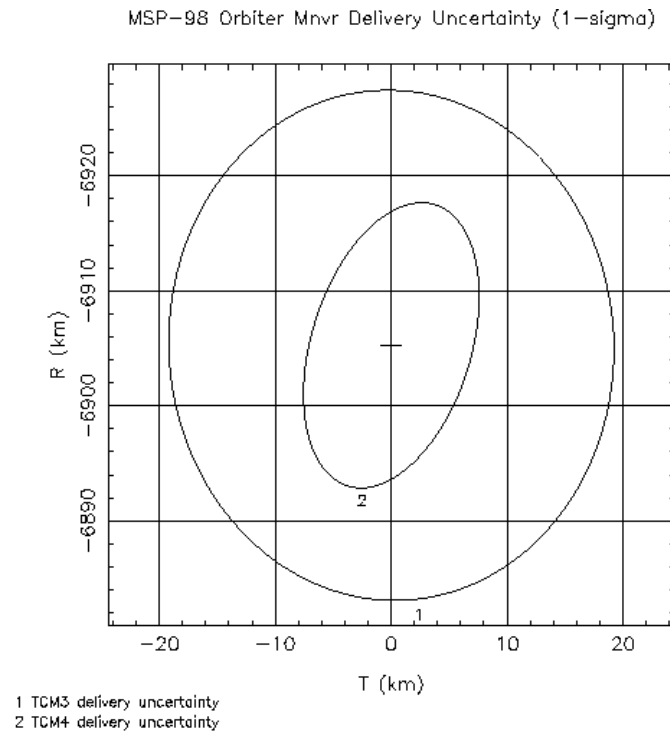
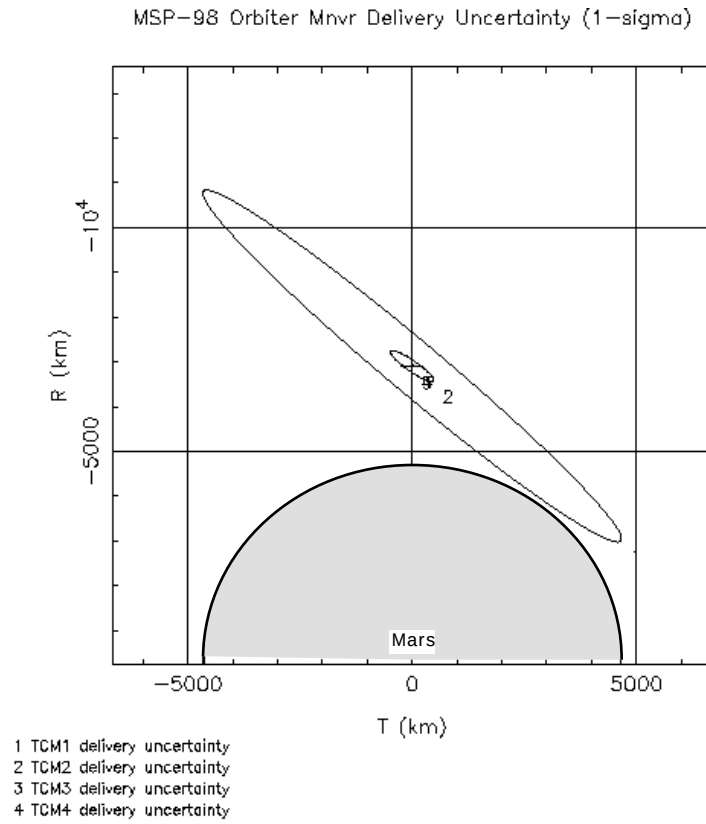


Figure 5: Guidance error results (1- σ) for the orbiter, mapped in the Mars-centered, Mars Mean Equator of Date B-plane

AEROBRAKING PHASE NAVIGATION ANALYSIS

A very preliminary study of the orbit determination capability during the aerobraking phase was performed to answer a few key questions concerning tracking data needs. The ODP was used on a set of orbits ranging in period from 100 hr. to 2 hr. This analysis was done similar to the Mars Global Surveyor aerobraking analysis [10,11], except that the tracking data is not continuous during this phase. Instead, tracking data was simulated to correspond to an expected "4 hours on/5 hours off" schedule, which is driven by power and thermal constraints on the orbiter transmitter.

In the analysis, one full orbit (minus 5 hour gaps) plus 4 hours after the last periapsis (designated P1) is fit assuming a 30% (1σ) uncertainty in the atmosphere. The atmosphere uncertainty is the dominant source of the overall orbit prediction error. It was further assumed that the variability in the atmosphere was so great that any knowledge gained from the last periapsis does not improve the uncertainty for the future aeropasses. The resulting orbit determination error covariance was mapped forward to successive periapsis times to obtain the uncertainty in time of periapsis passage (T_p) and the radius at periapsis (R_p). For those orbits where the period was less than 9 hours, the tracking was scheduled so that half the orbit was tracked starting 30 minutes after periapsis. Figure 6 illustrates the aerobraking orbit analysis.

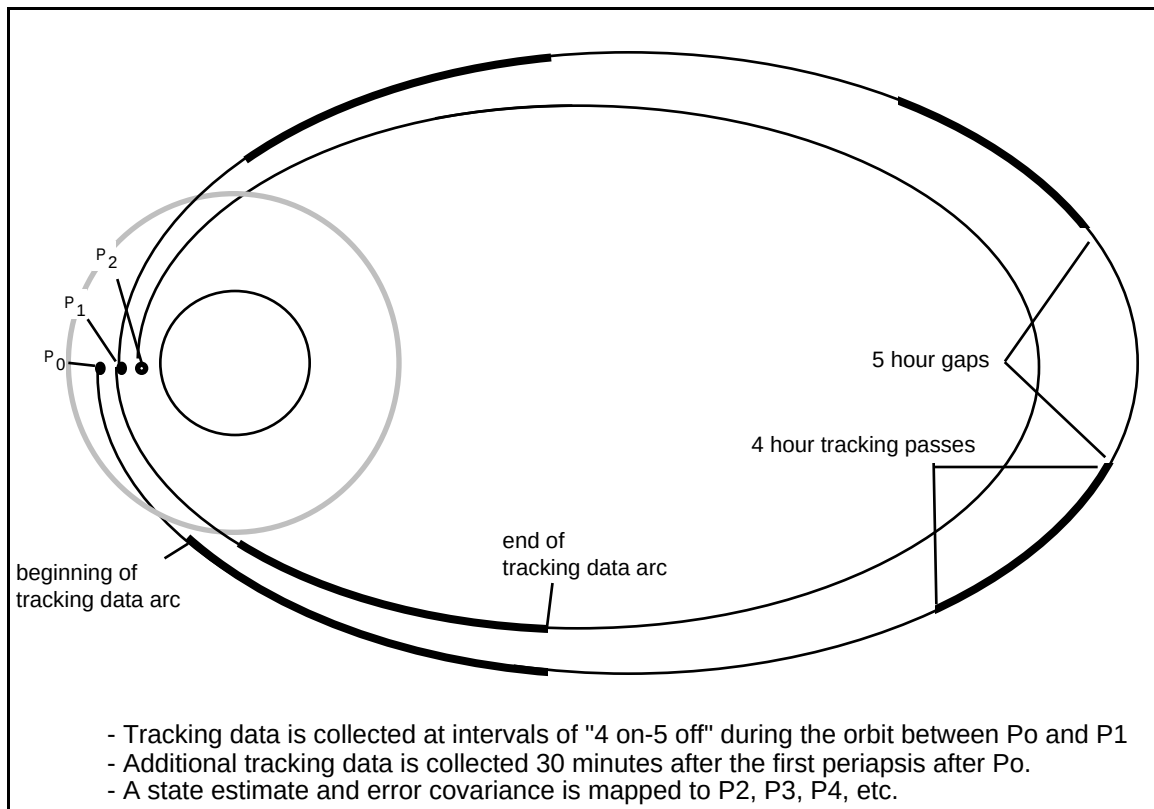


Figure 6: Aerobraking orbit determination

Table 9 gives the estimated uncertainty in predicted periapsis time and radius for aerobraking orbits of 100 hr., 48 hr., 6 hr. and 2 hr periods. Although no formal requirement for Tp error has been adapted for the MSP '98 mission, the MGS requirement in Tp is 225 seconds (3σ) and in Rp is 1.5 km (3σ) [10].

Table 9: Preliminary results of aerobraking phase orbit determination analysis

100-hour period orbit

periapsis #	1 σ error in Tp (s)	1 σ error in Rp (km)
P2	9.2	0.01
P3	1489	0.01

48-hour period orbit

periapsis #	1 σ error in Tp (s)	1 σ error in Rp (km)
P2	4.7	0.02
P3	790	0.03
P4	1525	0.04

6-hour period orbit

periapsis #	1 σ error in Tp (s)	1 σ error in Rp (km)
P2	.45	0.1
P3	17.2	0.1
P4	52.6	0.1

2-hour period orbit

periapsis #	1 σ error in Tp (s)	1 σ error in Rp (km)
P2	0.30	0.1
P3	4.9	0.1
P4	14.2	0.1
P5	28.1	0.1
P6	46.5	0.1
P7	69.5	0.1
P8	97.6	0.1
P9	130.2	0.1
P10	166.7	0.11
P11	207.4	0.11
P12	253.0	0.12

Topics for future study

- 1) On the opening day of the primary launch period (12/10/98), there is 5% chance the launch vehicle will have a velocity deficit that will have to be corrected at TCM-1. Although the data on the probability and value of this deficit has been received from McDonnell-Douglas, I haven't had the time to properly incorporate it into the LAMBIC analysis. Cliff Helfrich is currently assuming the maneuver design duties from me and will perform this study in the next two weeks.
- 2) The MOI and subsequent aerobraking strategy may benefit from moving the final midcourse maneuver from Arrival-10 days to Arrival-5 or Arrival-2 days. A TCM-4 at Arrival-2 days has been adapted as the baseline for the MSP '98 lander mission. An OD analysis could be done with this orbiter trajectory to see how much improvement in maneuver delivery uncertainty is obtained with 5 or more days of tracking data. The magnitude of TCM-4 would be 2-5 times higher than if it were performed at Arrival-10 days, but should not be prohibitively large.
- 3) The aerobraking OD analysis presented in this report was performed in January, 1996. Since that time, the aerobraking plan has changed dramatically to a more aggressive campaign that completes aerobraking in 2 months. Furthermore, in comparing the aerobraking results in this report with those from the MGS NAV plan, I have discovered some differences. The most likely explanation is a difference in how I used the exponential atmosphere model versus how Stuart Demcak used it for the MGS study. For revisiting the MSP '98 aerobraking OD study, I would recommend using the latest MarsGRAM atmosphere modeling capability in DPTRAJ.

DISTRIBUTION

JPL:

Gene Bollman
Pat Esposito
Phil Knocke
Cliff Helfrich
Jim McDanell
David Spencer
Sam Thurman
Bobby Williams

LMA:

Phil Hong
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Bill Willcockson
Steve Jolly

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9. Kallemeyn, P., "Different maneuver analysis strategies for the Mars '98 orbiter", JPL IOM 312.3-95-027.
10. Mars Global Surveyor Navigation Plan (Final), JPL document D-12002, Jet Propulsion Laboratory, Pasadena, California, September 15, 1995.
11. Conversations with Pat Esposito and Stuart Demcak, Dec. 1995 through Jan. 1996.

Appendix A

Definition of the Asymptotic Aiming Plane Coordinate System (B-plane)

The asymptotic aiming plane, or *B-plane*, coordinate system, is shown in Fig. 7. The orientation of this system in space is defined by the arrival asymptote direction, designated $\mathbf{S}$, which is parallel to the velocity vector $\mathbf{V}_\infty$. The unit vectors $\mathbf{T}$ and $\mathbf{R}$ form an orthogonal triad with $\mathbf{S}$; the direction of $\mathbf{T}$ is chosen to lie in the Martian equatorial plane, at a given date. The point of aim corresponding to the desired landing site is defined by the miss vector, $\mathbf{B}$, in Fig. 7, which is oriented in the $\mathbf{T}$ - $\mathbf{R}$ plane, called the *B-plane*, by the angle ϕ , and has magnitude $|\mathbf{B}|$. The miss vector specifies where the point of closest approach would be if the target body had no mass and did not deflect the flight path. Navigational uncertainty is characterized by a two-dimensional dispersion ellipse in the B-plane with semi-major axis $SMAA$, semi-minor axis $SMIA$, and orientation angle θ , and by the uncertainty in the time of arrival at the point of atmospheric entry, the time of arrival.

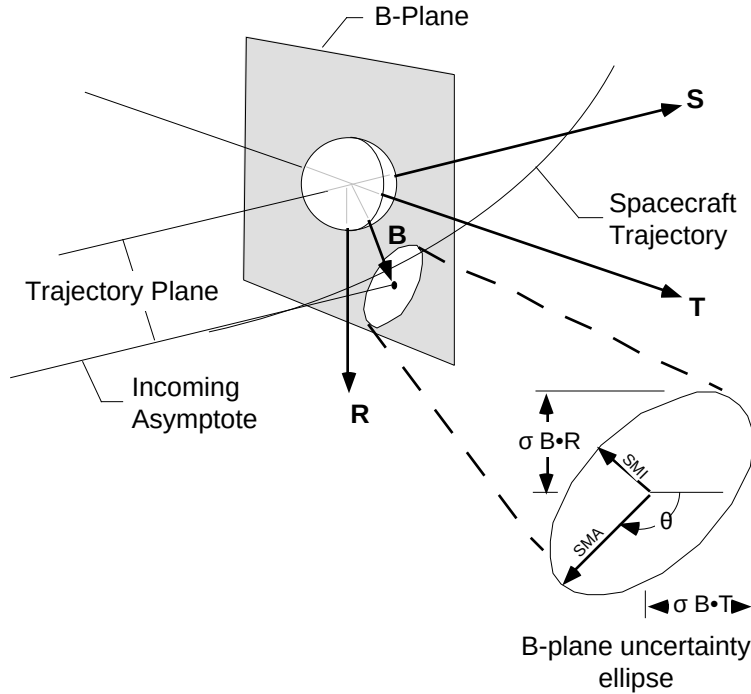


Figure 7: Target-centered aiming plane (B-plane) coordinate system.

Appendix B

Injection error covariance of the Delta II 7425 Launch Vehicle for the Mars Surveyor '98 orbiter mission (12/10/98 launch)

Delta 7425 MARS Orbiter Mission - 12/10/98 Launch Date
Preliminary Orbit Injection Covariance Matrix without PCS Effects
9/5/96 - Updated Velocity Pointing Error and Coning Velocity Loss
Tau at ignition = 182 sec Tau at burnout=56 sec Rgain start uniform from 55 sec to 80 sec

MSP ORBITER - 12/10/98 -- 95 % PCS -- 95 FLT AZ

COVARIANCE MATRIX OF TECO INJECTION CONDITIONS BASED ON -3 SIGMA SENSITIVITIES

		VELOCITY FT/SEC	GAMMA DEGREES	AZIMUTH DEGREES	LONG. + W DEGREES	LATITUDE DEGREES	RADIUS FEET
VELOCITY	FT/SEC	0.20181546E+03	0.44187331E+00	0.69277287E-01	-0.14061408E+00	-0.36883505E-01	-0.23056336E+05
GAMMA	DEGREES	0.44187331E+00	0.21136523E-01	-0.14560763E-02	-0.33297234E-02	-0.91135862E-03	-0.19186262E+02
AZIMUTH	DEGREES	0.69277287E-01	-0.14560763E-02	0.21874953E-01	0.42792515E-02	0.11717830E-02	0.44735897E+02
LONG. + W	DEGREES	-0.14061408E+00	-0.33297234E-02	0.42792515E-02	0.98455124E-02	0.26907739E-02	0.10884905E+03
LATITUDE	DEGREES	-0.36883505E-01	-0.91135862E-03	0.11717830E-02	0.26907739E-02	0.73871678E-03	0.27980987E+02
RADIUS	FEET	-0.23056336E+05	-0.19186262E+02	0.44735897E+02	0.10884905E+03	0.27980987E+02	0.26086771E+08
THETA LP	DEGREES	0.15058810E+01	0.69339403E-01	-0.43135543E-02	-0.98544942E-02	-0.26946305E-02	-0.10279562E+03
PSI LP	DEGREES	0.36547449E+00	-0.14680300E-02	0.67923257E-01	0.42792614E-02	0.11696496E-02	0.44749689E+02
		THETA LP DEGREES	PSI LP DEGREES				
VELOCITY	FT/SEC	0.15058810E+01	0.36547449E+00				
GAMMA	DEGREES	0.69339403E-01	-0.14680300E-02				
AZIMUTH	DEGREES	-0.43135543E-02	0.67923257E-01				
LONG. + W	DEGREES	-0.98544942E-02	0.42792614E-02				
LATITUDE	DEGREES	-0.26946305E-02	0.11696496E-02				
RADIUS	FEET	-0.10279562E+03	0.44749689E+02				
THETA LP	DEGREES	0.22775448E+00	-0.43657570E-02				
PSI LP	DEGREES	-0.43657570E-02	0.21996929E+00				

Delta 7425 MARS Orbiter Mission - 12/10/98 Launch Date
Preliminary Orbit Injection Covariance Matrix (NASA System) without PCS Effects
9/5/96 - Updated Velocity Pointing Error and Coning Velocity Loss
Tau at ignition = 182 sec Tau at burnout=56 sec Rgain start uniform from 55 sec to 80 sec

MSP ORBITER - 12/10/98 -- 95 % PCS -- 95 FLT AZ

COVARIANCE MATRIX OF TECO INJECTION CONDITIONS BASED ON -3 SIGMA SENSITIVITIES

		X (NASA) FEET	Y (NASA) FEET	Z (NASA) FEET	VX (NASA) FT/SEC	VY (NASA) FT/SEC	VZ (NASA) FT/SEC
X (NASA)	FEET	0.13933555E+10	-0.10119626E+07	-0.35294272E+08	0.39287805E+05	-0.16697828E+02	-0.16190124E+07
Y (NASA)	FEET	-0.10119626E+07	0.41384520E+06	0.40332584E+05	-0.42255790E+02	-0.49013929E+03	0.11838380E+04
Z (NASA)	FEET	-0.35294272E+08	0.40332584E+05	0.26152156E+08	-0.22559951E+05	0.13773348E+02	0.51565839E+05
VX (NASA)	FT/SEC	0.39287805E+05	-0.42255790E+02	-0.22559951E+05	0.20943257E+03	-0.11595209E+03	0.32046145E+03
VY (NASA)	FT/SEC	-0.16697828E+02	-0.49013929E+03	0.13773348E+02	-0.11595209E+03	0.87078393E+04	0.38670597E+01
VZ (NASA)	FT/SEC	-0.16190124E+07	0.11838380E+04	0.51565839E+05	0.32046145E+03	0.38670597E+01	0.10578415E+05
THETA LP	DEGREES	0.37075735E+04	-0.26912080E+01	-0.93985345E+02	0.20088161E+01	0.19175826E-01	0.39207332E+02
PSI LP	DEGREES	-0.16099316E+04	0.99934921E+00	0.40924619E+02	0.53613886E+00	-0.43574952E+02	0.18542801E+01
		THETA LP DEGREES	PSI LP DEGREES				
X (NASA)	FEET	0.37075735E+04	-0.16099316E+04				
Y (NASA)	FEET	-0.26912080E+01	0.99934921E+00				
Z (NASA)	FEET	-0.93985345E+02	0.40924619E+02				
VX (NASA)	FT/SEC	0.20088161E+01	0.53613886E+00				
VY (NASA)	FT/SEC	0.19175826E-01	-0.43574952E+02				
VZ (NASA)	FT/SEC	0.39207332E+02	0.18542801E+01				
THETA LP	DEGREES	0.22775448E+00	-0.43657570E-02				
PSI LP	DEGREES	-0.43657570E-02	0.21996929E+00				

X, Y, Z (NASA) Coordinate System:

Positive x-axis is parallel to the projection of the instantaneous vehicle velocity vector onto a plane perpendicular to the radius vector.

Z-axis is positive away from the earth along the radius vector.

Y-axis completes the right-handed orthogonal system.

The origin is at the nominal vehicle present position point and the system is inertial.

Delta 7425 MARS Orbiter Mission - 12/10/98 Launch Date
Preliminary 95 % PCS Effects on Injection Velocity

MSP ORBITER - 12/10/98 -- 95 % PCS -- 95 FLT AZ

=====			
VELOCITY DEFICIT VS. PROBABILITY			
=====			
VELOCITY DEFICIT (FPS)	PROBABILITY LEVEL	VELOCITY DEFICIT (FPS)	PROBABILITY LEVEL
0.00	0.95130	73.38	0.98730
3.47	0.95370	83.75	0.98970
6.74	0.95610	94.29	0.99210
9.85	0.95850	109.79	0.99450
14.10	0.96090	130.79	0.99690
18.89	0.96330	133.77	0.99720
23.35	0.96570	148.63	0.99800
27.52	0.96810	155.70	0.99860
31.31	0.97050	164.95	0.99900
34.86	0.97290	171.86	0.99930
40.03	0.97530	180.55	0.99950
48.00	0.97770	207.52	0.99970
52.36	0.98010	244.24	0.99980
57.45	0.98250	254.84	0.99990
66.90	0.98490	304.82	1.00000
=====			

THE CORRESPONDING SENSITIVITIES TO THE ABOVE VELOCITY DEFICITS ARE: *

IN POLAR COORDINATES- PARAMETER	SENSITIVITY
-----	-----
INERTIAL RADIUS	-0.000352 (NMI/FPS)
INERTIAL VELOCITY	0.996670 (FPS/FPS)
INERTIAL FLIGHT PATH ANGLE	0.000140 (DEG/FPS)
AZIMUTH	-0.000079 (DEG/FPS)
LONGITUDE (+W)	-0.000186 (DEG/FPS)
GEOCENTRIC LATITUDE	-0.000047 (DEG/FPS)

* BASED ON A VELOCITY DEFICIT OF 155.70 FPS (0.99860 PROBABILITY LEVEL)

Delta 7425 MARS Orbiter Mission
Preliminary 99.865 % Probable Maximum and Minimum
Injection Condition Dispersions

Based on 9/5/96 Updated Velocity Pointing Error and Coning Velocity Loss

Tau at ignition = 182 sec Tau at burnout = 56 sec Rgain start uniform from 55 sec to 80 sec

McDonnell Douglas Aerospace-Space Transportation Division

Launch Date: 12/10/98
PCS (%): 95

Launch Date: 12/10/98
PCS (%): 95

Parameter

Parameter

Injection altitude (nmi) **+2.5**
-2.7

Inclination (deg) **+0.22**
-0.22

Injection Velocity (fps) **+39.3**
-163.3

Longitude of the ascending node (deg) **+0.75**
-0.79

Elevation angle (deg) **+0.45**
-0.43

Argument of perigee (deg) **+1.01**
-1.04

Azimuth angle (deg) **+0.44**
-0.46

True anomaly (deg) **+0.82**
-0.80

Longitude (+w,deg) **+0.29**
-0.30

Perigee altitude (nmi) **+2.5**
-2.7

Geocentric latitude (deg) **+0.08**
-0.08

V infinity magnitude (fps) **+130.1**
-577.2

Right ascension of V infinity (deg) **+1.48**
-0.86

Declination of V infinity (fps) **+0.74**
-0.44

Note: Errors do not include launch time effects

A.9 Orbiter Monte Carlo Simulation Description

6/3/97

TO: Distribution

FROM: Philip Knocke

SUBJECT: **ORBITER END-TO-END PROPELLANT CONSUMPTION:
MONTE CARLO ANALYSIS PROGRAM**

Overview:

This memo provides a brief overview of a model for determining end-to-end propellant consumption for the MSP98 Orbiter.

Assumptions:

Figure 1 summarizes the parameter values and models used.

Interplanetary Trajectories:

Two thousand dispersed interplanetary trajectories have been calculated using the LAMBIC program, for the end of the Orbiter primary launch period. The effects of launch vehicle injection errors, orbit determination errors, and maneuver execution errors are modeled, as are the effects of solar radiation pressure and non-gravitational perturbations due to attitude thruster firing. The launch vehicle injection aimpoint was chosen to ensure $< 1E-4$ probability of upper stage impact with Mars, as required by Planetary Protection regulations. Each of the cases has a different value of each of the four TCM's, and hence a different approach mass, as well as a different approach aimpoint.

MOI:

For a given oxidizer propellant load, the resultant capture orbit for each trajectory is calculated, accounting for MOI pointing errors and the concurrent effects of RCS thruster usage during the biprop MOI burn. The latter effect is modeled by slightly "derating" the biprop Isp and increasing effective thrust to account for the RCS system supplying a small amount of additional translational ΔV during the MOI biprop burn. It is assumed the oxidizer is burned to depletion during the biprop burn. Both the biprop MOI maneuver and the hydrazine makeup maneuver are modeled as finite burn gravity turns. In reality, both burns will be constant pitch rate maneuvers. The difference in performance can be simulated by using an MOI aimpoint for the gravity turn approximately 4 km higher than that used for the constant pitch rate. The aimpoint used in the gravity turn calculations was designed to keep the final periapse altitude $> \sim 150$ km, to avoid overheating during MOI.

Inclination Trim:

The effects of the incoming dispersed trajectories and MOI pointing errors result in small errors in the desired inclination of the capture orbit. It is assumed in this analysis that these errors will be removed during the early phase of aerobraking, when the orbit period is 20 hrs. The corrective maneuver is assumed to occur at the optimum point on the orbit, resulting in a small node change as well as an inclination change. A second inclination trim is also calculated when the orbit period is 10 hrs, also at the optimum point on the orbit. This maneuver removes the majority of the inclination dispersions caused by Aerobraking; these dispersions are modeled as a uniform random distribution between 0 and 0.2 deg.

Additional ΔV :

Walk-in ΔV is calculated at apoapse of the final capture orbit, assuming that the periapse must be lowered to 100 km. The ΔV required to transfer from the final aerobraking orbit [apoapse altitude = 405 ± 15 km] to the mapping orbit is modeled as a uniform distribution between 84.5 and 91.9 m/s [Open Primary], or 84 - 90.4 m/s [Close Primary], assuming insertion into the frozen 405 km circular orbit and a North approach. Remaining ΔV 's and mass drops are currently calculated as fixed quantities.

Verification:

This program was used to estimate propellant load and maximum dry mass capability for the mission. The calculations were verified by comparison with Phil Hong's propellant spreadsheet, version XC0151. With identical assumptions, the Monte Carlo program agreed with the spreadsheet calculations to within 0.1 kg.

Mission Requirements and Constraints:

It is required that the Orbiter, if launched within its primary launch period, achieve a minimum 95% probability of completing aerobraking by the time of lander arrival. Assuming Orbiter launch at the end of its primary period [launch 12/17/98, arrival 9/29/99] and launch of the Lander during its primary period [arrival 12/3/99], the maximum allowable capture orbit period is approximately 29 hrs. This is the most stressful case within the Orbiter's primary launch period because it allows the least time for aerobraking, and also has the highest arrival V-infinity value. For this analysis, a maximum wet mass capability of 643 kg was assumed, consistent with the performance of the Delta II 7425 launched at the start of the Orbiter's primary period, where the launch energy is highest [$C3 = 11.19 \text{ km}^2/\text{s}^2$].

Acknowledgments:

Major portions of this analysis were provided by the following:

Pieter Kallemeyn:	Interplanetary trajectories, TCM ΔV's
Cliff Helfrich:	TCM ΔV's, 95% PCS calculations
Andrey Sergeyevsky:	Approach mass program, detailed MOI analysis
Ted Sweetser:	Integration subroutine for MOI burns
Phil Hong:	Model parameter values & statistics
Bill Willcockson:	Aerobraking analyses

ORBITER Monte Carlo Simulation Assumptions

Rev 1.6

Date 6/3/97

TCM Summary	TCM #	Placement	95% Low ΔV	Mean ΔV	95% High ΔV	Modeling includes maneuver execution and OD errors MACDAC Injection covariance dated 9/5/96, including effects of 95% PCS.
	1	Launch + 15 days	12.36	33.98	68.11	
	2	Launch + 45 days	0.07	0.29	0.69	
	3	MOI - 60 days	0.03	0.19	0.51	
	4	MOI - 10 days	0.01	0.04	0.08	
	Totals		12.66	34.51	68.81	

Description		Mean	Units	3 σ Variation	Model	Comments	
LV Data	Max Injected Wet Mass	643	kg			For open of Primary Launch Period, C3 = 11.16 km2/s2	
ΔV Modeling	TCM Maneuver Execution errors	Proportional magnitude error	0	%	1% for TCM1 2% for other TCMs	Gaussian	Exhibit 1 requirement 3.C.1
		Proportional pointing error	0	radians / axis	0.01 for TCM1 0.02 for other TCMs	Gaussian	Based on Exhibit 1 requirement 3.C.1
		Fixed magnitude error	0	m/s	0.01 m/s for burns ≤ 2 m/s 0.1 m/s for burns > 2 m/s	Gaussian	Exhibit 1 requirement 3.C.2
		Fixed pointing error	0	m/s / axis		fixed	
	MOI-1[biprop] and MOI-2 [hydrazine]						Both modeled as finite burn gravity turns, calibrated to simulate constant pitch rate burns.
	MOI-1	Isp factor	0.99695			fixed	Multiply by Nominal Biprop Isp to get "effective" Biprop Isp including effect of concurrent RCS
		Thrust factor	1.0082			fixed	Multiply by Nominal Biprop Thrust to get "effective" Biprop Thrust including effect of concurrent RCS
	MOI-2 [Hydrazine makeup]	Start MOI-2 at end of MOI-1 burn +	60	s		fixed	
	Target Orbit Period, end Primary	End Primary = 12/17/98	29	h			[TBR] Required to finish aerobraking 24h before lander arr: 12/3/99
	Inclination Trims [2]						Two trims are calculated: one at 20 hrs for correcting inclination dispersions at MOI, the other at 10 hrs to correct up to 0.2 deg. of AB dispersions. The latter is modeled as a uniform distribution from 0 to 0.2 degrees. Both ΔV's are assumed to occur at the optimum point on the orbit, which results in both an inclination change and a change in node.
	Walk-in	Translational					ΔV required to reduce altitude after MOI-2 to 100 km
	Transfer to Map Orbit	Translational	85.4 - 91.9 84 - 90.4	m/s m/s	Open LP Close LP	uniform uniform	Based on uncertainties in final AB state [N. approach]
	Corridor Control	Translational	12.00	m/s		fixed	
		Rotational	15.22	m/s		fixed	
	Aero exit/reentry	Translational	17.00	m/s		fixed	
	End Game	Translational	1.50	m/s		fixed	
	RCS map/relay ops	Rotational	22.63	m/s		fixed	
	Orbit maintenance	Translational	0.00	m/s		fixed	
	RCS contingency	Rotational	15.97	m/s		fixed	RCS uncertainty, failed reaction wheel, other contingency, project mgr reserve

Mass Drops	Cruise RCS	2.03	kg		fixed	divided equally between TCM's
	MOI-1RCS mass	0.9	kg		fixed	RCS mass consumed during MOI

S/C Data	Nominal Biprop Isp	318	s	1	Uniform		
	Hydrazine Isp	Translational	225	s	10	Gaussian	
		Rotational	170	s	10	Gaussian	
	MOI Pointing Error	Crosstrack	0	deg.	0.25	Gaussian	
		Normal	0	deg.	0.017	Gaussian	
	Fuel Mixture Ratio	0.85		0.04	Gaussian		
	Nominal Biprop Thrust	640.355	N		fixed		
	Hydrazine Thrust	80.1	N		fixed		
	Trapped oxidizer	0.2	kg		fixed		
	% Trapped Hydrazine	2	%		fixed		
	Pressurant	0.91	ka		fixed		

FIGURE 1 - ORBITER MONTE CARLO ASSUMPTIONS - Rev 1.6

A.10 Orbiter Data Rates, Earth Contact Durations, Daily Data Volumes

A.10.1 Orbiter and Lander Communication Strategy during the Mission
Memo MSP-SE-97-0162

A.10.2 Data Rates, Data Volumes during Mapping

Interoffice Memo



Memo No.: MSP-SE-97-0162

Date: 3/31/97

To: P. Knocke

cc: MSP

From: K. Nii

Subject: Orbiter and Lander Communication Strategy during Cruise

=====

This memo documents the Mission Operations plan for communication strategies with the orbiter and lander during the Cruise portion of the mission.

Orbiter Cruise Comm Strategy Overview:

Each mission phase drives one or more subsystem performance parameter. After separation, key engineering data are broadcast to available X-band sites to support post-flight anomaly investigation. As the S/C approaches the first DSN station, the 34 m antenna will be used to acquire and track the Orbiter. Coherent two way ranging is key during daily telecommunication passes throughout all the phases. The Orbiter transmits 2.1 kbps on the MGA and receives 125 bps on the LGA during the S/C Init and Cruise Phases. Each DSN contact nominally lasts four hours. The Orbiter transfers from the MGA/LGA to the HGA at Launch + 80 days. During the rest of Cruise the Orbiter transmits at 2100 bps and receives at 125 bps. At MOI - 45 days, the orbiter will transition to a communicating strategy of 4 hours on and 5 hours off.

When not in planned communication with the ground the orbiter will be in receive mode on the LGA at 7.8125 bps.

Lander Cruise Comm Strategy Overview:

Each mission phase drives one or more subsystem performance parameter. After separation, key engineering data are broadcast to available X-band sites to support post-flight anomaly investigation. As the S/C approaches the first DSN station, the 34 m antenna will be used to acquire and track the Lander. Coherent two way ranging is key during daily telecommunication passes throughout the Cruise phase. The lander uses the cruise MGA to transmit and receive for the entire cruise phase. DSN contacts are planned to occur once/day for all of cruise until EDL-46 days. At this time the lander will transition to a four hours on five hours off communication strategy.

When not in planned communication with the ground the lander will be in receive mode on the LGA at 7.8125 bps.

Orbiter

Possible Transmit Rates: MGA/HGA 40, 2100, 5688, 9954, 33180, 71100, 110600 bps
 8 kbps UHF
 Possible Receive Rates: LGA 7.8125, 125 bps
 HGA 7.8125, 125, 500, 1000* bps (* No ranging)
 128 kbps UHF

Phase:	Nominal Transmit Rates:	Nominal Receive Rates:
Initial Acquisition	2.1K bits per second	125 bits per second
Cruise	2.1 kbps	125 bps

Lander

Possible Transmit Rates: Cruise MGA 40, 100, 2100 bits per second (bps)
 Landed MGA 40, 395 (R=1/2), 700 (R=1/6), 1400 bps
 8 kbps, 128 kbps UHF (nominal)
 Possible Receive Rates: Cruise MGA 7.8125, 125, 500 bps
 Landed MGA 7.8125, 125, 500 bps
 8 kbps UHF (nominal) (128 kbps possible)

Phase:	Transmit	Receive
Initial Acquisition	2.1 kbits per second	125 bits per second
Cruise	100 bps	125 bps
Approach (EDL-46 days)	40 bps	7.8125 bps

Orbiter DSN Cruise Contact Plan (Open of Launch period):

# Days	Mission Day	Frequency	Antenna	Operations
80	1-80	1/day	LGA/MGA	Cruise (4 hours)
164	81-244	1/day	HGA	Cruise (4 hours)
45	245-289	3/day*	HGA	Approach (*4 hours on, 5 hours off) Includes TCM-4

Orbiter DSN Cruise Contact Plan (Close of Launch period):

# Days	Mission Day	Frequency	Antenna	Operations
80	1-80	1/day	LGA/MGA	Cruise (4 hours)
160	81-240	1/day	HGA	Cruise (4 hours)
45	241-285	3/day*	HGA	Approach (*4 hours on, 5 hours off) Includes TCM-4

Lander DSN Cruise Contact Plan (Open of Launch period):

# Days	Mission Day	Frequency	Antenna	Operations
301	1-302	1/day	MGA	Cruise (4 hours)
46	303-347	3/day*	MGA	Approach (*4 hours on, 5 hours off) Includes TCM-4

Lander DSN Cruise Contact Plan (Close of Launch period):

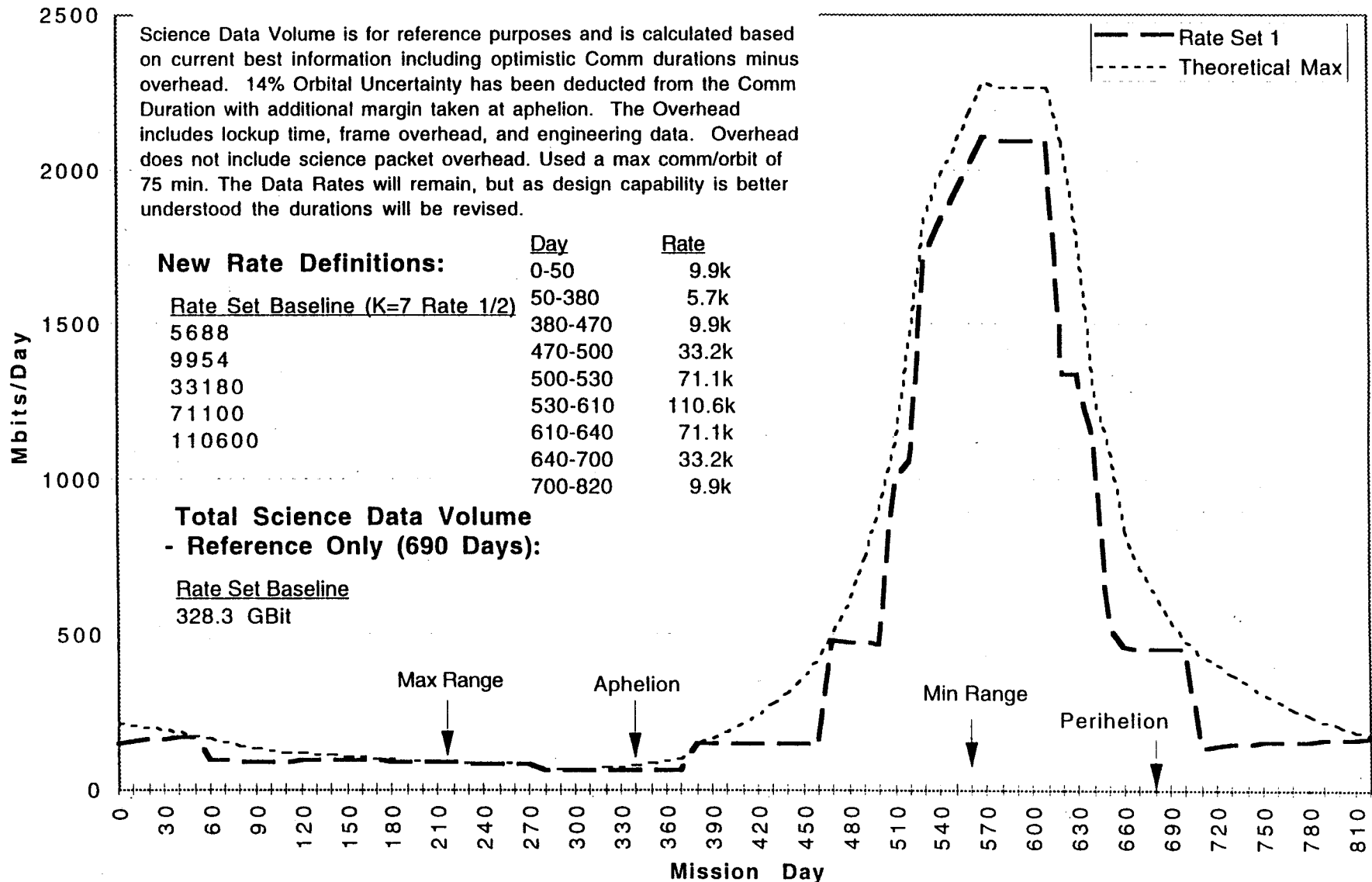
# Days	Mission Day	Frequency	Antenna	Operations
289	1-290	1/day	MGA	Cruise (4 hours)
46	291-335	3/day*	MGA	Approach (*4 hours on, 5 hours off) Includes TCM-4

original signed by

Kendall M. Nii

5 New Rates with SA Management ==> High Science Vol.

MSP 98 Orbiter Data Rate Change XC0117 Supl. C



Maximum Telecom Data Rate vs. Orbiter Mission Day

** Includes Frame, RS encoding, Transfer overhead [does not include packet overhead]				
Engineering data (Mbits)			2.52825	
* Includes 2 min lock up time				
Mission Day	minutes/ orbit	Rate Set 1	Total Mbits /Day *	Science Mbits /Day **
0	61	9954	176	150
10	64	9954	184	157
20	65	9954	189	161
30	66	9954	192	163
40	67	9954	194	166
50	68	9954	197	168
60	68	5688	113	95
70	66	5688	110	92
80	65	5688	107	90
90	65	5688	107	90
100	65	5688	107	90
110	65	5688	107	90
120	65	5688	108	91
130	65	5688	108	91
140	65	5688	108	91
150	65	5688	108	91
160	65	5688	108	91
170	65	5688	108	91
180	65	5688	107	90
190	64	5688	105	88
200	63	5688	104	87
210	62	5688	102	86
220	61	5688	101	85
230	60	5688	99	83
240	59	5688	98	82
250	59	5688	98	82
260	59	5688	96	81
270	58	5688	95	80
280	57	5688	93	78
290	42	5688	69	57
300	42	5688	69	57
310	42	5688	69	57
320	42	5688	68	57
330	42	5688	68	57
340	42	5688	68	57
350	42	5688	68	57
360	42	5688	68	56
370	42	5688	68	56
380	42	9954	119	100
390	42	9954	119	100

9/15/97

10:25 AM

A.10.2 Data Rates, Volumes

Maximum Telecom Data Rate vs. Orbiter Mission Day

** Includes Frame, RS encoding, Transfer overhead				
400	59	9954	171	146
410	59	9954	171	146
420	59	9954	171	146
430	60	9954	174	148
440	59	9954	171	146
450	59	9954	171	146
460	59	9954	169	143
470	59	33180	562	484
480	58	33180	554	477
490	58	33180	554	477
500	57	33180	545	469
510	57	71100	1169	1008
520	59	71100	1224	1056
530	61	110600	1961	1693
540	65	110600	2103	1817
550	69	110600	2217	1916
560	72	110600	2332	2014
570	75	110600	2437	2105
580	75	110600	2420	2090
590	75	110600	2420	2090
600	75	110600	2420	2090
610	75	110600	2420	2090
620	75	110600	2420	2090
630	75	71100	1555	1343
640	63	71100	1297	1119
650	64	33180	614	528
660	56	33180	537	462
670	55	33180	528	454
680	55	33180	528	454
690	55	33180	528	454
700	55	33180	528	454
710	56	9954	161	137
720	59	9954	169	143
730	60	9954	174	148
740	61	9954	176	150
750	62	9954	179	152
760	63	9954	182	155
770	64	9954	184	157
780	64	9954	184	157
790	65	9954	187	159
800	65	9954	189	161
810	66	9954	192	163
820	67	9954	194	166
		Total MBits	Science+Eng	Science
		820 Days	41625	35796
		690 Days	38925	33493

A.11 Mapping Phase Navigation Capabilities

The data in this appendix represent very preliminary estimates of downtrack prediction capabilities in the MSP98 Orbiter orbit. Shown are downtrack prediction capabilities for 95% and 99.9% confidence levels, as a function of prediction interval, due to atmospheric uncertainty. Data are presented for three dates: 1/1/2000 [during the Lander Support Phase], 12/1/00 [near the middle of the Mapping Phase] and 7/7/01 [near the end of Mapping].

1/1/00				
Pred. Interval	95.0%	95.0%	99.9%	99.9%
[days]	[km]	[sec]	[km]	[sec]
1	0.89	0.27	4.81	1.43
2	3.42	1.02	18.50	5.51
3	8.02	2.39	43.36	12.92
4	13.98	4.16	75.56	22.51
5	21.57	6.43	116.63	34.75
6	30.81	9.18	166.59	49.64
7	42.68	12.72	230.74	68.75
14	167.78	49.99	907.04	270.28
21	375.30	111.83	2028.97	604.58
12/1/00				
Pred. Interval	95.0%	95.0%	99.9%	99.9%
[days]	[km]	[sec]	[km]	[sec]
1	0.11	0.03	0.60	0.18
2	0.41	0.12	2.32	0.69
3	0.96	0.29	5.43	1.62
4	1.67	0.50	9.47	2.82
5	2.57	0.77	14.61	4.35
6	3.68	1.10	20.87	6.22
7	5.09	1.52	28.91	8.61
14	20.02	5.96	113.65	33.86
21	44.77	13.34	254.22	75.75
7/7/01				
Pred. Interval	95.0%	95.0%	99.9%	99.9%
[days]	[km]	[sec]	[km]	[sec]
1	0.16	0.05	0.82	0.25
2	0.63	0.19	3.17	0.95
3	1.47	0.44	7.43	2.22
4	2.56	0.76	12.96	3.86
5	3.95	1.18	20.00	5.96
6	5.64	1.68	28.57	8.51
7	7.82	2.33	39.56	11.79
14	30.72	9.15	155.53	46.34
21	68.72	20.48	347.90	103.67

A.12 34m BWG Usage and Tracking Schedule Modifications

DSN coverage for the majority of the mission is via the 34m subnet and the 70m subnet. Use of the 34m HEF antennae has been maximized, but 34m BWG support is necessary for limited intervals, to accommodate DSN usage conflicts and to maximize tracking of the Orbiter during the last 30 days of Lander approach [interval of near-simultaneous tracking]. 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. The following data summarize the use of BWG antennae and/or modifications to the tracking schedule required during the mission.

A.12.1 DSN Contention Resolution

A.12.2 Approach, near-Simultaneous Tracking Integrated Schedule: an integrated [Orbiter + Lander] schedule of tracks for the interval of near-simultaneous tracking starting 30 days from Entry. These tracks have not been edited to be consistent with Earth view periods, but are intended to show the approximate variation of lander track durations and timing as a function of date.

Summary of Recommendations - DSN Resource Contention Resolution [Mars98]

PCK DRAFT - 4/29/97, updated 7/18/97

Contention Period	Recommendation (Source)	Dates	M98 Orbiter Action	Impact on M98 Orbiter	M98 Lander Action	Impact on M98 Lander	Comments
# 6 [1/4/99 - 3/7/99]	M98 Lander and Orbiter use BWG on days when MGS has continuous coverage. (RAP)	1/5/99 - 1/12/99	Use GLD & CAN HEF overlap [6 2-hr passes/week?]. Supplement with BWG to total 7 4-hr passes/week. Some coverage from all 3 stations required.	No Impact.	BWG: continuous coverage to 1/10/99 BWG: 7 4-hr passes/week 1/10/99 - 1/12/99	No Impact.	• GLD/CAN overlap pass duration of 2-hrs is an estimate, with pre&post-cal taken out.
		1/13/99 - 1/19/99	HEF: 6 4-hr passes/week	Reduced monitoring	BWG: 7 4-hr passes/week	No Impact.	
		1/20/99 - 1/27/99	Use GLD & CAN HEF overlap [6 2-hr passes/week?]. Supplement with BWG to total 7 4-hr passes/week. Some coverage from all 3 stations required.	No Impact.	BWG: 7 4-hr passes/week	No Impact.	
		1/28/99 - 2/2/99	HEF: 6 4-hr passes/week	Reduced monitoring	BWG: 7 4-hr passes/week	No Impact.	
		2/3/99 - 2/10/99	Use GLD & CAN HEF overlap [6 2-hr passes/week?]. Supplement with BWG to total 7 4-hr passes/week. Some coverage from all 3 stations required.	No Impact.	BWG: 7 4-hr passes/week	No Impact.	
		2/11/99 - 2/17/99	HEF [MAD only]: 7 4-hr passes/week	Reduced Nav accuracy	BWG: 7 4-hr passes/week	No Impact.	• MGS diametric occultations
		2/18/99 - 2/22/99	BWG: 7 4-hr passes/week	No Impact.	Use GLD & CAN HEF overlap [6 2-hr passes/week?].	Reduced monitoring, nav accuracy	
		2/23/99 - 3/5/99	BWG: 7 4-hr passes/week from GLD & CAN	Reduced Nav accuracy	HEF: GLD 4 hr/day, CAN 1 hr/day	Reduced nav accuracy	
# 8 [5/3/99 - 5/9/99]	M98 Lander and Orbiter use BWG (RAP)	5/3/99 - 5/9/99	BWG: 7 4-hr passes/week	No Impact.	Use GLD/CAN HEF overlap [7 3-hr passes/week?]. Supplement with BWG to total 7 4-hr passes/week. Some coverage from all 3 stations required.	No Impact.	• Lander's use of BWG requires deadbands tightened to $\pm 9'$, leading to minimal propellant hit [< 0.1 kg].
# 9 [6/21/99 - 7/25/99]	M98 Lander & Orbiter use BWG every 3rd day (RAP)	6/21/99 - 7/25/99	1 4-hr HEF pass/day* except every 3rd day, go to 1 4-hr BWG pass.	No Impact.	No action required.	No impact.	
# 10 [7/26/99 - 8/15/99]	M98 Lander & Orbiter use BWG (RAP)	8/2/99 - 8/9/99	BWG: 7 4-hr passes/week	No Impact.	Use GLD/CAN HEF overlap [7 3-hr passes/week?]. Supplement with BWG to total 7 4-hr passes/week. Some coverage from all 3 stations required.	No Impact.	• Lander's use of BWG may require deadbands tightened to $\pm$ TBD*, leading to propellant hit.
# 11 [8/16/99 - 10/16/99]	M98 Lander use BWG (RAP)	8/16/99 - 10/16/99	No action required. Orbiter receives needed HEF tracking during approach.	No Impact.	Lander uses HEF throughout. 1 4-hr pass/day* except every 3rd day, the Lander pass is truncated to fit within DSN capability.	Reduction in monitoring. Other impacts TBD [e.g. impact on TCM-3 10/4/99].	• Lander alternative: use BWG during 8/16-9/10/99 only, requiring deadbands tightened to $\pm 2'$ for 25 days, leading to propellant hit of 0.1 kg. + TBD impacts.
# 12 [10/18/99 - 12/5/99]	Give Stardust 6 contiguous hrs/week of HEF time. (Stardust)	10/18/99 - 12/5/99	No action required. Orbiter receives needed HEF tracking during aerobraking.	No Impact.	Lander gets requisite HEF tracking [near-simultaneous w/ Orbiter] except for Stardust tracks. Per 4/24/97 agreement, no Stardust tracks occur 11/26/99 - 12/5/99.	No impact.	
week 38-39, 1999	Accept 2-3 hr/day gap in continuous 70m coverage for Orbiter. (GLL)	9/21/99 - 9/25/99	Accept, per GLL memo 4/1/97, 2-3 hr gap in continuous 70m coverage.	No Impact	No action required.	No impact.	
week 48 - 49, 1999	Maximize use of Canberra 70m antenna for Lander D/L during Sol 0,1. (GLL)	12/1/99 - 12/5/99	Accept, per GLL memo 4/1/97, reduction in DSS-14 [Goldstone] coverage in favor of DSS-43 [Canberra].	No Impact	No action required.	No impact..	

* Baseline Coverage

Legend: GLD = Goldstone, MAD = Madrid, CAN = Canberra

Integrated Tracking Schedule
Near-Simultaneous Tracking
Open Primary [Starting E-30d]

Assumptions:

- Minimum 2 hr / lander track
- Minimum 1h 24 m between tracks
- 4 on/ 5 off or equivalent
- Use 0.5h Orbiter tracks and 4 on/5 off Lander tracks 2d before end of AB
- End near-simul tracking NLT Entry-30h

Days	to s/c.	Start	Track 1	End
Entry	antenna	Track	duration	Track
-30.7	Orb.HEF	11/3/99 4:25	3.83	11/3/99 8:15
-30.5	Lander	11/3/99 9:39	2.05	11/3/99 11:42
-30.3	Orb.HEF	11/3/99 13:06	3.77	11/3/99 16:52
-30.1	Lander	11/3/99 18:16	4.00	11/3/99 22:16
-30.0	Orb.BWG	11/3/99 21:40	3.72	11/4/99 1:24
-29.6	Orb.HEF	11/4/99 6:06	3.68	11/4/99 9:46
-29.4	Lander	11/4/99 11:10	4.00	11/4/99 15:10
-29.3	Orb.BWG	11/4/99 14:26	3.62	11/4/99 18:03
-28.9	Orb.HEF	11/4/99 22:38	3.57	11/5/99 2:12
-28.7	Lander	11/5/99 3:36	4.00	11/5/99 7:36
-28.6	Orb.BWG	11/5/99 6:45	3.53	11/5/99 10:17
-28.3	Orb.HEF	11/5/99 14:44	3.47	11/5/99 18:13
-28.1	Lander	11/5/99 19:37	4.00	11/5/99 23:37
-27.9	Orb.BWG	11/5/99 22:37	3.43	11/6/99 2:03
-27.6	Orb.HEF	11/6/99 6:25	3.39	11/6/99 9:48
-27.4	Lander	11/6/99 11:12	4.00	11/6/99 15:12
-27.3	Orb.BWG	11/6/99 14:05	3.34	11/6/99 17:26
-27.0	Orb.HEF	11/6/99 21:40	3.30	11/7/99 0:59
-26.8	Lander	11/7/99 2:23	4.00	11/7/99 6:23
-26.7	Orb.BWG	11/7/99 5:10	3.25	11/7/99 8:25
-26.3	Orb.HEF	11/7/99 12:33	3.21	11/7/99 15:46
-26.2	Lander	11/7/99 17:10	4.00	11/7/99 21:10
-26.0	Orb.BWG	11/7/99 19:51	3.18	11/7/99 23:02
-25.7	Orb.HEF	11/8/99 3:03	3.13	11/8/99 6:11
-25.6	Lander	11/8/99 7:35	4.00	11/8/99 11:35
-25.4	Orb.BWG	11/8/99 10:09	3.10	11/8/99 13:15
-25.2	Orb.HEF	11/8/99 17:11	3.05	11/8/99 20:14
-25.0	Lander	11/8/99 21:38	4.00	11/9/99 1:38
-24.9	Orb.BWG	11/9/99 0:07	3.02	11/9/99 3:09
-24.6	Orb.HEF	11/9/99 6:58	2.98	11/9/99 9:57
-24.4	Lander	11/9/99 11:21	4.00	11/9/99 15:21
-24.3	Orb.BWG	11/9/99 13:44	2.94	11/9/99 16:41
-24.0	Orb.HEF	11/9/99 20:26	2.91	11/9/99 23:20
-23.8	Lander	11/10/99 0:44	4.00	11/10/99 4:44
-23.7	Orb.BWG	11/10/99 3:02	2.87	11/10/99 5:54
-23.5	Orb.HEF	11/10/99 9:33	2.84	11/10/99 12:24
-23.3	Lander	11/10/99 13:48	4.00	11/10/99 17:48
-23.2	Orb.BWG	11/10/99 15:59	2.81	11/10/99 18:48
-22.9	Orb.HEF	11/10/99 22:22	2.78	11/11/99 1:09
-22.8	Lander	11/11/99 2:33	4.00	11/11/99 6:33
-22.7	Orb.BWG	11/11/99 4:40	2.75	11/11/99 7:24
-22.4	Orb.HEF	11/11/99 10:54	2.72	11/11/99 13:37
-22.2	Lander	11/11/99 15:01	4.00	11/11/99 19:01
-22.2	Orb.BWG	11/11/99 17:04	2.68	11/11/99 19:45
-21.9	Orb.HEF	11/11/99 23:09	2.65	11/12/99 1:48
-21.7	Lander	11/12/99 3:12	4.00	11/12/99 7:12
-21.7	Orb.BWG	11/12/99 5:10	2.62	11/12/99 7:47
-21.4	Orb.HEF	11/12/99 11:06	2.59	11/12/99 13:41
-21.2	Lander	11/12/99 15:05	4.00	11/12/99 19:05
-21.2	Orb.BWG	11/12/99 16:59	2.56	11/12/99 19:32
-20.9	Orb.HEF	11/12/99 22:47	2.53	11/13/99 1:19
-20.8	Lander	11/13/99 2:43	4.00	11/13/99 6:43
-20.7	Orb.BWG	11/13/99 4:31	2.50	11/13/99 7:01
-20.4	Orb.HEF	11/13/99 10:11	2.47	11/13/99 12:39
-20.3	Lander	11/13/99 14:03	4.00	11/13/99 18:03
-20.2	Orb.BWG	11/13/99 15:47	2.44	11/13/99 18:13
-20.0	Orb.HEF	11/13/99 21:19	2.41	11/13/99 23:44
-19.8	Lander	11/14/99 1:08	4.00	11/14/99 5:08
-19.8	Orb.BWG	11/14/99 2:48	2.39	11/14/99 5:11
-19.5	Orb.HEF	11/14/99 8:13	2.36	11/14/99 10:35

**Integrated Tracking Schedule
Near-Simultaneous Tracking
Open Primary [Starting E-30d]**

Days	s/c.	Start	Track 1	End
to	antenna	Track	duration	Track
Entry			h	
-19.4	Lander	11/14/99 11:59	4.00	11/14/99 15:59
-19.3	Orb.BWG	11/14/99 13:34	2.34	11/14/99 15:54
-19.1	Orb.HEF	11/14/99 18:52	2.31	11/14/99 21:11
-18.9	Lander	11/14/99 22:35	4.00	11/15/99 2:35
-18.9	Orb.BWG	11/15/99 0:06	2.28	11/15/99 2:23
-18.6	Orb.HEF	11/15/99 5:17	2.25	11/15/99 7:33
-18.5	Lander	11/15/99 8:57	4.00	11/15/99 12:57
-18.4	Orb.BWG	11/15/99 10:24	2.22	11/15/99 12:38
-18.2	Orb.HEF	11/15/99 15:28	2.20	11/15/99 17:40
-18.1	Lander	11/15/99 19:04	4.00	11/15/99 23:04
-18.0	Orb.BWG	11/15/99 20:28	2.17	11/15/99 22:38
-17.8	Orb.HEF	11/16/99 1:24	2.15	11/16/99 3:33
-17.7	Lander	11/16/99 4:57	4.00	11/16/99 8:57
-17.6	Orb.BWG	11/16/99 6:17	2.13	11/16/99 8:24
-17.4	Orb.HEF	11/16/99 11:06	2.10	11/16/99 13:12
-17.3	Lander	11/16/99 14:36	4.00	11/16/99 18:36
-17.2	Orb.BWG	11/16/99 15:53	2.08	11/16/99 17:58
-17.0	Orb.HEF	11/16/99 20:36	2.06	11/16/99 22:40
-16.9	Lander	11/17/99 0:04	4.00	11/17/99 4:04
-16.8	Orb.BWG	11/17/99 1:17	2.04	11/17/99 3:20
-16.6	Orb.HEF	11/17/99 5:55	2.02	11/17/99 7:56
-16.5	Lander	11/17/99 9:20	4.00	11/17/99 13:20
-16.4	Orb.BWG	11/17/99 10:31	2.00	11/17/99 12:31
-16.2	Orb.HEF	11/17/99 15:02	1.98	11/17/99 17:01
-16.1	Lander	11/17/99 18:25	3.95	11/17/99 22:22
-16.1	Orb.BWG	11/17/99 19:32	1.95	11/17/99 21:29
-15.9	Orb.HEF	11/17/99 23:58	1.93	11/18/99 1:54
-15.7	Lander	11/18/99 3:18	3.87	11/18/99 7:10
-15.7	Orb.BWG	11/18/99 4:21	1.91	11/18/99 6:16
-15.5	Orb.HEF	11/18/99 8:42	1.89	11/18/99 10:36
-15.4	Lander	11/18/99 12:00	3.78	11/18/99 15:46
-15.3	Orb.BWG	11/18/99 13:00	1.87	11/18/99 14:52
-15.2	Orb.HEF	11/18/99 17:15	1.85	11/18/99 19:06
-15.0	Lander	11/18/99 20:30	3.69	11/19/99 0:12
-15.0	Orb.BWG	11/18/99 21:27	1.83	11/18/99 23:17
-14.8	Orb.HEF	11/19/99 1:36	1.81	11/19/99 3:25
-14.7	Lander	11/19/99 4:49	3.57	11/19/99 8:23
-14.6	Orb.BWG	11/19/99 5:42	1.79	11/19/99 7:30
-14.5	Orb.HEF	11/19/99 9:47	1.77	11/19/99 11:33
-14.3	Lander	11/19/99 12:57	3.44	11/19/99 16:24
-14.3	Orb.BWG	11/19/99 13:49	1.75	11/19/99 15:34
-14.1	Orb.HEF	11/19/99 17:48	1.73	11/19/99 19:32
-14.0	Lander	11/19/99 20:56	3.29	11/20/99 0:14
-14.0	Orb.BWG	11/19/99 21:44	1.71	11/19/99 23:27
-13.8	Orb.HEF	11/20/99 1:38	1.70	11/20/99 3:19
-13.7	Lander	11/20/99 4:43	3.19	11/20/99 7:55
-13.6	Orb.BWG	11/20/99 5:30	1.68	11/20/99 7:10
-13.5	Orb.HEF	11/20/99 9:19	1.66	11/20/99 10:58
-13.4	Lander	11/20/99 12:22	3.05	11/20/99 15:25
-13.3	Orb.BWG	11/20/99 13:05	1.65	11/20/99 14:43
-13.2	Orb.HEF	11/20/99 16:49	1.63	11/20/99 18:27
-13.0	Lander	11/20/99 19:51	2.94	11/20/99 22:47
-13.0	Orb.BWG	11/20/99 20:31	1.61	11/20/99 22:08
-12.9	Orb.HEF	11/21/99 0:11	1.59	11/21/99 1:47
-12.7	Lander	11/21/99 3:11	2.81	11/21/99 6:00
-12.7	Orb.BWG	11/21/99 3:49	1.58	11/21/99 5:24
-12.6	Orb.HEF	11/21/99 7:24	1.56	11/21/99 8:57
-12.4	Lander	11/21/99 10:21	2.69	11/21/99 13:03
-12.4	Orb.BWG	11/21/99 10:57	1.55	11/21/99 12:30
-12.3	Orb.HEF	11/21/99 14:27	1.53	11/21/99 15:59

**Integrated Tracking Schedule
Near-Simultaneous Tracking
Open Primary [Starting E-30d]**

Days to Entry	s/c. antenna	Start Track	Track 1 duration h	End Track
-12.1	Lander	11/21/99 17:23	2.61	11/21/99 19:59
-12.1	Orb.BWG	11/21/99 17:56	1.52	11/21/99 19:27
-12.0	Orb.HEF	11/21/99 21:23	1.50	11/21/99 22:53
-11.9	Lander	11/22/99 0:17	2.47	11/22/99 2:45
-11.8	Orb.BWG	11/22/99 0:48	1.49	11/22/99 2:17
-11.7	Orb.HEF	11/22/99 4:09	1.48	11/22/99 5:38
-11.6	Lander	11/22/99 7:02	2.40	11/22/99 9:26
-11.6	Orb.BWG	11/22/99 7:31	1.47	11/22/99 8:59
-11.4	Orb.HEF	11/22/99 10:50	1.46	11/22/99 12:17
-11.3	Lander	11/22/99 13:41	2.36	11/22/99 16:03
-11.3	Orb.BWG	11/22/99 14:10	1.45	11/22/99 15:37
-11.1	Orb.HEF	11/22/99 17:27	1.45	11/22/99 18:54
-11.0	Lander	11/22/99 20:18	2.31	11/22/99 22:36
-11.0	Orb.BWG	11/22/99 20:44	1.44	11/22/99 22:11
-10.9	Orb.HEF	11/23/99 0:00	1.43	11/23/99 1:26
-10.8	Lander	11/23/99 2:50	2.23	11/23/99 5:04
-10.7	Orb.BWG	11/23/99 3:15	1.42	11/23/99 4:40
-10.6	Orb.HEF	11/23/99 6:28	1.41	11/23/99 7:52
-10.5	Lander	11/23/99 9:16	2.17	11/23/99 11:27
-10.5	Orb.BWG	11/23/99 9:39	1.40	11/23/99 11:03
-10.3	Orb.HEF	11/23/99 12:51	1.39	11/23/99 14:14
-10.2	Lander	11/23/99 15:38	2.08	11/23/99 17:43
-10.2	Orb.BWG	11/23/99 16:00	1.38	11/23/99 17:22
-10.1	Orb.HEF	11/23/99 19:07	1.37	11/23/99 20:29
-10.0	Lander	11/23/99 21:53	2.03	11/23/99 23:54
-9.9	Orb.BWG	11/23/99 22:14	1.36	11/23/99 23:35
-9.8	Orb.HEF	11/24/99 1:18	1.35	11/24/99 2:39
-9.7	Lander	11/24/99 4:03	4.00	11/24/99 8:03
-9.7	Orb.BWG	11/24/99 4:23	1.34	11/24/99 5:43
-9.6	Orb.BWG	11/24/99 7:24	1.33	11/24/99 8:44
-9.4	Orb.HEF	11/24/99 10:26	1.32	11/24/99 11:45
-9.3	Lander	11/24/99 13:09	3.96	11/24/99 17:06
-9.3	Orb.BWG	11/24/99 13:26	1.31	11/24/99 14:44
-9.2	Orb.BWG	11/24/99 16:24	1.30	11/24/99 17:42
-9.1	Orb.HEF	11/24/99 19:21	1.30	11/24/99 20:39
-9.0	Lander	11/24/99 22:03	3.88	11/25/99 1:56
-8.9	Orb.BWG	11/24/99 22:17	1.29	11/24/99 23:34
-8.8	Orb.BWG	11/25/99 1:13	1.28	11/25/99 2:30
-8.7	Orb.HEF	11/25/99 4:07	1.27	11/25/99 5:23
-8.6	Lander	11/25/99 6:47	3.82	11/25/99 10:37
-8.6	Orb.BWG	11/25/99 7:01	1.27	11/25/99 8:17
-8.5	Orb.BWG	11/25/99 9:53	1.26	11/25/99 11:08
-8.3	Orb.HEF	11/25/99 12:44	1.25	11/25/99 13:59
-8.2	Lander	11/25/99 15:23	3.76	11/25/99 19:09
-8.2	Orb.BWG	11/25/99 15:35	1.24	11/25/99 16:50
-8.1	Orb.BWG	11/25/99 18:24	1.24	11/25/99 19:38
-8.0	Orb.HEF	11/25/99 21:12	1.23	11/25/99 22:26
-7.9	Lander	11/25/99 23:50	3.69	11/26/99 3:32
-7.9	Orb.BWG	11/26/99 0:01	1.22	11/26/99 1:14
-7.8	Orb.BWG	11/26/99 2:47	1.21	11/26/99 3:59
-7.6	Orb.HEF	11/26/99 5:32	1.20	11/26/99 6:44
-7.5	Lander	11/26/99 8:08	3.59	11/26/99 11:44
-7.5	Orb.BWG	11/26/99 8:15	1.19	11/26/99 9:27
-7.4	Orb.BWG	11/26/99 10:58	1.18	11/26/99 12:09
-7.3	Orb.HEF	11/26/99 13:39	1.17	11/26/99 14:50
-7.2	Lander	11/26/99 16:14	3.52	11/26/99 19:45
-7.2	Orb.BWG	11/26/99 16:19	1.17	11/26/99 17:29
-7.1	Orb.BWG	11/26/99 18:57	1.16	11/26/99 20:07
-7.0	Orb.HEF	11/26/99 21:36	1.15	11/26/99 22:45
-6.9	Lander	11/27/99 0:09	3.45	11/27/99 3:36

Integrated Tracking Schedule
Near-Simultaneous Tracking
Open Primary [Starting E-30d]

Orbiting Schedule ous Tracking [Starting E-30d]	Days		Track 1		
	to	s/c.	Start	duration	End
Entry	antenna	Track	h	Track	
-6.9	Orb.BWG	11/27/99 0:11	1.14	11/27/99 1:20	
-6.8	Orb.BWG	11/27/99 2:47	1.13	11/27/99 3:55	
-6.6	Orb.HEF	11/27/99 5:23	1.13	11/27/99 6:30	
-6.5	Lander	11/27/99 7:54	3.38	11/27/99 11:17	
-6.5	Orb.BWG	11/27/99 7:55	1.12	11/27/99 9:02	
-6.4	Orb.BWG	11/27/99 10:28	1.11	11/27/99 11:35	
-6.3	Orb.HEF	11/27/99 13:01	1.11	11/27/99 14:07	
-6.2	Orb.BWG	11/27/99 15:31	1.10	11/27/99 16:37	
-6.2	Lander	11/27/99 15:31	3.32	11/27/99 18:50	
-6.1	Orb.BWG	11/27/99 18:01	1.09	11/27/99 19:06	
-6.0	Orb.HEF	11/27/99 20:30	1.09	11/27/99 21:36	
-5.9	Orb.BWG	11/27/99 22:59	1.08	11/28/99 0:03	
-5.9	Lander	11/27/99 23:00	3.25	11/28/99 2:15	
-5.8	Orb.BWG	11/28/99 1:26	1.07	11/28/99 2:30	
-5.7	Orb.HEF	11/28/99 3:51	1.06	11/28/99 4:55	
-5.6	Orb.BWG	11/28/99 6:15	1.05	11/28/99 7:18	
-5.6	Lander	11/28/99 6:19	3.17	11/28/99 9:29	
-5.5	Orb.BWG	11/28/99 8:38	1.04	11/28/99 9:40	
-5.4	Orb.HEF	11/28/99 11:01	1.03	11/28/99 12:03	
-5.3	Orb.BWG	11/28/99 13:22	1.02	11/28/99 14:23	
-5.3	Lander	11/28/99 13:27	3.10	11/28/99 16:32	
-5.2	Orb.BWG	11/28/99 15:42	1.02	11/28/99 16:43	
-5.1	Orb.HEF	11/28/99 18:00	1.01	11/28/99 19:00	
-5.0	Orb.BWG	11/28/99 20:17	1.00	11/28/99 21:17	
-5.0	Lander	11/28/99 20:24	3.01	11/28/99 23:25	
-4.9	Orb.BWG	11/28/99 22:34	0.99	11/28/99 23:33	
-4.8	Orb.HEF	11/29/99 0:49	0.99	11/29/99 1:49	
-4.7	Orb.BWG	11/29/99 3:03	0.98	11/29/99 4:02	
-4.7	Lander	11/29/99 3:12	2.89	11/29/99 6:06	
-4.6	Orb.BWG	11/29/99 5:17	0.97	11/29/99 6:16	
-4.6	Orb.HEF	11/29/99 7:30	0.96	11/29/99 8:28	
-4.5	Orb.BWG	11/29/99 9:41	0.50	11/29/99 10:11	
-4.4	Orb.BWG	11/29/99 11:52	0.50	11/29/99 12:22	
-4.3	Lander	11/29/99 12:52	4.00	11/29/99 16:52	
-4.3	Orb.BWG	11/29/99 14:02	0.50	11/29/99 14:32	
-4.2	Orb.BWG	11/29/99 16:10	0.50	11/29/99 16:40	
-4.1	Orb.HEF	11/29/99 18:17	0.50	11/29/99 18:47	
-4.0	Orb.BWG	11/29/99 20:24	0.50	11/29/99 20:54	
-4.0	Lander	11/29/99 21:52	4.00	11/30/99 1:52	
-3.9	Orb.BWG	11/29/99 22:28	0.50	11/29/99 22:58	
-3.8	Orb.BWG	11/30/99 0:31	0.50	11/30/99 1:01	
-3.8	Orb.BWG	11/30/99 2:34	0.50	11/30/99 3:04	
-3.7	Orb.HEF	11/30/99 4:34	0.50	11/30/99 5:04	
-3.6	Orb.BWG	11/30/99 6:32	0.50	11/30/99 7:02	
-3.6	Lander	11/30/99 6:52	4.00	11/30/99 10:52	
-3.5	Orb.BWG	11/30/99 8:31	0.50	11/30/99 9:01	
-3.4	Orb.BWG	11/30/99 10:29	0.50	11/30/99 10:59	
-3.4	Orb.HEF	11/30/99 12:25	0.50	11/30/99 12:55	
-3.3	Orb.BWG	11/30/99 14:21	0.50	11/30/99 14:51	
-3.2	Lander	11/30/99 15:52	4.00	11/30/99 19:52	
-3.2	Orb.BWG	11/30/99 16:17	0.50	11/30/99 16:47	
-3.1	Orb.BWG	11/30/99 18:14	0.50	11/30/99 18:44	
-3.0	Orb.BWG	11/30/99 20:08	0.50	11/30/99 20:38	
-3.0	Orb.HEF	11/30/99 22:03	0.50	11/30/99 22:33	
-2.9	Orb.BWG	11/30/99 23:58	0.50	12/1/99 0:28	
-2.8	Lander	12/1/99 0:52	4.00	12/1/99 4:52	
-2.8	Orb.BWG	12/1/99 1:53	0.50	12/1/99 2:23	
-2.7	Orb.BWG	12/1/99 3:47	0.50	12/1/99 4:17	
-2.6	Orb.BWG	12/1/99 5:41	0.50	12/1/99 6:11	
-2.5	Orb.BWG	12/1/99 8:09	1.35	12/1/99 9:30	

Integrated Tracking Schedule		Days	Track 1	
Near-Simultaneous Tracking		to s/c.	Start	End
Open Primary [Starting E-30d]		Entry antenna	Track	Track
Start Transfer to Map	-2.5	Lander	12/1/99 9:52	12/1/99 13:52
	-2.4	Orb.BWG	12/1/99 11:37	12/1/99 12:37
	-2.3	Orb.BWG	12/1/99 13:36	12/1/99 14:36
	-2.2	Orb.HEF	12/1/99 15:34	12/1/99 16:34
	-2.1	Orb.BWG	12/1/99 17:33	12/1/99 18:33
	-2.1	Lander	12/1/99 18:52	12/1/99 22:52
	-2.1	Orb.BWG	12/1/99 19:31	12/1/99 20:31
	-2.0	Orb.BWG	12/1/99 21:30	12/1/99 22:30
	-1.9	Orb.BWG	12/1/99 23:29	12/2/99 0:29
	-1.8	Orb.HEF	12/2/99 1:27	12/2/99 2:27
	-1.7	Orb.BWG	12/2/99 3:26	12/2/99 4:26
	-1.7	Lander	12/2/99 3:52	12/2/99 7:52
	-1.6	Orb.BWG	12/2/99 5:24	12/2/99 6:24
	-1.6	Orb.BWG	12/2/99 7:23	12/2/99 8:23
Last Near Simultaneous track	-1.5	Orb.HEF	12/2/99 9:22	12/2/99 10:22
	-1.4	Orb.BWG	12/2/99 11:20	12/2/99 12:20
	-1.3	Lander	12/2/99 12:52	12/2/99 16:52
	-1.3	Orb.BWG	12/2/99 13:19	12/2/99 14:19
	-1.2	Orb.BWG	12/2/99 15:18	12/2/99 16:18
	-1.1	Orb.BWG	12/2/99 17:16	12/2/99 18:16
	-1.1	Orb.BWG	12/2/99 19:15	12/2/99 20:15
	-1.0	Orb.BWG	12/2/99 21:13	12/2/99 22:13
	-1.0	Lander	12/2/99 21:52	12/3/99 1:52
	-0.9	Orb.BWG	12/2/99 23:12	12/3/99 0:12
	-0.8	Orb.BWG	12/3/99 1:11	12/3/99 2:11
	-0.7	Orb.BWG	12/3/99 3:09	12/3/99 4:09
Final Track pre TCM-5	-0.7	Orb.BWG	12/3/99 5:08	12/3/99 6:08
	-0.6	Lander	12/3/99 6:52	12/3/99 10:52
	-0.6	Orb.BWG	12/3/99 7:07	12/3/99 8:07
	-0.5	Orb.BWG	12/3/99 9:05	12/3/99 10:05
	-0.4	Orb.BWG	12/3/99 11:04	12/3/99 12:04
	-0.3	Lander	12/3/99 12:57	12/3/99 13:27
	-0.3	Orb.BWG	12/3/99 13:02	12/3/99 14:02
	-0.3	TCM-5	12/3/99 13:32	12/3/99 14:07
	-0.2	Orb.BWG	12/3/99 15:01	12/3/99 16:01
	-0.2	Lander	12/3/99 15:52	12/3/99 16:52
DSN-3	-0.2	Orb.BWG	12/3/99 17:00	12/3/99 18:00
	-0.1	Orb.BWG	12/3/99 18:58	12/3/99 19:58
DSN-4	0.0	Lander	12/3/99 20:27	12/3/99 20:42
	0.0	Landing	12/3/99 20:56	12/3/99 20:56
	0.0	Orb.BWG	12/3/99 20:57	12/3/99 21:57

E-30d

Near-Simultaneous Tracking:

1hr 24 min. separation between tracks



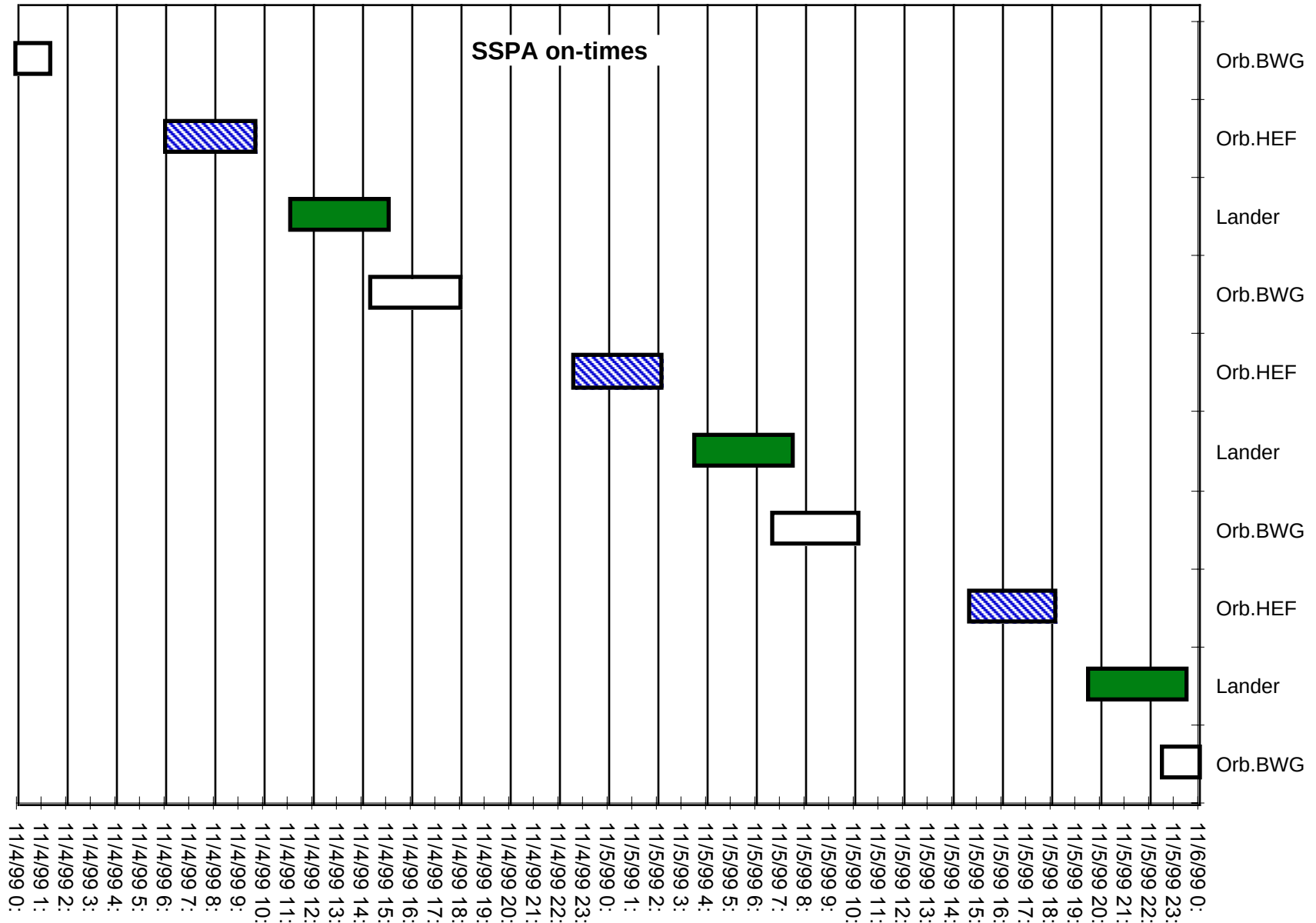
Lander HEF



Orbiter HEF



Orbiter BWG Track



E-20d Near-Simultaneous Tracking:

1hr 24 min. separation between tracks



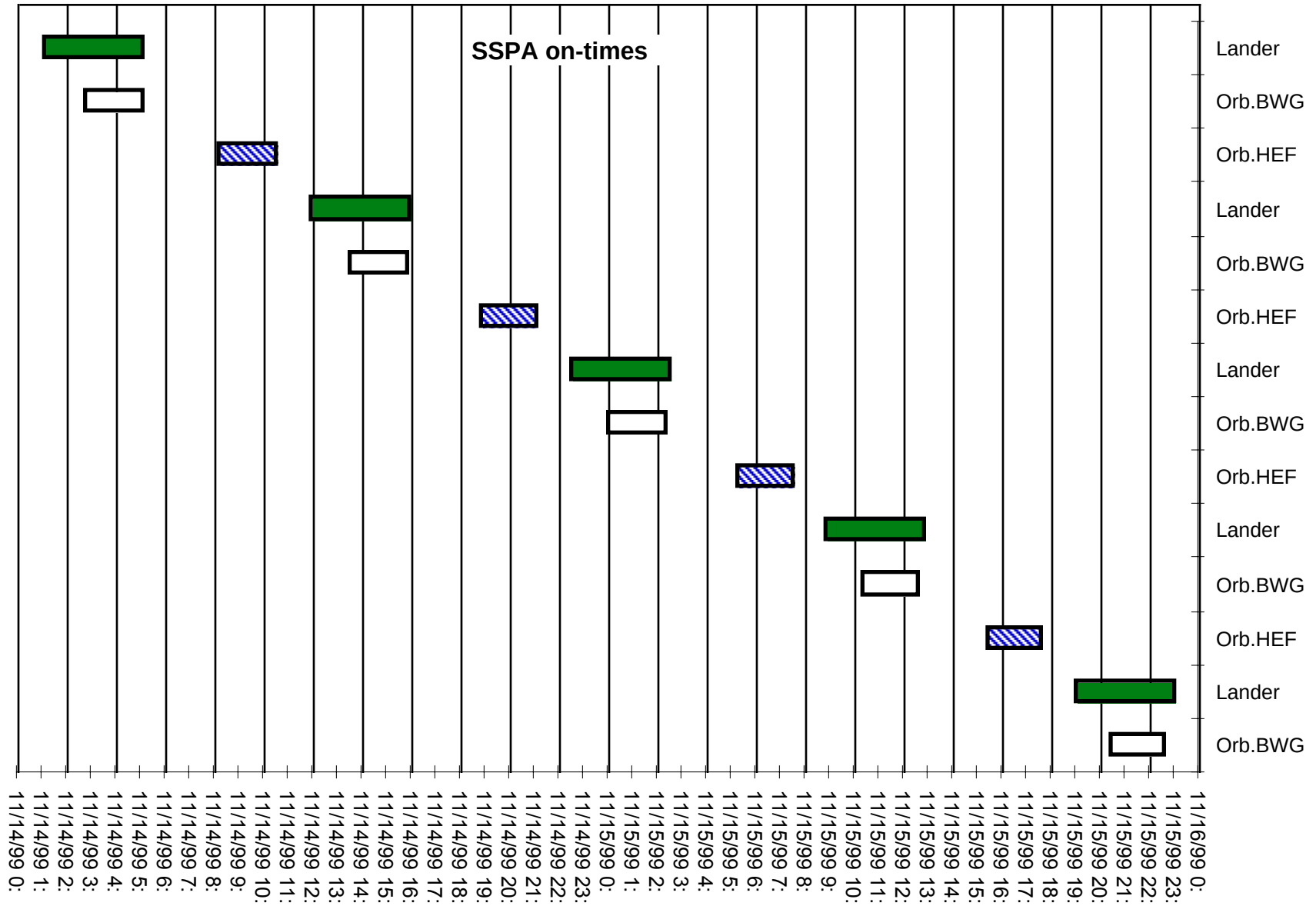
Lander HEF



Orbiter HEF



Orbiter BWG Track



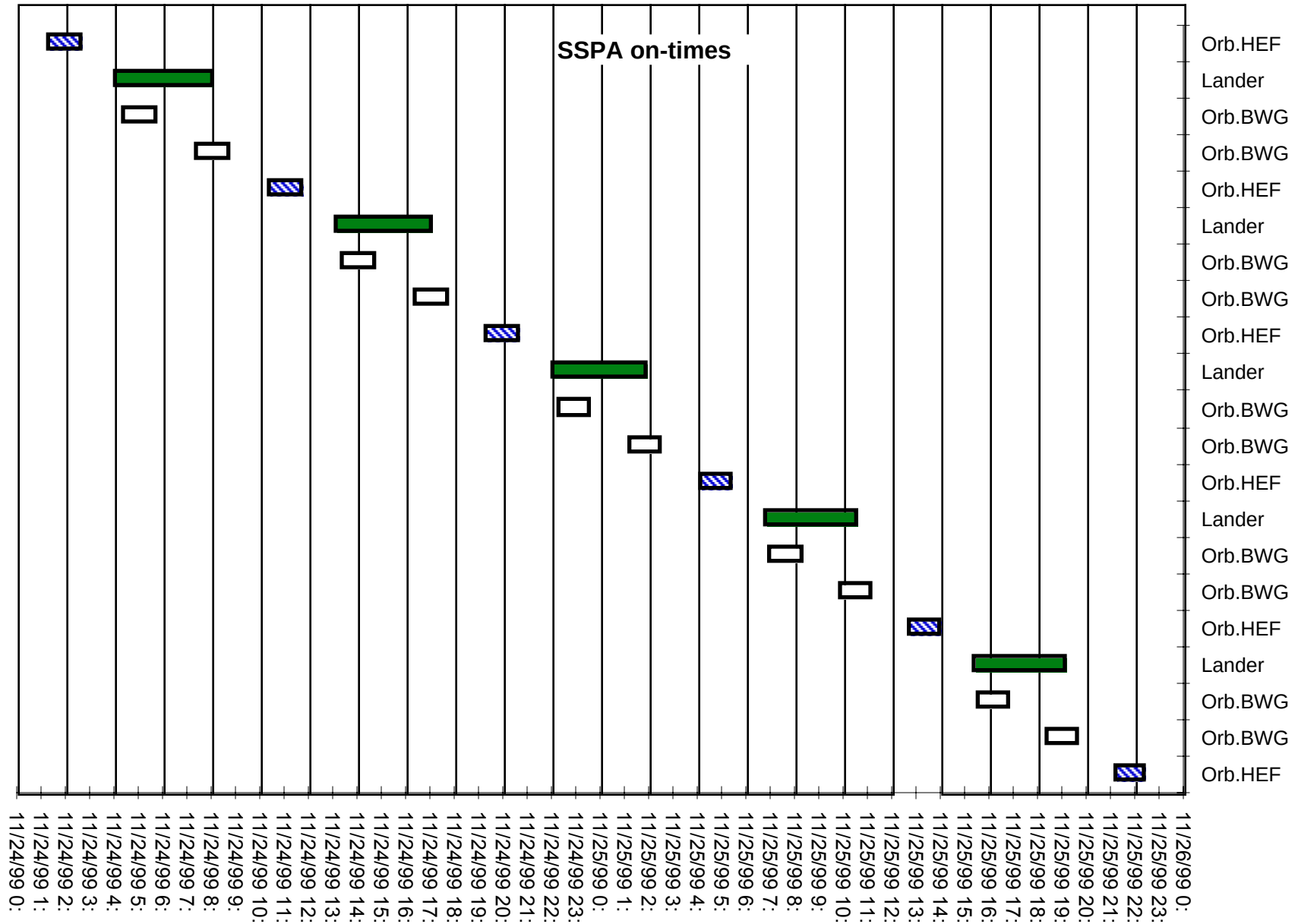
E-10d Near-Simultaneous Tracking:

Lander HEF

Orbiter HEF

Orbiter BWG Track

1hr 24 min. separation between tracks



E-4d Near-Simultaneous Tracking:

1hr 24 min. separation between tracks



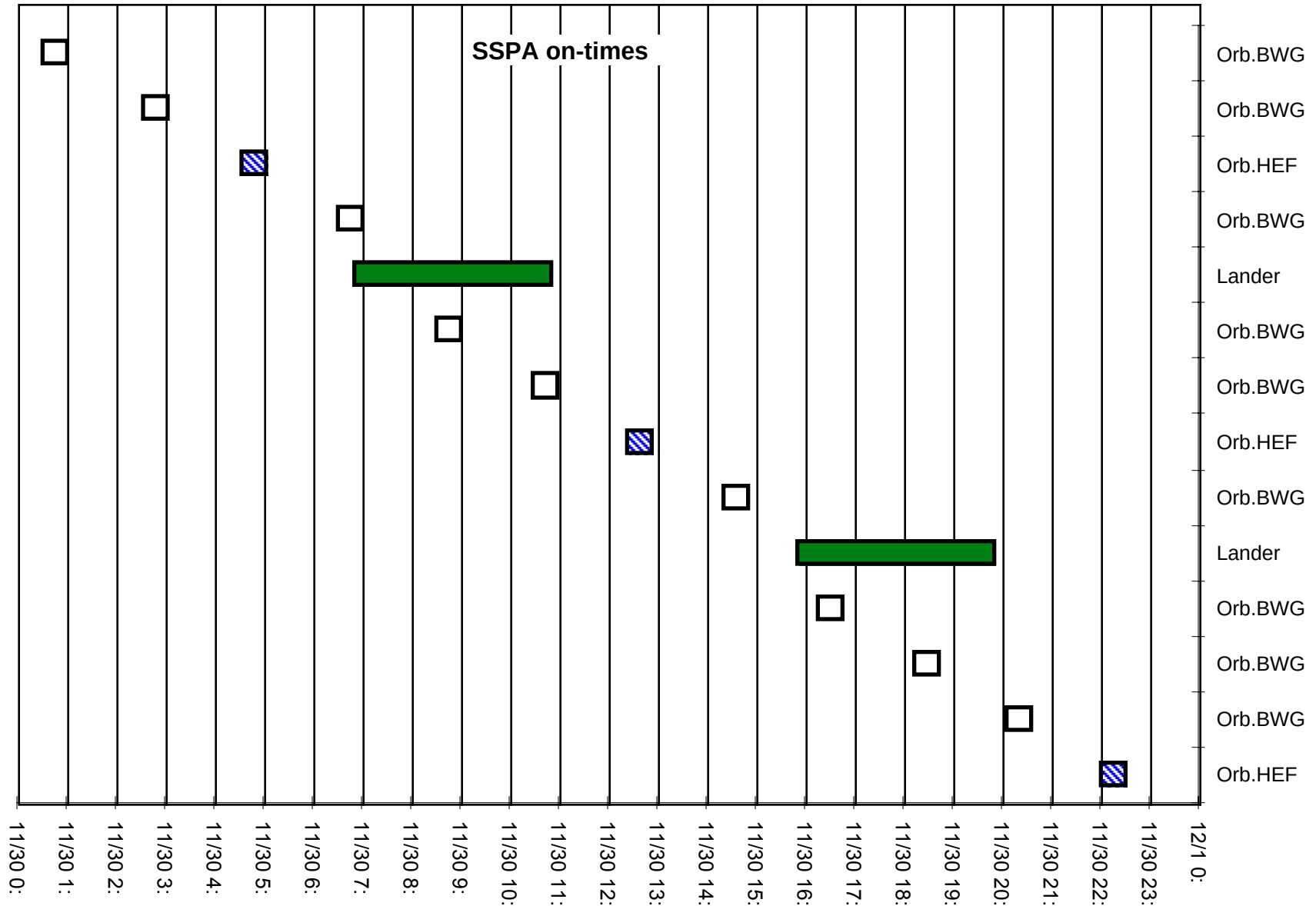
Lander HEF



Orbiter HEF



Orbiter BWG Track



E-3d Near-Simultaneous Tracking:

1hr 24 min. separation between tracks



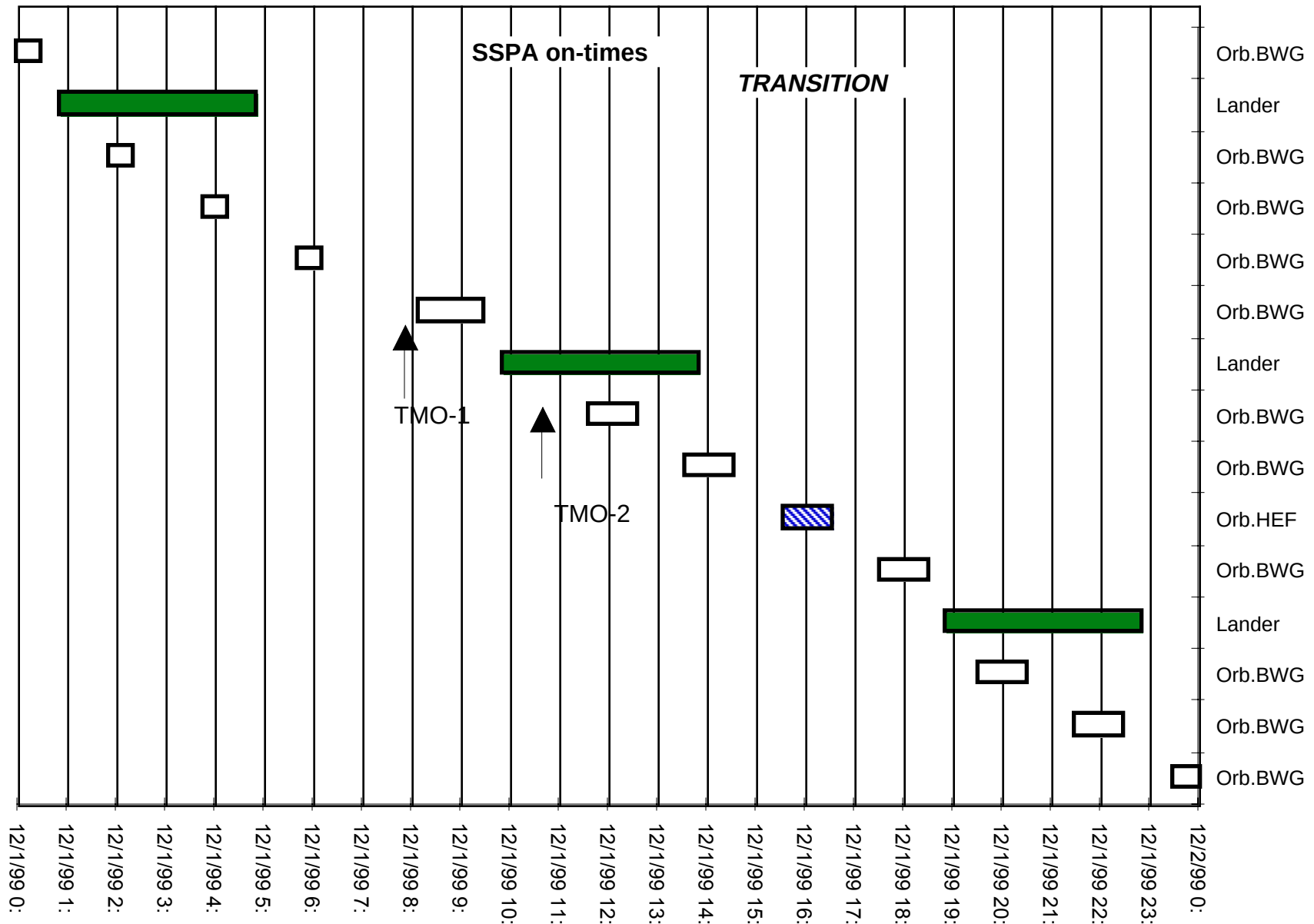
Lander HEF



Orbiter HEF



Orbiter BWG Track (Optional)



E-2d End Near-Simultaneous Tracking:

1hr 24 min. separation between tracks



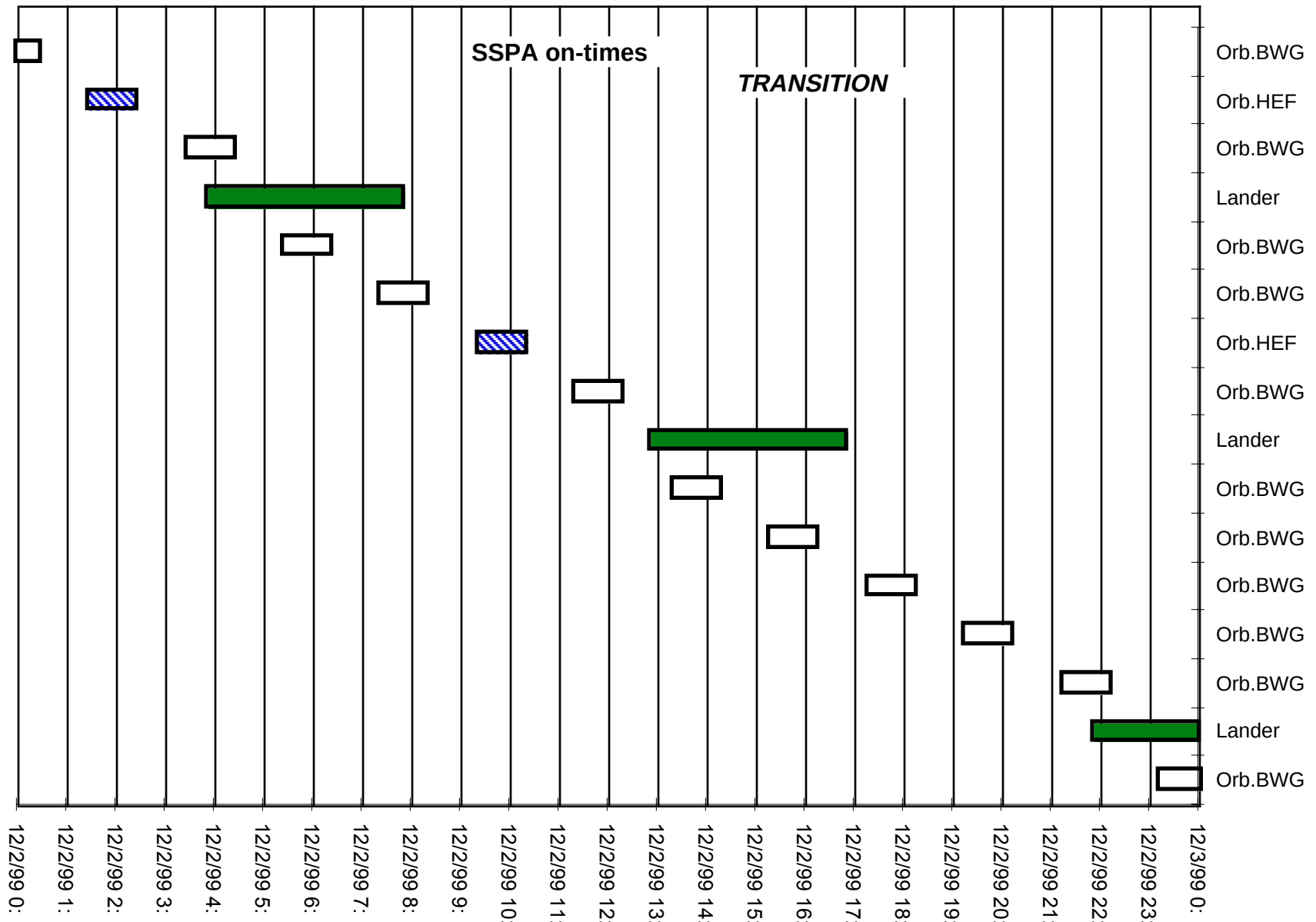
Lander HEF



Orbiter HEF



Orbiter BWG Track (Optional)



E-1d



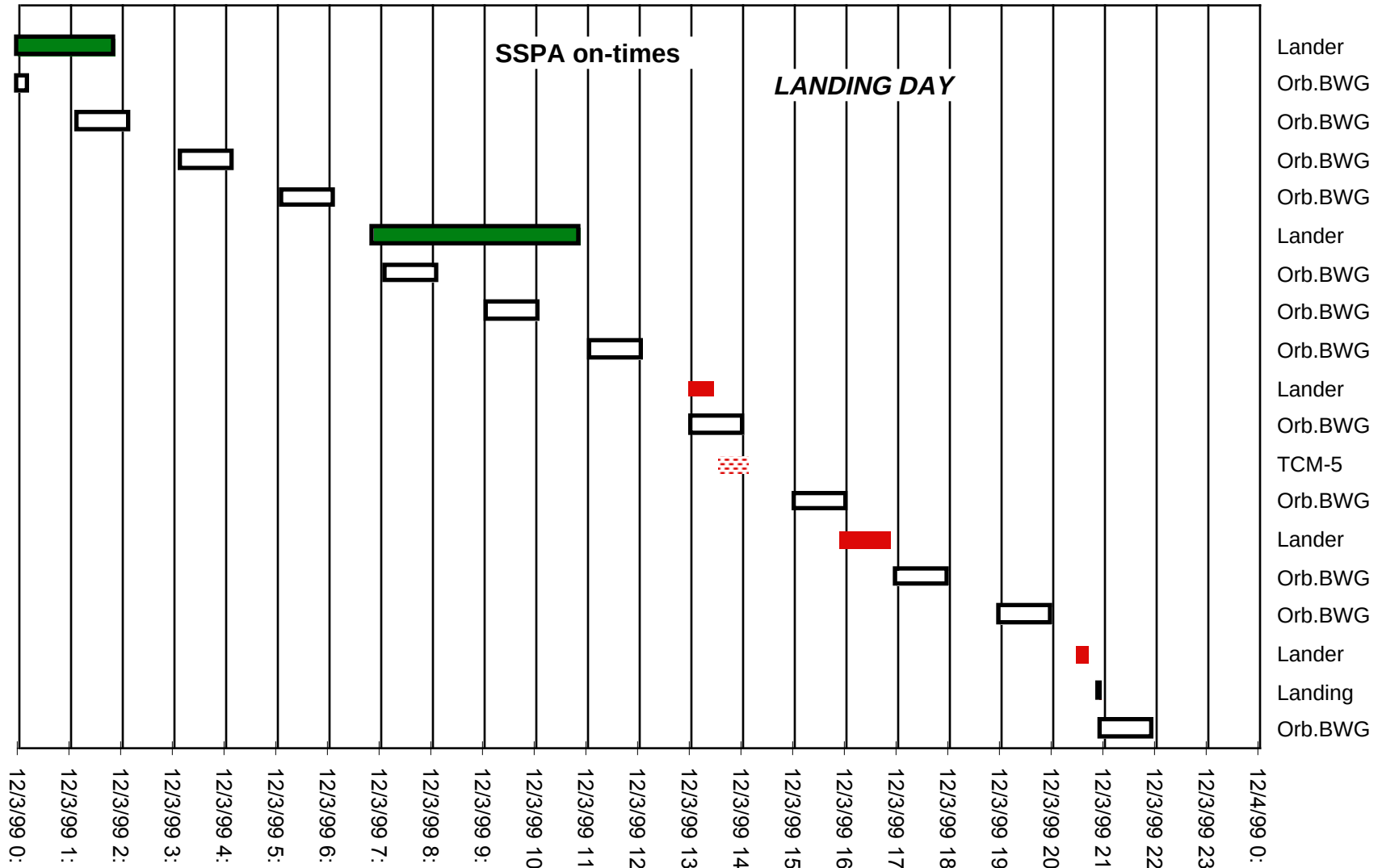
Lander HEF



Orbiter HEF



Orbiter BWG Track (Optional)

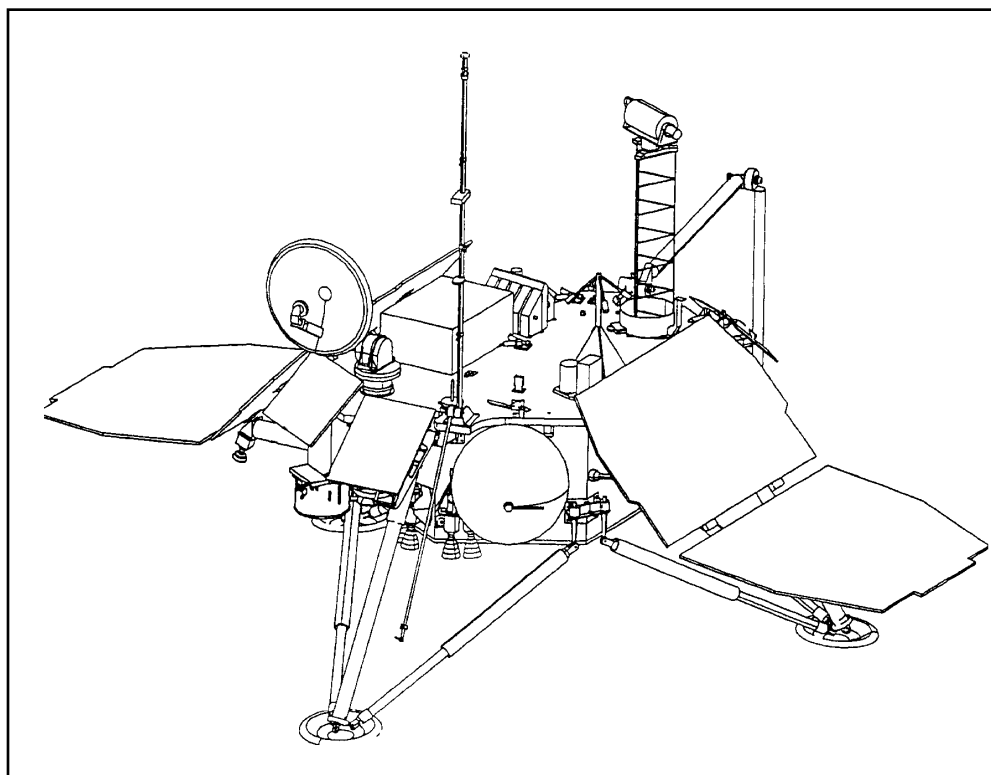
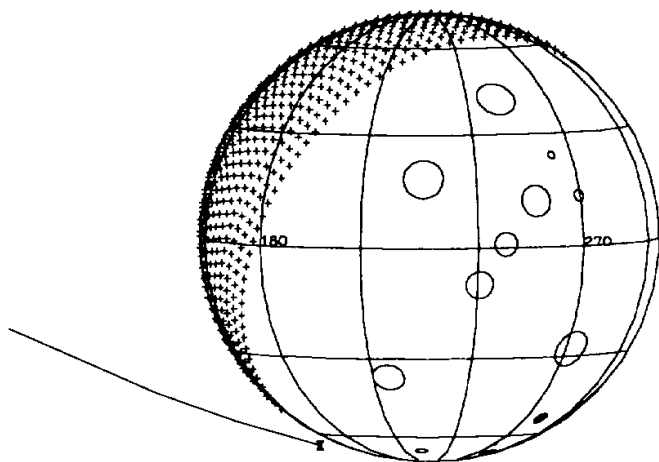


A.13 Orbiter Approach Targeting Data **This Section under Change Control**

[To be Supplied] This section contains approach data to be used for MOI analyses.

MARS SURVEYOR '98 PROJECT

LANDER MISSION PLAN and DATABOOK



August 8, 1997

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APPENDIX B: LANDER MISSION DATABOOK

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B.1 Lander Mission Database

B.2 Lander DSN and Air Force Tracking Initial Acquisition Geometry

B.3 Lander Cruise Trajectory Characteristics

B.4 Approach/Entry Illustrations

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B.5.2: Orbiter/Lander Geometry Timelines

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B.5.6: Design Reference Mission Power Profiles

B.5.7: Payload Scenarios

B.6 Lander Configuration Drawings

B.7 Lander Navigation Memo

B.8 BWG usage

B.9 Approach Tracking Schedule

B.9.1: Entry - 45d to Entry - 30d

B.9.2: Near Simultaneous Tracking - Integrated Tracking Schedule

B.9.3: Lander Track Durations

B.10 Lander Data Rates

B.11 Lander Approach Targeting Data **This Section under Change Control**

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/m², 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.

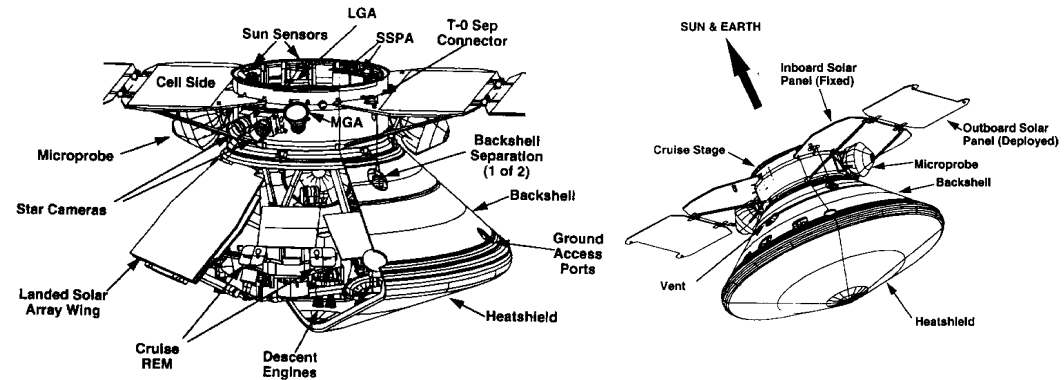
Propulsion System: Two diaphragm propellant tanks contain the 64 kg of purified hydrazine propellant used for both cruise maneuvers and attitude control as well as for lander powered descent. This is a pressure-regulated system with serially-redundant pressure regulators utilizing helium gas pressurant. 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

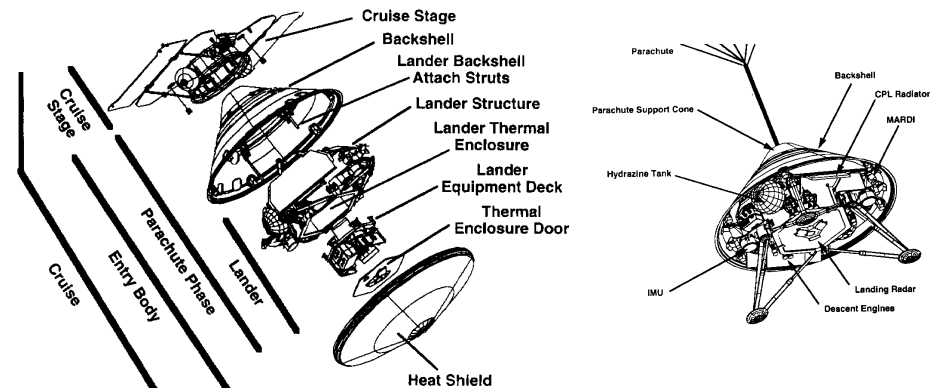
• Cruise Stage:

- Redundant star cameras, sun sensors
- Two solar arrays: 2.6 m² 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°].



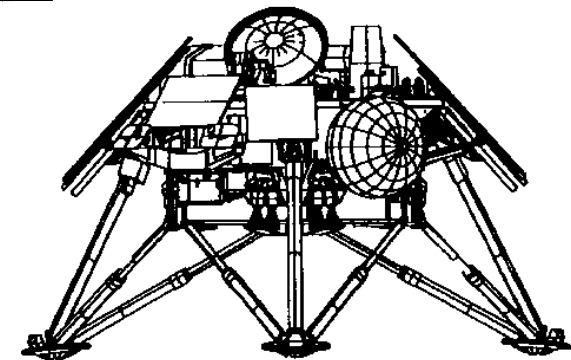
• EDL System:

- 2.4 m diameter heatshield [ablator] based on PF design
- Ballistic coefficient 58 - 62 kg/m², 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
- Flight 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 delayed] 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 (τ) = 0.5. Survival under full dust storm conditions (τ = 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.

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LANDER BUS - STRUCTURE, POWER/THERMAL, TELECOM

- **Lander Structure**

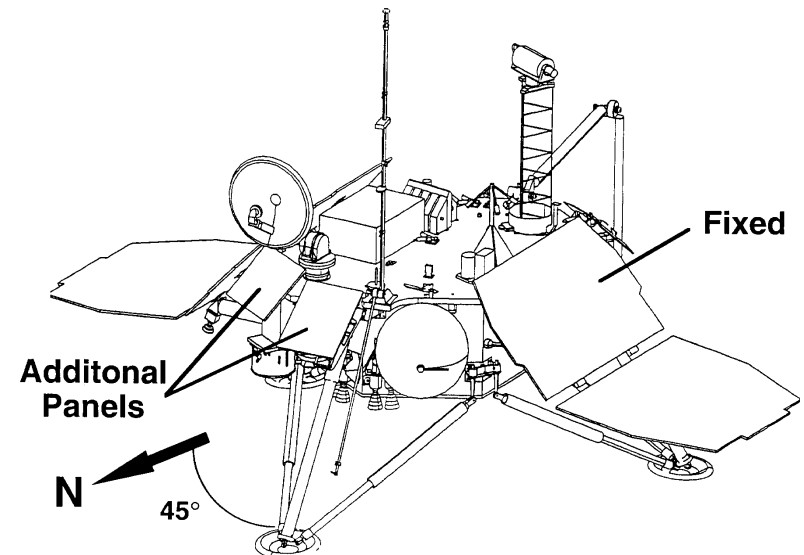
- Composite: honeycomb Aluminum core with graphite-epoxy facesheets
- Legs: spring-deployed, Aluminum, with crushable inserts
- Thermally isolated component deck inside central thermal enclosure, contains C&DH, PDDU, CCU, Ni-H common pressure vessel batteries, telecom [X-band direct and UHF relay], heat pipe
- Externally mounted components 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 [$\tau=1$] 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 supported 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

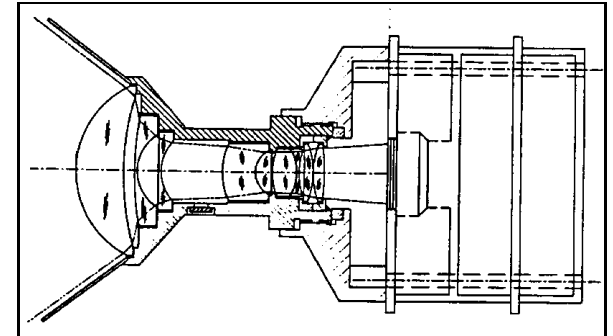
Two microprobes supplied by the New Millenium Project will be carried aboard the Lander cruise stage and will deploy themselves 15–20 seconds after separation of the cruise stage from the aeroshell. Each battery-powered microprobe penetrator will activate on separation, collect temperature, accelerometer, 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.

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

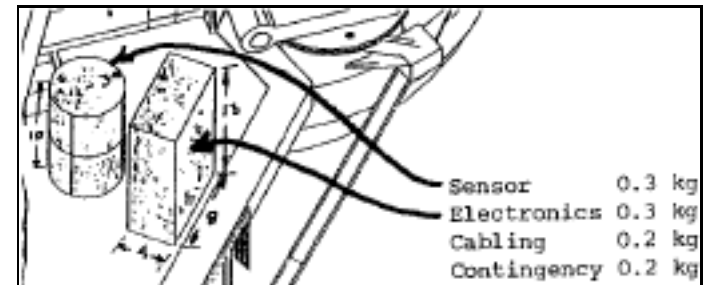
- **Mars Descent Imager (MARDI)**

- 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.



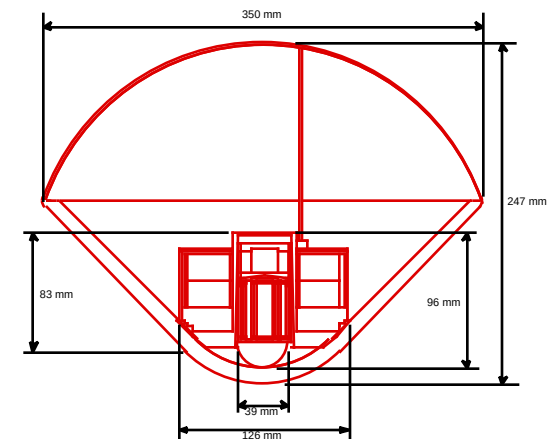
- **LIDAR [Light Detection and Ranging]**

- 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 their return timed to locate and characterize ice and dust hazes below 2-3 km
 - Acoustic device [microphone]



- **NEW MILLENNIUM 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.

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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]**

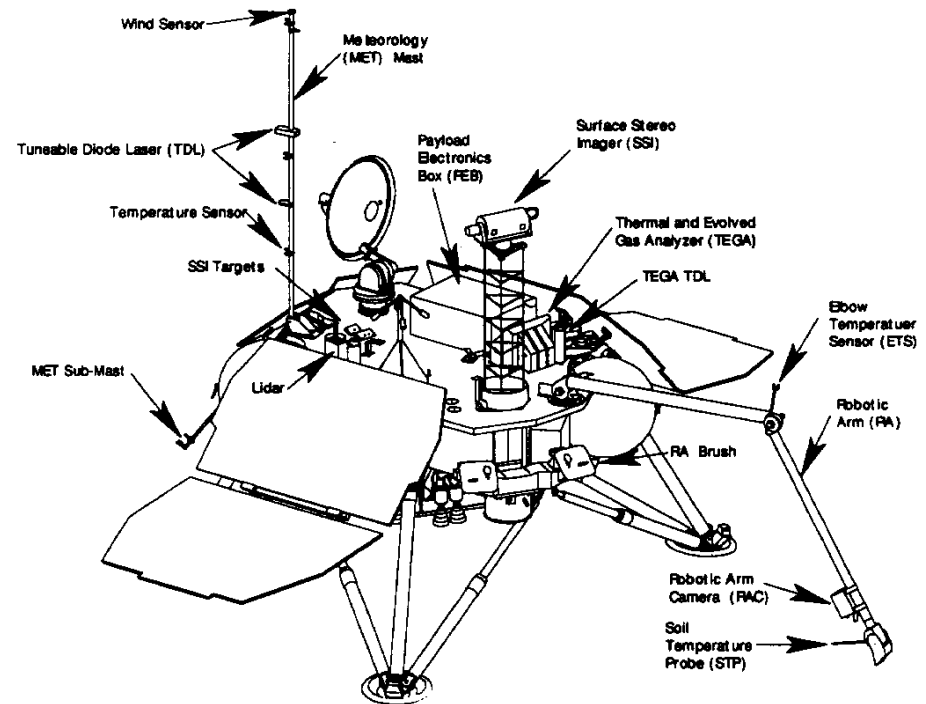
- 2-meter arm with articulated end member, camera, and temperature probe
- Digs trenches, to acquire samples of surface and subsurface materials, and support operations of the RAC
- RAC images surface and subsurface to reveal fine-scale layering if present and characterize fine-scale texture of the samples 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 $1E-4$ probability 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.

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OVERALL MISSION DESCRIPTION

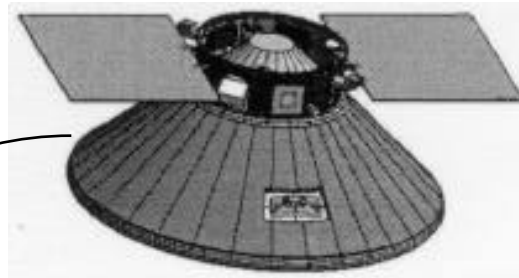
S/C Initialization

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



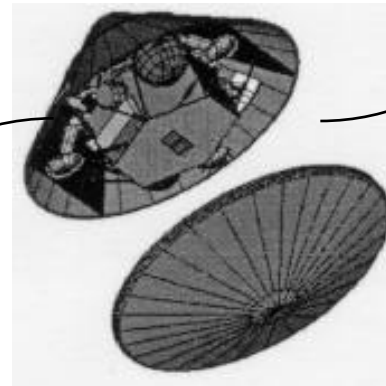
Launch

- 615 kg Launch Mass
- Delta II 7425 Vehicle



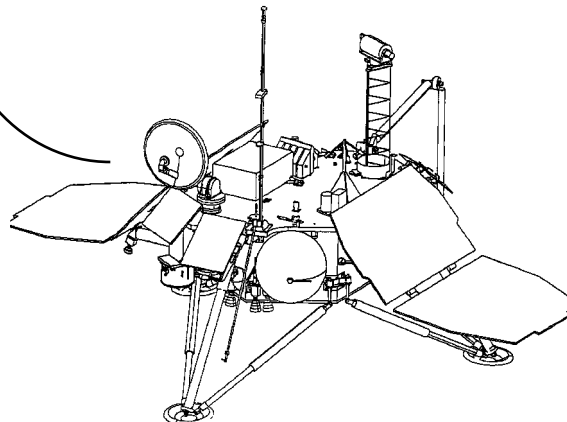
Cruise

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



Entry, Descent & Landing

- Direct entry
- Propulsive Landing



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.

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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

** This page under Change Control **

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 strategy, 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 $\pm 1.5^\circ$ for an entry angle corridor of 0.45° [3 σ]. [See B.1, the Lander Mission Database for more data.] The probability of staying within the required entry angle corridor of $\pm 0.25^\circ$ 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 latitude 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.

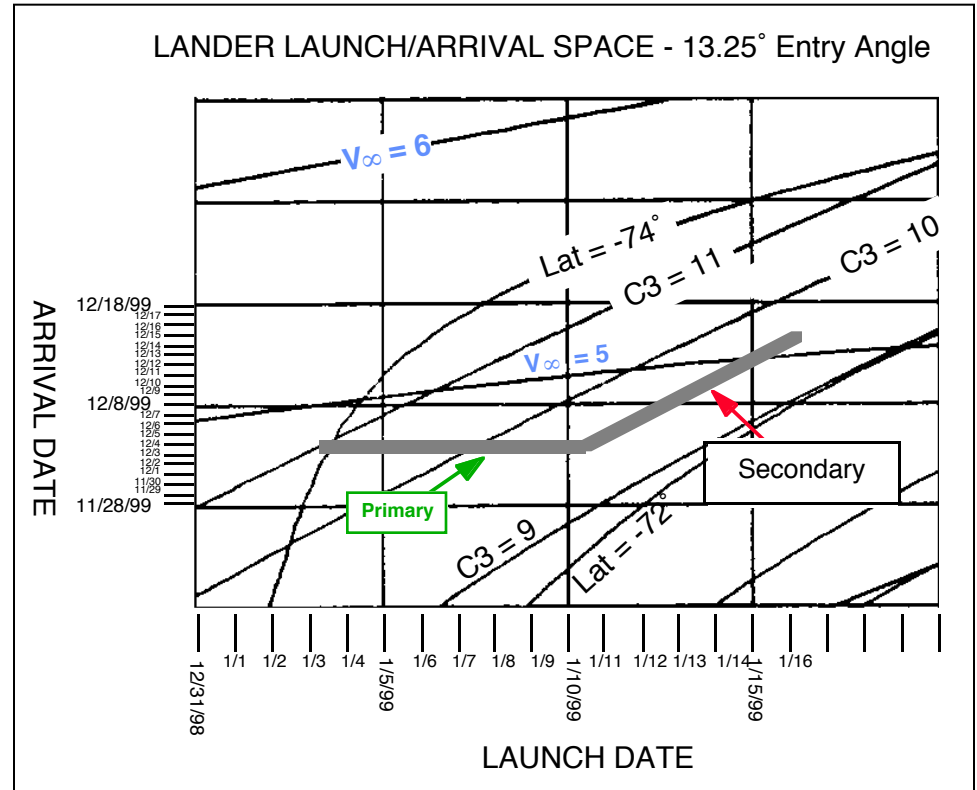
Contingency Launch Period [1/17/99 - 1/27/99]: Launch beyond the end of the Secondary period is feasible, by following a launch/arrival strategy which does not increase arrival V_{∞} beyond the limit imposed by the ablator thickness. As the following graph indicates, this leads to landing sites at more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

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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 $C3 < \sim 11$, for constant arrival date 12/3/99
 - 12/3/99 corresponds to $L_s = 256^\circ$, 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 $fpa = -13.25^\circ$, Nominal Landing Latitude = 76° [open primary] - 75° [close primary]
 - $\sim \pm 1.5^\circ$ footprint for entry corridor = 0.45° [3σ]
 - Probability of staying within required $\pm 0.25^\circ$ entry angle corridor = TBD
 - Range of longitudes [ice-free] $\sim 170^\circ$ - 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

Open of Primary
Close of Primary
Close Secondary

Day in Launch Period	Launch Date	Arrival Date	Depart $C3$ [km ² /s ²]	Arrival V_{∞} [km/s]	Landing L_s [deg.]	Landing Sun angle [deg.]	Landing True Solar Time	Landing Latitude [deg.]
1	1/3/99	12/3/99	11.17	4.84	256.3	18.3	4:14:33	76S
8	1/10/99	12/3/99	9.76	4.76	256.3	17.5	4:10:10	75S
14	1/16/99	12/15/99	9.71	5.08	263.5	16.5	3:36:35	~ 75 S

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 $\pm$ 5 days. [Note: 70m support is also being requested for the Orbiter during the entire Lander surface mission.]

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Lander Open Primary Launch Period

				DSN REQUIREMENTS									
Phase	Sub-Phase	Event		Start Date	Start DOM	End Date	End DOM	# Days	Hrs/Pass	Passes/Day	Passes/Week	Total Hrs	Note
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

				DSN REQUIREMENTS									
Phase	Sub-Phase	Event		Start Date	Start DOM	End Date	End DOM	# Days	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

				DSN REQUIREMENTS									
Phase	Sub-Phase	Event		Start Date	Start DOM	End Date	End DOM	# Days	Hrs/ Pass	Passes/ Day	Passes/ Week	Total Hrs	Note
Launch				1/16/99	13			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.

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5.2.5 Lander ΔV and Propellant Mass Summary

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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 Millennium microprobes. The site elevation goal is $5 \text{ km} \pm 1 \text{ km}$ 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 magnitude 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 $\pm 1^\circ$ 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.

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LANDER ΔV AND PROPELLANT MASS SUMMARY

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• 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 $\pm$ 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 aerodynamics, including angle of attack
 - » Maximum angle of attack = $\pm 1^\circ$. 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)									
Terminal descent (bshell,chute jett)	TBS			TBS	TBS	TBS	TBS	TBS	TBS

TO BE UPDATED

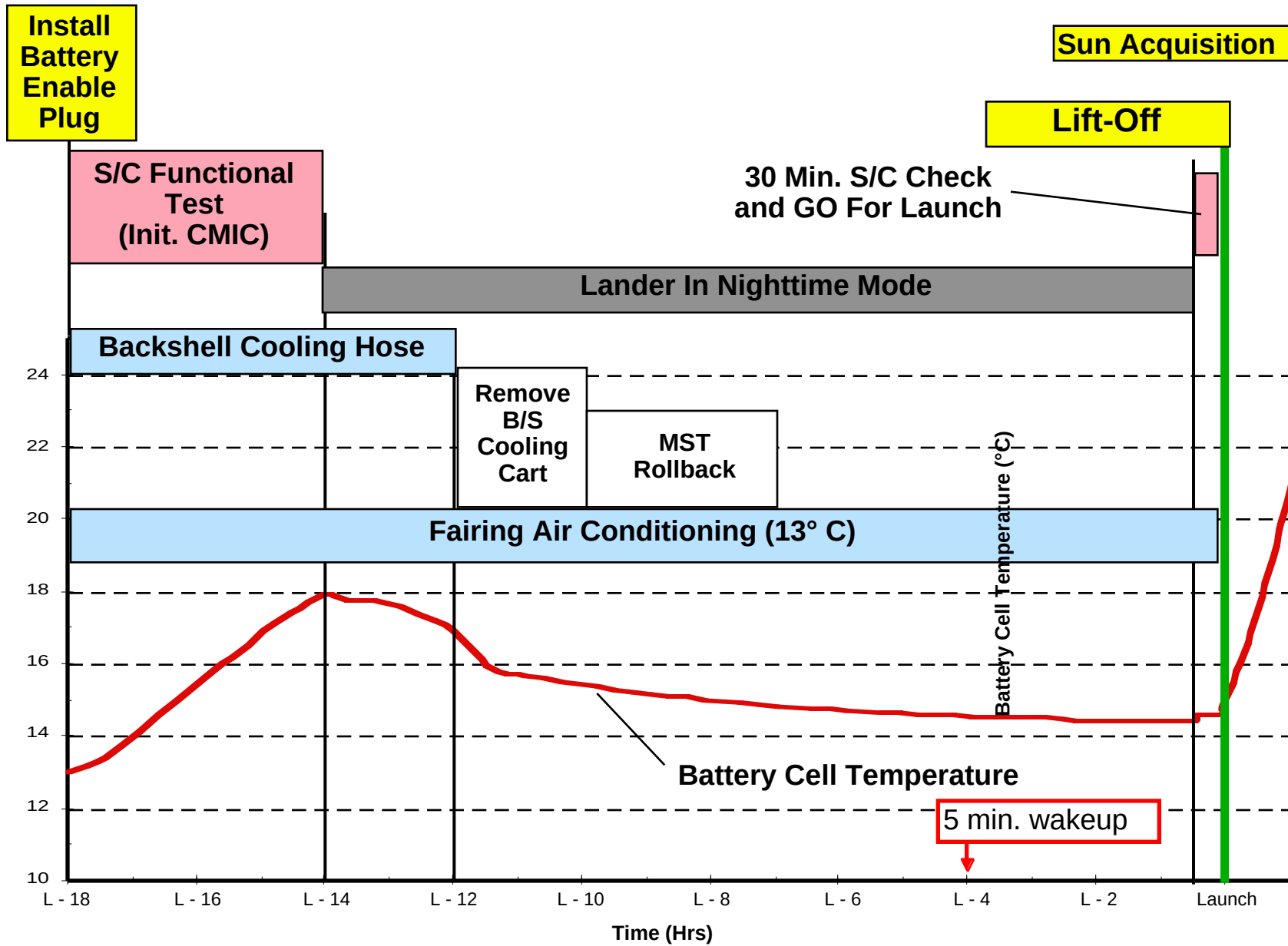
5.3 LANDER LAUNCH AND BOOST & S/C INITIALIZATION PHASES

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.

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LANDER COUNTDOWN AND PRE-LAUNCH SOE

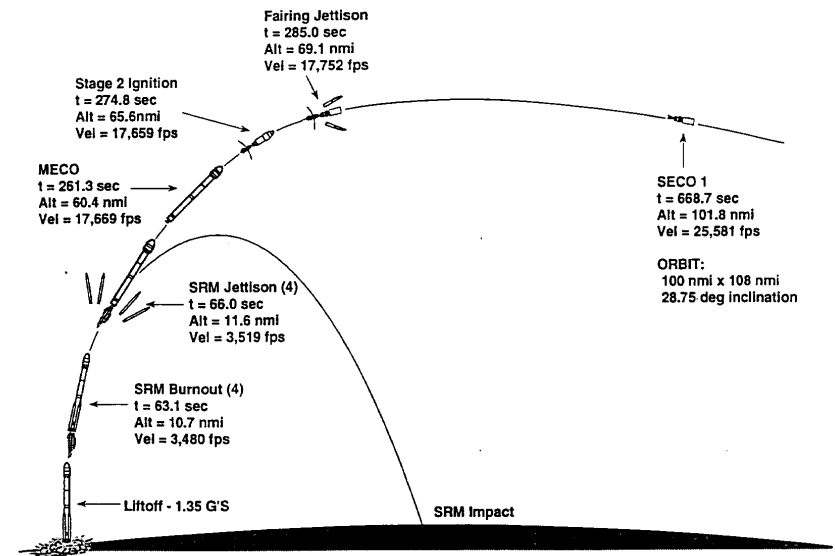


5.3.2 Lander Launch Events Summary

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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.	

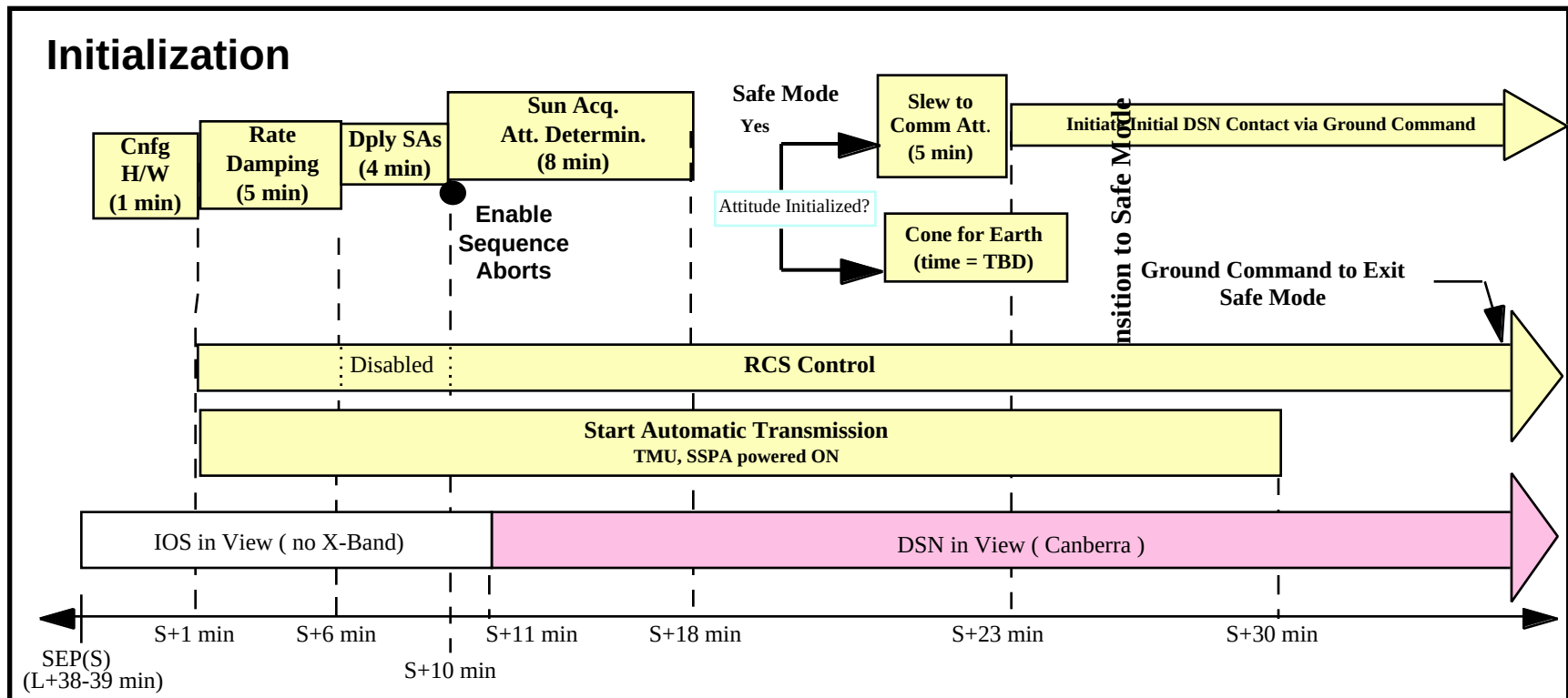
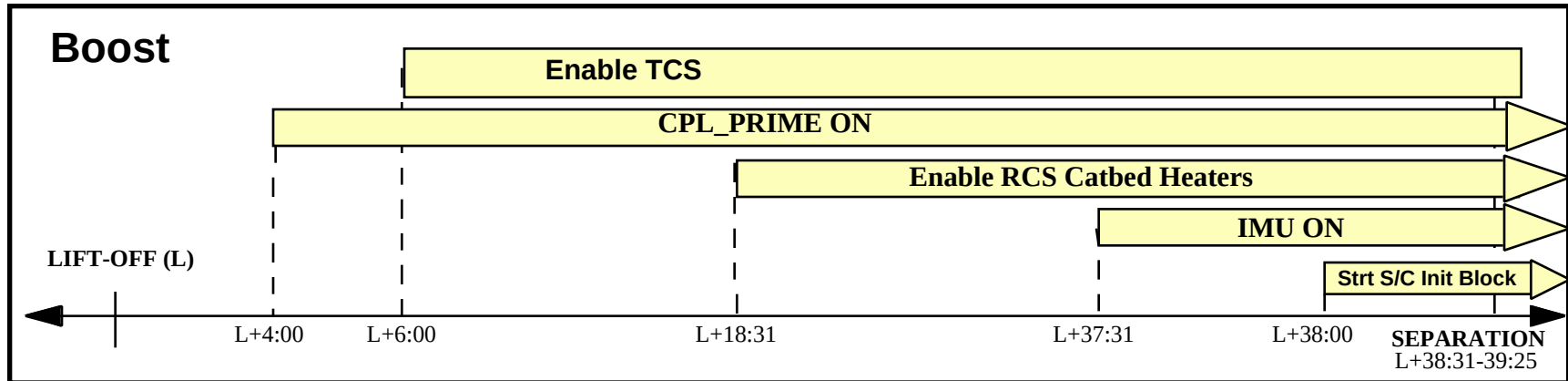


5.3.3 Lander Boost and Spacecraft Initialization Timeline

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.

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LANDER BOOST AND SPACECRAFT INITIALIZATION TIMELINE



LL-8

5.4 LANDER CRUISE PHASE

5.4.1 Lander Cruise Navigation

** This page under Change Control**

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 occurring 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

** This page under Change Control**

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.

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LANDER CRUISE NAVIGATION

** This page under Change Control**

- **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]**

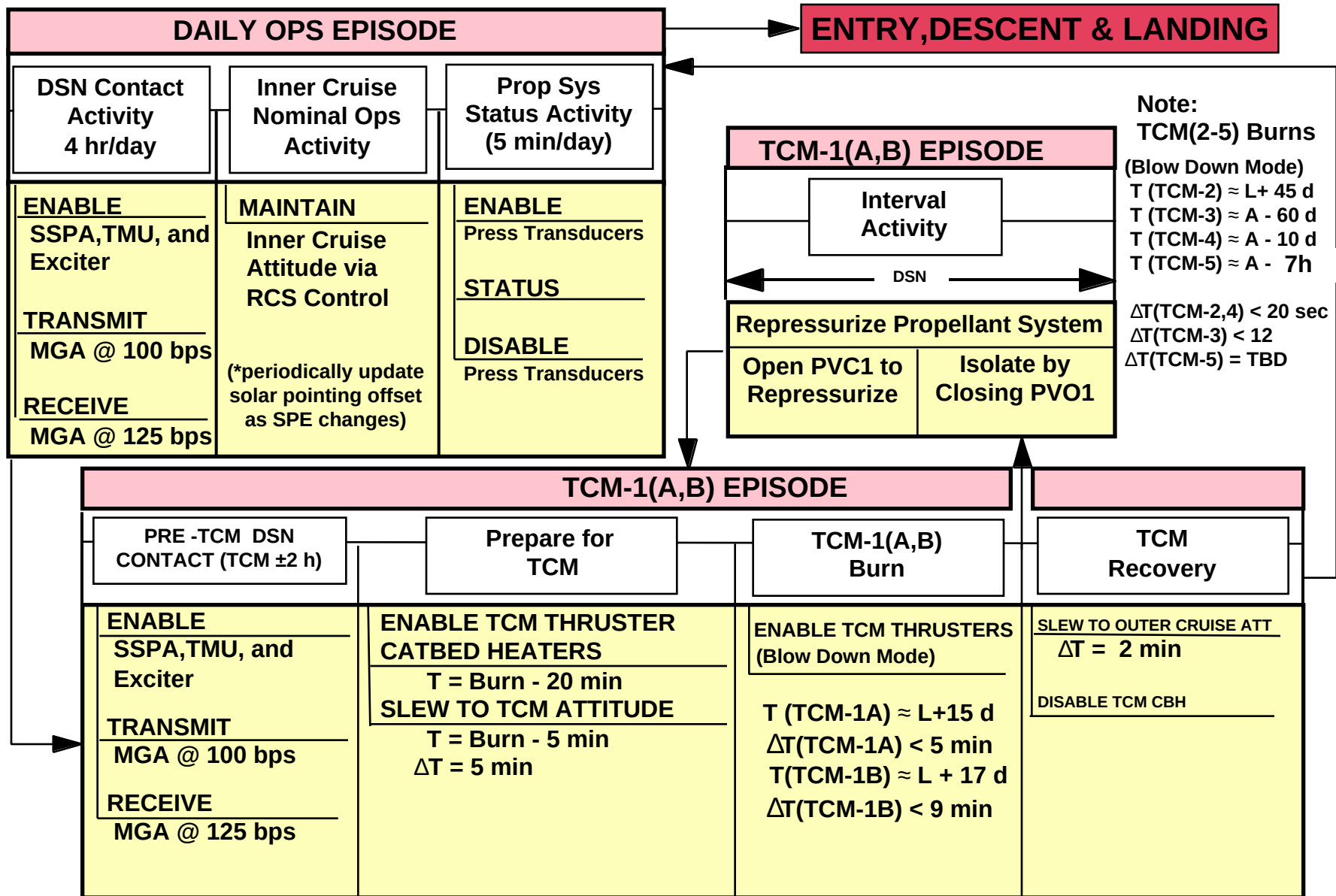
TCM #	Placement	95% Low ΔV [m/s]	Mean ΔV [m/s]	95% High ΔV [m/s]	Comments
1	Launch + 15 days	9.86	30.28	59.90	Will be broken into 2 maneuvers if > 24 m/s
2	Launch + 30 days	0.08	0.41	1.07	
3	Entry - 60 days	0.01	0.17	0.53	
4	Entry - 4 days	0.03	0.09	0.18	
5	Entry - 7 hrs	0.04	0.16	0.36	Contingency maneuver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

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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.

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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.

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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 = $2100 \text{ bits/sec} * 3.92 \text{ hours /day (interleaved portion of one DSN pass, assuming 5 minutes for lockup at 2100 bps)} * 3600 \text{ sec/hr} * 0.3 * [1-.15] = 7.55 \text{ Mbits per day}$. This data volume assumes the use of a 70m station.

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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 = $2100 \text{ bits/sec} * 3.67 \text{ hours /day (interleaved portion of one DSN pass, w/ 5 minutes for lockup)} * 3600 \text{ sec/hr} * 0.3 * [1-.15] = \mathbf{7.55 \text{ Mbits}}$ 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 Jettison: 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.

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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**, pry 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 μ probes are jettisoned from the cruise stage shortly thereafter.]
 - Lander commanded to Inertial Hold mode with $\pm 1^\circ$ 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.

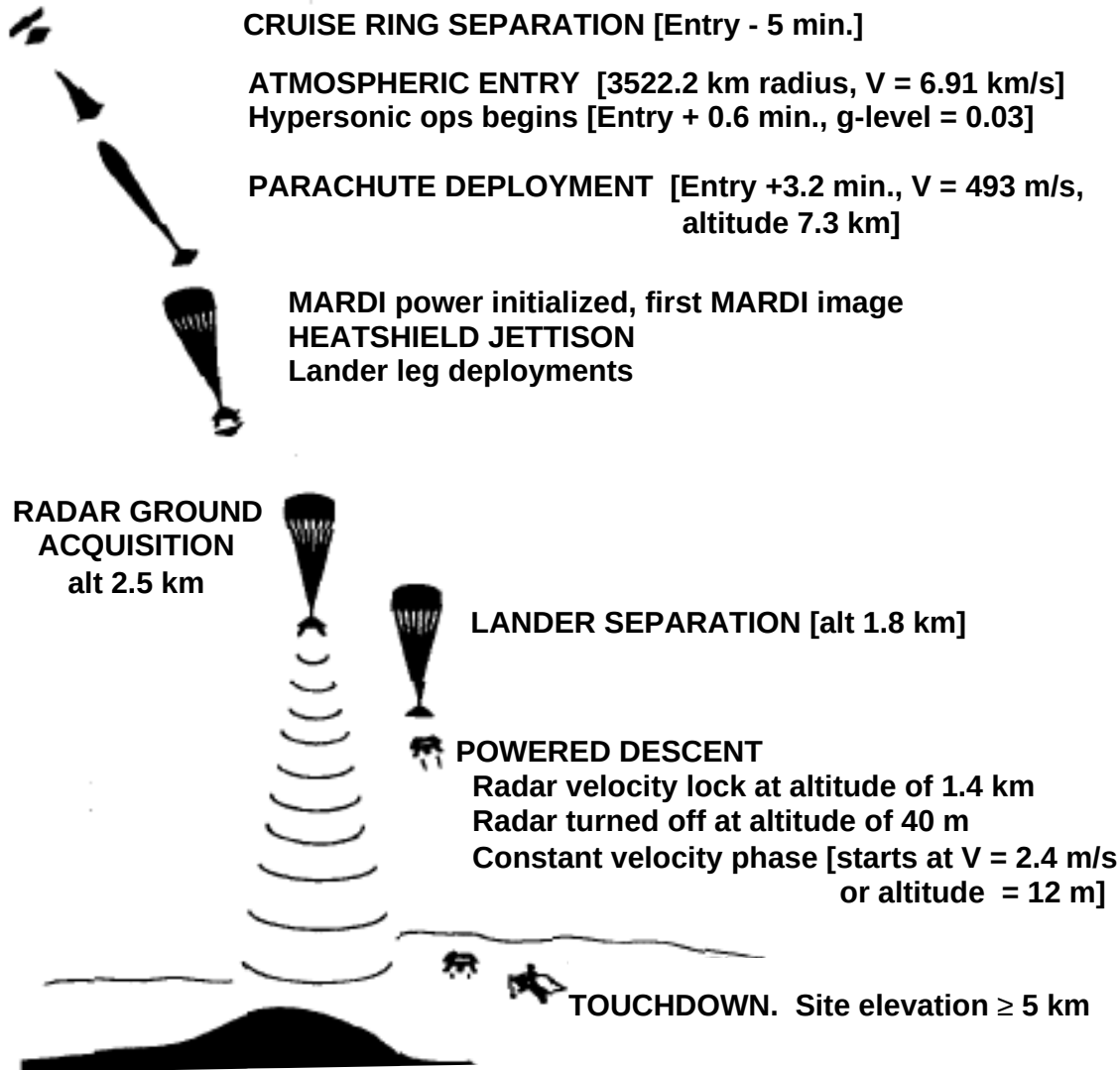
Hypersonic Operations: Hypersonic operation begins approximately 33-37.5 seconds later, when a deceleration level of 0.03 g is sensed by the accelerometers on the X axis. During hypersonic entry, RCS and TCM thrusters controlled by the onboard IMU's maintain aeroshell attitude to within 1° of the nominal 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.

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ENTRY OVERVIEW



HYPERSONIC	PARACHUTE	TERMINAL DESCENT
<u>HYPER</u>	<u>DEPLOY</u>	<u>LANDSEP</u>
HYPER + 00:01:00 • Fill Descent Engines	DEPLOY DEPLOY PARACHUTE	LANDSEP SEPARATE LANDER
HYPER + 00:01:09 • Enable Landing Radar in Standby Mode	DEPLOY + 00:00:05 • Flight Processor to 20 MHz	LANDSEP + 00:00:00.5 ENABLE DESCENT ENGINES
HYPER + 00:02:28 • Roll to Radar Lock Altitude	• first MARDI image DEPLOY + 00:00:07 SEPARATE HEATSHIELD	ALTITUDE = 1425 m • Radar to Alt/Vel Mode
HYPER + 00:02:30 • Disable TCM and RCS Calbed Heaters		LANDSEP + 00:00:03 • Begin Gravity Turn
	DEPLOY + 00:00:09 DEPLOY LANDER LEGS	ALTITUDE = roll_to_land • Begin Roll to Landed Altitude
	DEPLOY + 00:00:10 • Activate Radar Beams	ALTITUDE = 40 m • Disable Landing Radar
	LANDSEP - 00:00:03 • Pulse Descent Engines	ALT = 12m OR Vel = 2.4 m/s • Contact Velocity Descent Begins
		<u>TOUCHDOWN</u> • Start Landed Operations Sequence

* 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.

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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 commandin; 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 opportunities and data volumes for the landed science mission.

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

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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 and 1, 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.

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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 throughout 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 established 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.

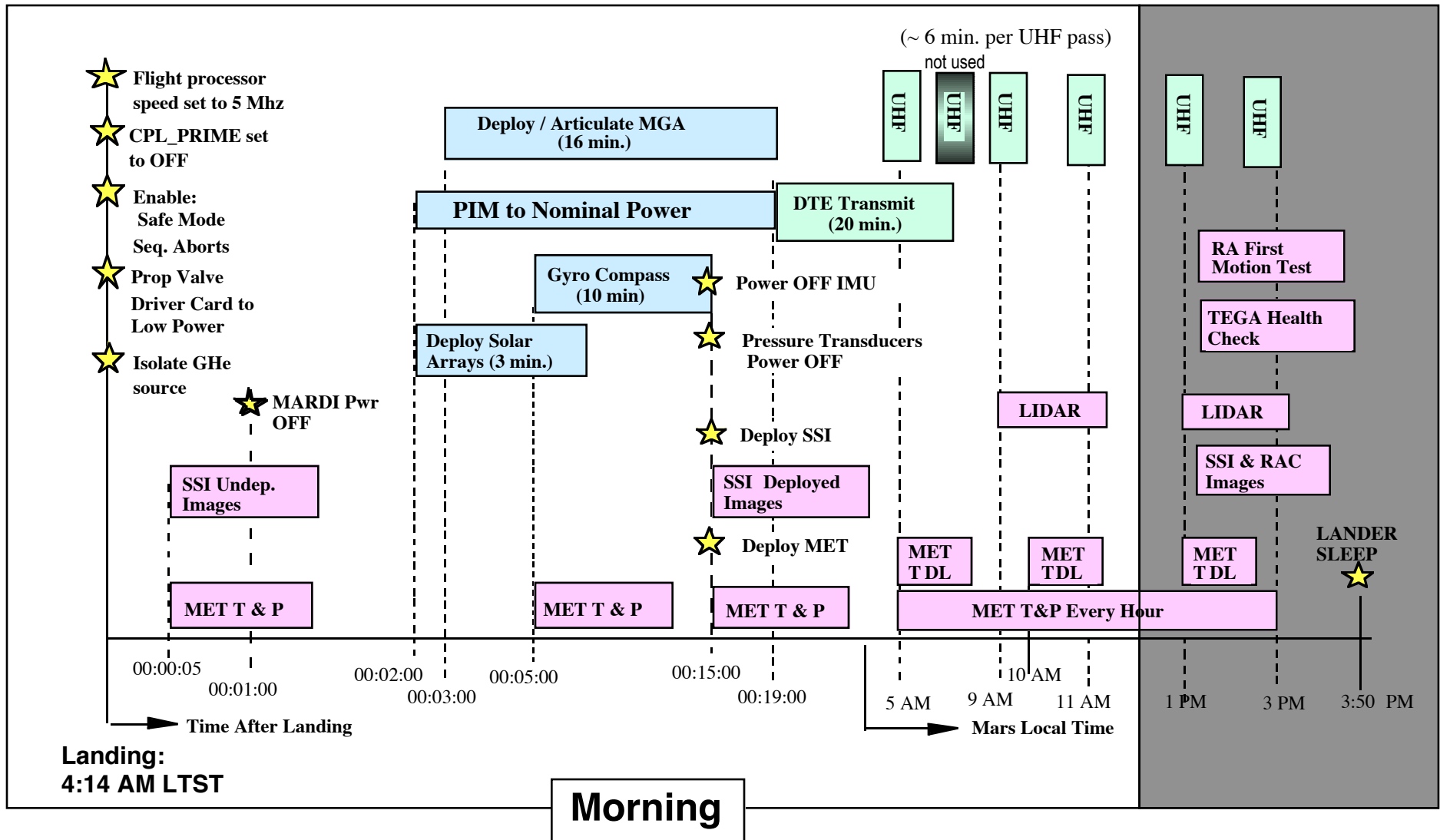
Science Activities and Data Transfer: Shortly after landing, transfer of the uncompressed MARDI data from volatile DRAM to flash memory is begun. MET observations are planned 5 seconds after landing, 5 minutes after landing, and 15 minutes after landing. [The last occurs after MET mast deployment]. MET 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 activities 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.

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SOL 0 DESIGN REFERENCE MISSION - Morning



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Label widths are not proportional to event durations

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 activities 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.

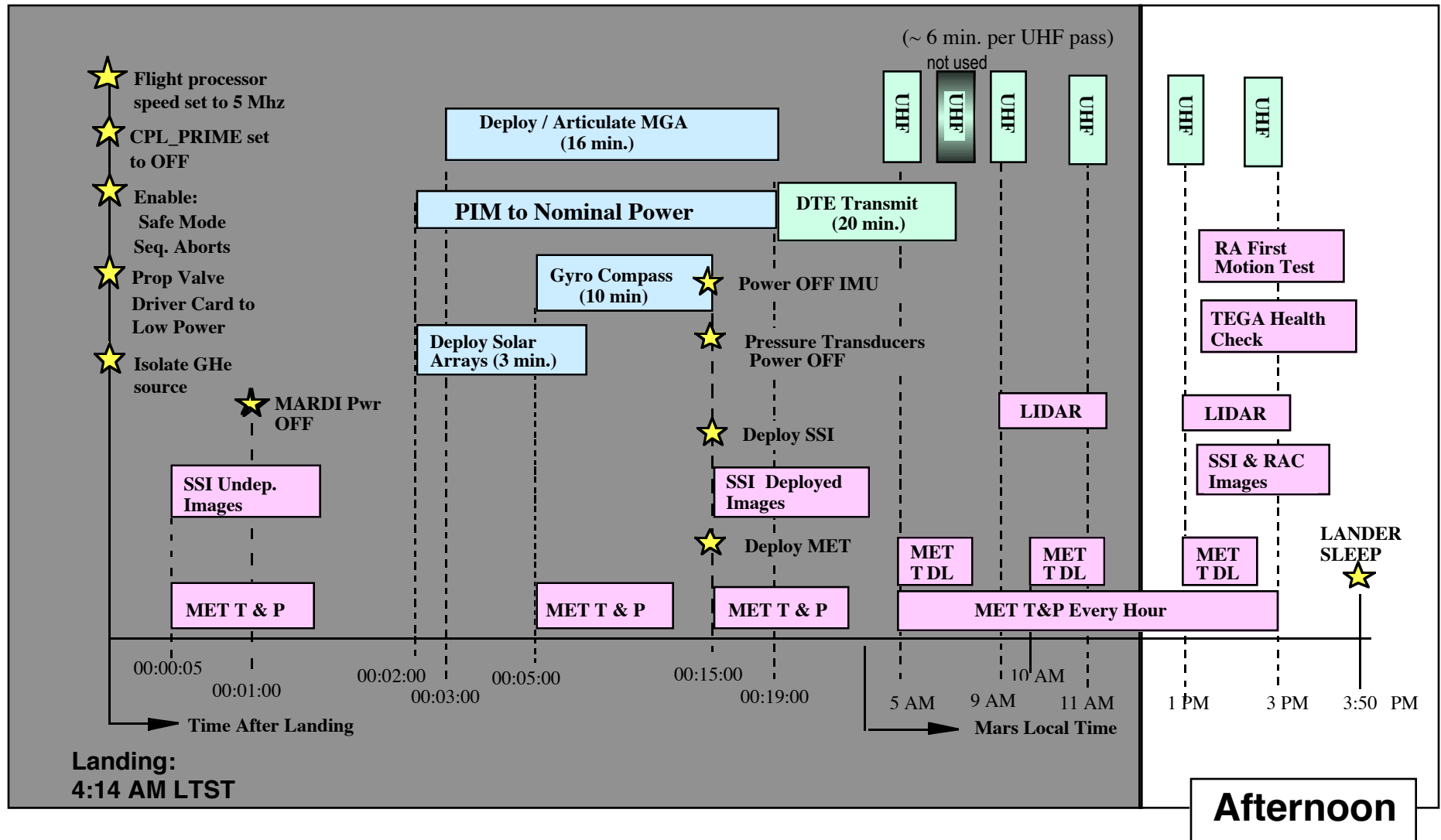
UHF Passes: Nominally, two additional UHF passes with the MSP98 Orbiter, occurring circa 1 PM and 3 PM LMST, are used to relay science data in the afternoon of the first landed sol. The highest priority is returning the remaining MARDI data, a portion of which was sent up during the morning UHF passes. 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.

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SOL 0 DESIGN REFERENCE MISSION - Afternoon



** This page under Change Control **

Label widths are not proportional to event durations

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

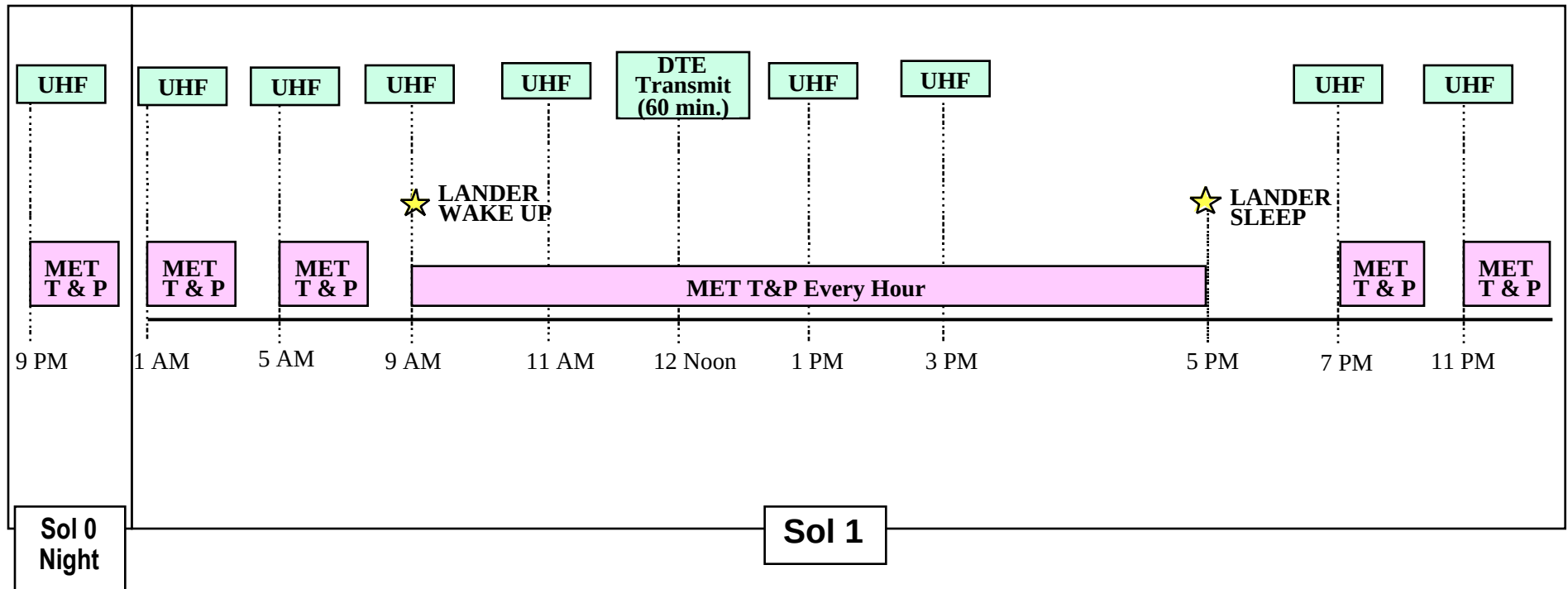
** This page under Change Control **

Sol 0,1 Night-time Activities: The Lander CPU and MET systems are activated several times during 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.

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SOL 0 NIGHT-TIME AND SOL 1 DESIGN REFERENCE MISSIONS



** This page under Change Control **

5.6.3 TEGA Day 1 Design Reference Mission

** This page under Change Control **

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 $L_s = 256^\circ$ [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:

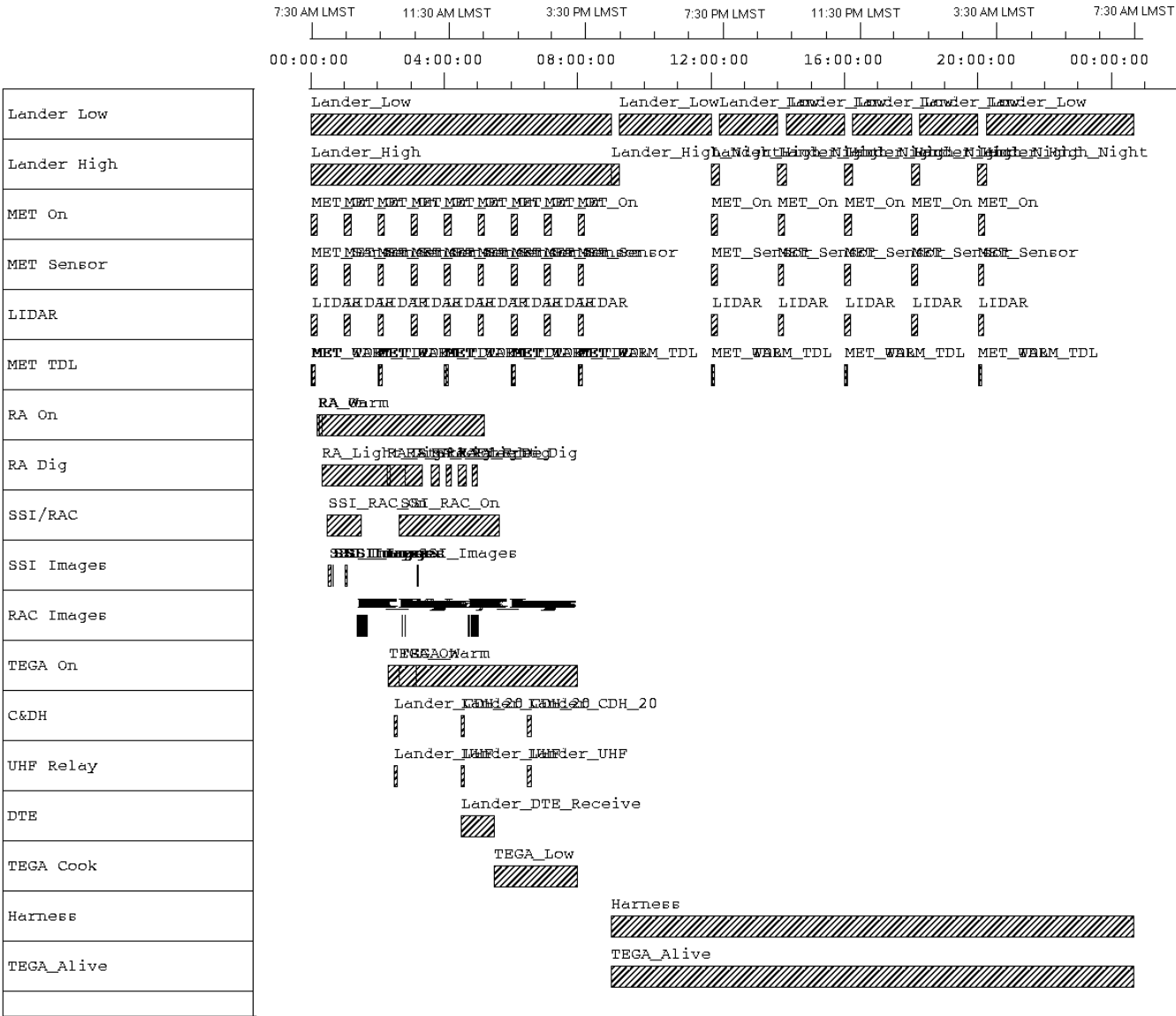
Robotic Arm, Imagers, TEGA: Prior to TEGA Day 1 the Robotic Arm [RA] will have excavated the trench to within a few cm of the desired depth. On TEGA Day 1 the RA excavates the remaining few cm. At preplanned pauses the SSI and RAC are used to image the trench and its interior. Near the end of the dig 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.

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TEGA DAY 1 DESIGN REFERENCE MISSION



APGEN Version E7.03
12/96

** This page under Change Control **

APPENDIX B: LANDER MISSION DATABOOK

B.1 Lander Mission Database

B.2 Lander DSN and Air Force Tracking Initial Acquisition Geometry

B.3 Lander Cruise Trajectory Characteristics

B.4 Approach/Entry Illustrations

B.5 Post-Landing Data

B.5.1: First Pass after Landing - Variability with Landing Site and Orbiter Mean Anomaly

B.5.2: Orbiter/Lander Geometry Timelines

B.5.3: UHF Pass Information: Pass Durations, Data Volumes during Landed Science Mission

B.5.4: Earth and Sun Azimuth and Elevation during Landed Science Mission

B.5.5: Sun and Earth Geometry with Respect to Mars

B.5.6: Design Reference Mission Power Profiles

B.5.7: Payload Scenarios

B.6 Lander Configuration Drawings

B.7 Lander Navigation Memo

B.8 BWG usage

B.9 Approach Tracking Schedule

B.9.1: Entry - 45d to Entry - 30d

B.9.2: Near Simultaneous Tracking - Integrated Tracking Schedule

B.9.3: Lander Track Durations

B.10 Lander Data Rates

B.11 Lander Approach Targeting Data **This Section under Change Control**

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B.1 Lander Mission Database

LANDER MISSION DATABASE

12/20/96

SUMMARY

Open of Primary
Close of Primary
Close Contingency

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.]
1	1/3/99	12/3/99	11.17	4.84	256.3	18.3	4:14:33	76S
8	1/10/99	12/3/99	9.76	4.76	256.3	17.5	4:10:10	75S
14	1/16/99	12/15/99	9.71	5.08	263.5	16.5	3:36:35	~ 75S

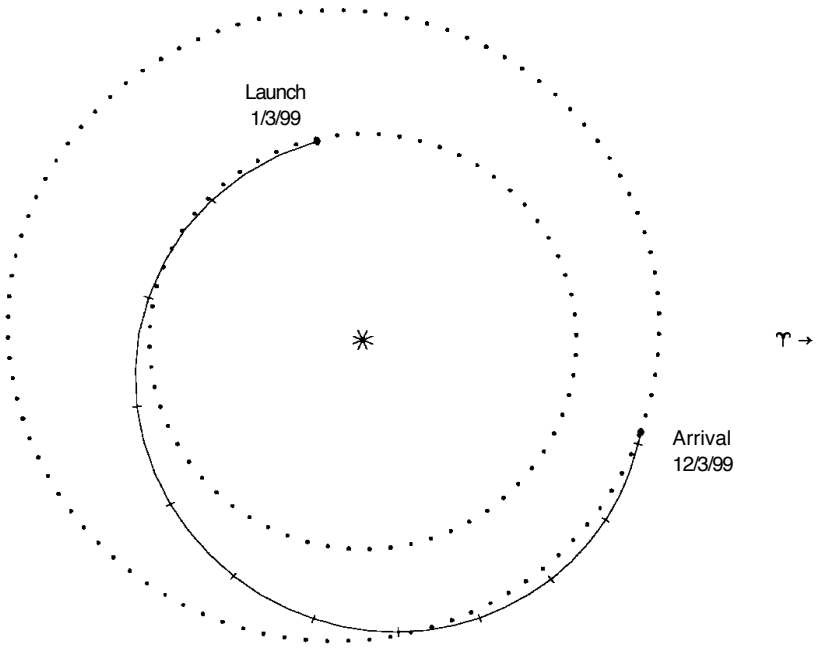
DATABASE

	Start Primary Launch Period	End Primary Launch Period	End Conting. Launch Period
inj_date_utc	3-Jan-99	10-Jan-99	16-Jan-99
inj_time_utc	21:19:09	20:19:52	20:34:18
inj_date_et	3-Jan-99	10-Jan-99	16-Jan-99
inj_time_et	21:20:10	20:20:53	20:35:19
inj_c3	11.165	9.76	9.71
inj_dla	0.92	4.66	1.69
inj_rla	-124.65	-125.02	-120.91
arrival_date_utc	3-Dec-99	3-Dec-99	15-Dec-99
arrival_time_utc	20:51:15	20:46:46	3:35:33
arrival_date_et	3-Dec-99	3-Dec-99	15-Dec-99
arrival_time_et	20:52:18	20:47:49	3:36:36
arrival_dla	-29.85	-31.19	-30.20
arrival_rla	166.67	167.95	171.33
arrival_vhp	4.84	4.76	5.08
arrival_bdt	285.58	260.01	167.89
arrival_bdr	4883.84	4930.04	4773.70
arrival_radius	3522.20	3522.21	3522.20
arrival_lat	-62.57	-61.67	-61.31
arrival_lon	143.37	144.83	146.63
arrival_vel	6.91	6.85	7.08
arrival_fpa	-13.25	-13.25	-13.25
arrival_az	173.69	174.55	176.37
arrival_ltst	4:10:05	4:05:44	3:32:03
descent_time [s.]	273.41	272.90	278.68
landing_time_et	20:56:51	20:52:21	3:41:14
landing_ltst	4:14:33	4:10:10	3:36:35
landing_earth_angle	18.5	18.3	19.0
landing_sun_angle	18.3	17.5	16.5
Landing Ls [deg.]	256.3	256.3	263.5
Max N. Landing Lat [99%]	74.5S	73.5	~ 73.5S
Nominal Landing Lat	76S	75S	~ 75S
Max S. Landing Lat [99%]	77.7S	76.7S	~ 76.7S
Nominal Landing Lon	210W	210W	210W

Coordinate Systems:

Earth Departure: Earth Mean Equator and Equinox of 2000
Mars Arrival: Mars Mean Equator and IAU node of date

LANDER TRAJECTORY
OPEN OF PRIMARY LAUNCH PERIOD



B.2 Lander DSN and Air Force Tracking Initial Acquisition Geometry

LANDER

JET PROPULSION LABORATORY

INTEROFFICE MEMORANDUM

312/96.2-2010

Aug 21, 1996

TO: Phil Knocke

FROM: Steve Williams *SW*

SUBJECT: Mars 98 Tracking Station Initial Acquisition Geometry Update

This memo provides Mars 98 Initial acquisition geometries for a 2 hour period following stage 3 burnout for the 3 DSN stations and the 12 Air Force tracking stations given below. The burnout states used here were provided by you in a personal communication. The data is arranged in seven groups:

- 1) day 1 lander trajectories launching on 3 Jan 99 (short coast)
- 2) day 8 lander trajectories launching on 10 Jan 99 (short coast)
- 3) day 16 lander trajectories launching on 16 Jan 99 (short coast)
- 4) day 25 lander trajectories launching on 27 Jan 99 (short coast)
- 5) day 1 orbiter trajectories launching on 10 Dec 98 (short coast)
- 6) day 8 orbiter trajectories launching on 17 Dec 98 (short coast)
- 7) day 16 orbiter trajectories launching on 25 Dec 98 (short coast)

As before, four parameters are plotted for each station: range, range rate, elevation angle, and aspect angle between the S/C z-axis and the vector to the station (z-axis is assumed to be the S/C velocity vector at burnout as we discussed).

Stations shown in this memo are :

GOLD : Goldstone

MAD : Madrid

CAN : Canberra

ANT : Antigua

ASC : Ascension Island

DGS : Diego Garcia

LBV : Libreville, Gabon

IOS : Indian Ocean

KWAJ : Ennylabegan

HTS : Hawaii

GTS : Guam

HBK : Hartebeesthoek, South Africa

TEL4 : Tel-4

VTN : Vandenberg

PRTH : Perth

Distribution

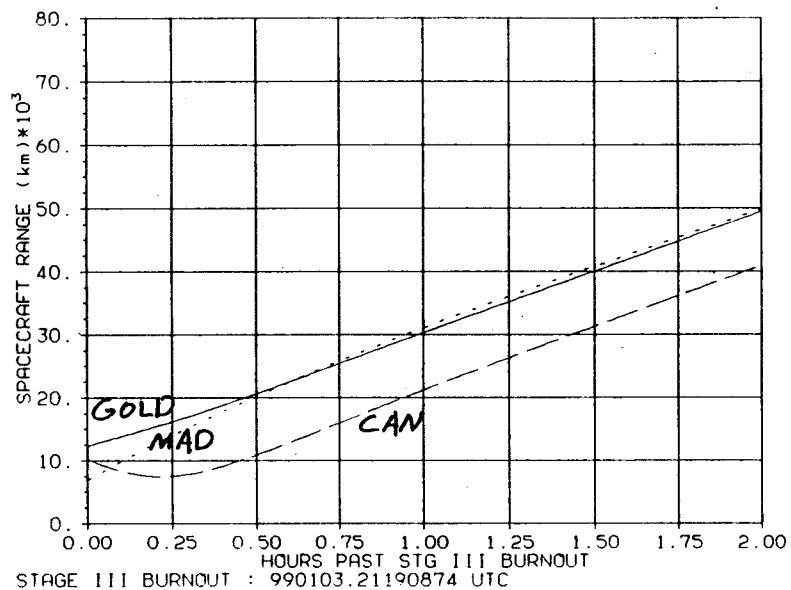
D. Murrow

R. Roncoli

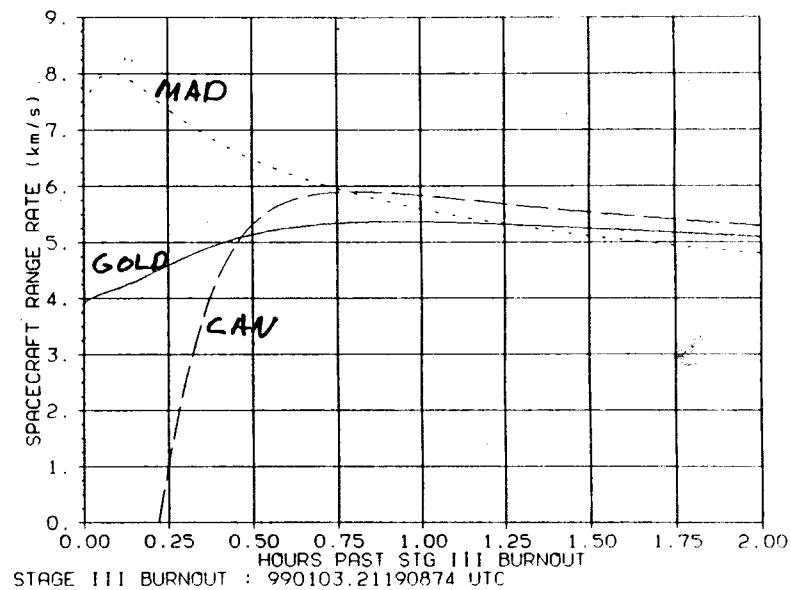
LANDER DAY 1 (1/3/99) SHORT COAST

TRACKING STATION GEOMETRY (LANDER) : DAY 1 SHORT COAST

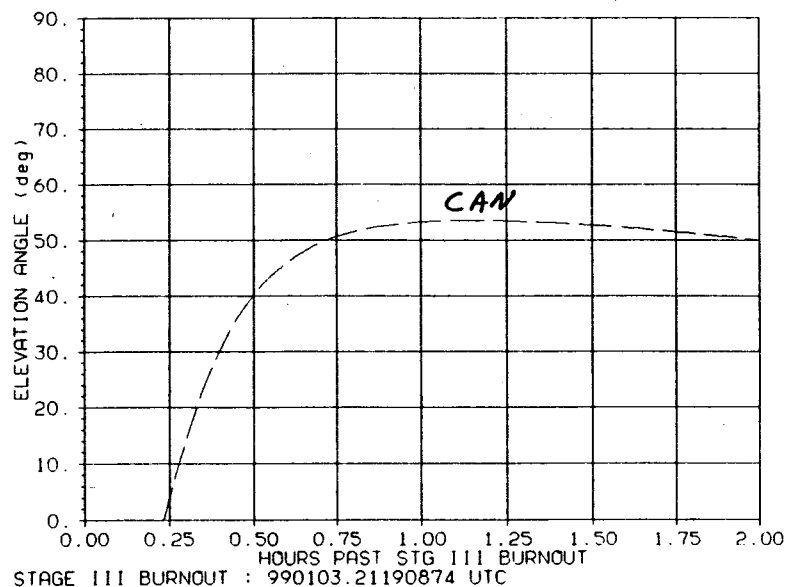
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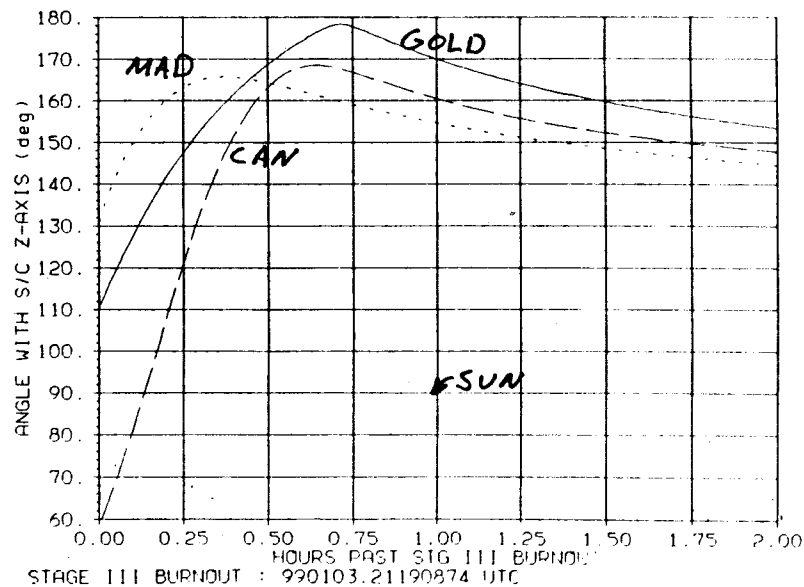
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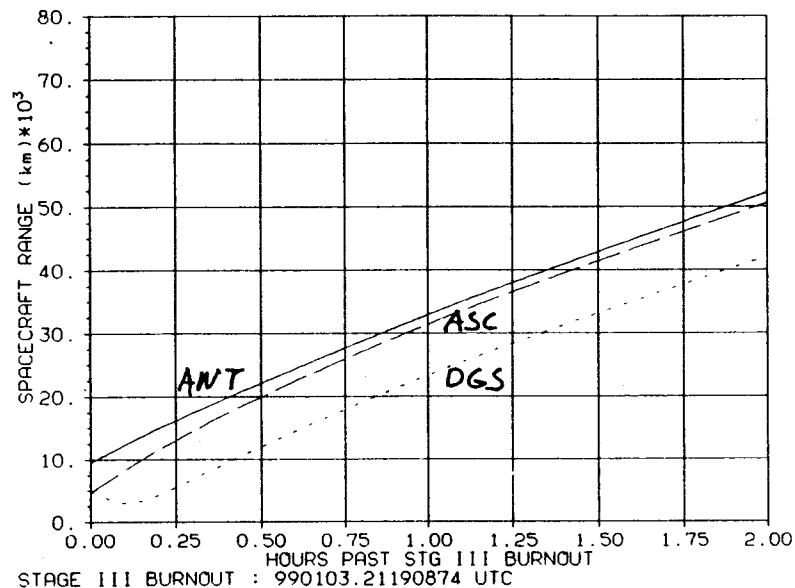


ASPECT ANGLE WITH S/C Z-AXIS

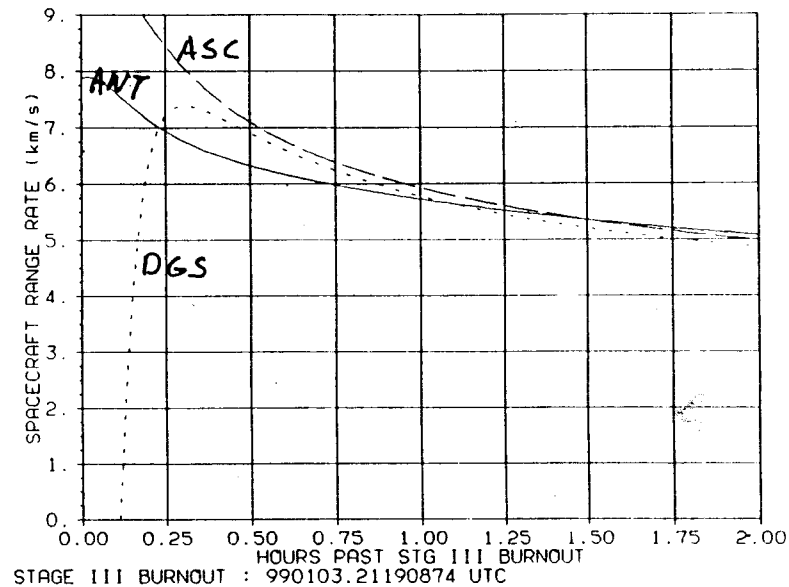


TRACKING STATION GEOMETRY (LANDER) : DAY 1 SHORT COAST

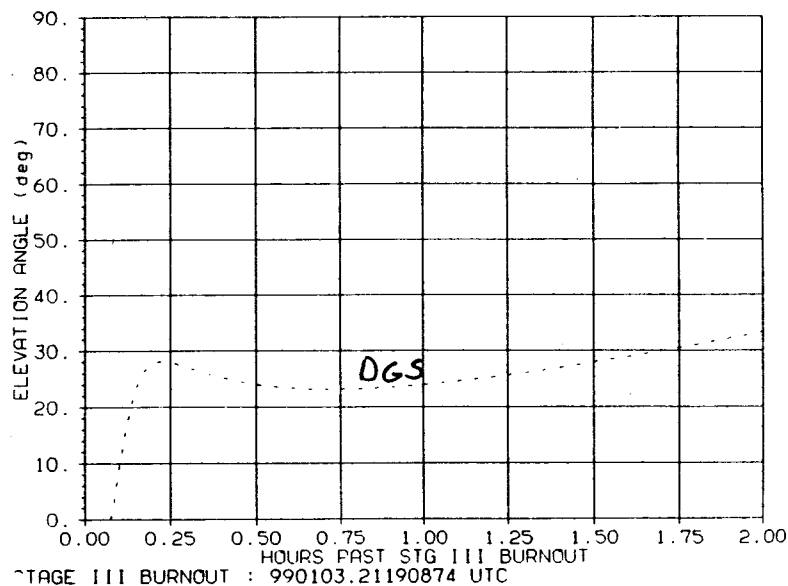
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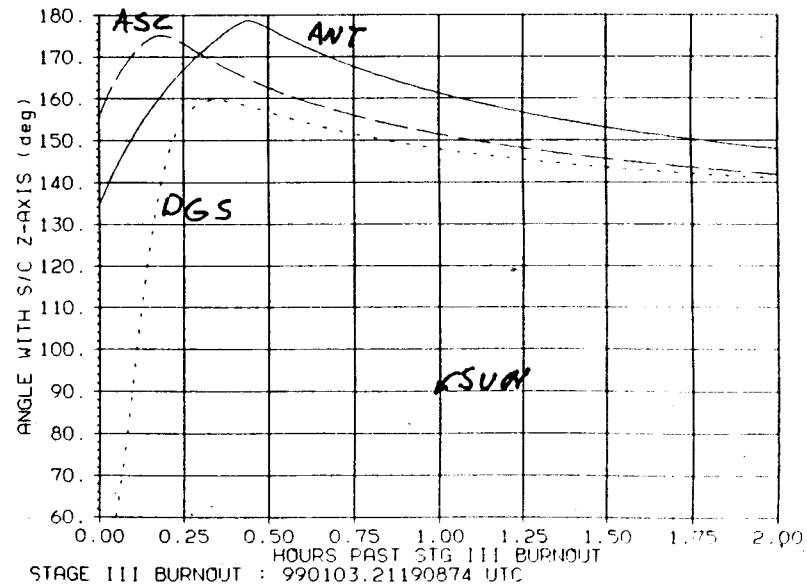
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SPACECRAFT ELEVATION ANGLE

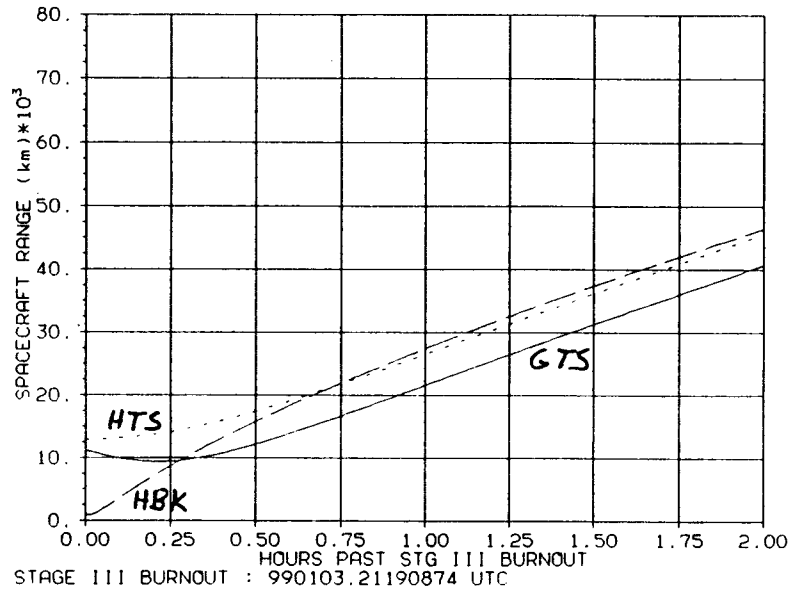


ASPECT ANGLE WITH S/C Z-AXIS

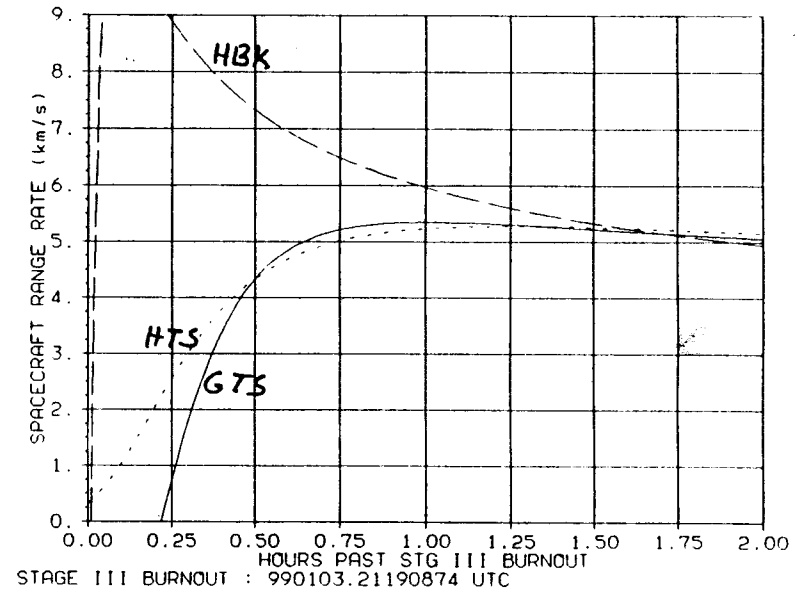


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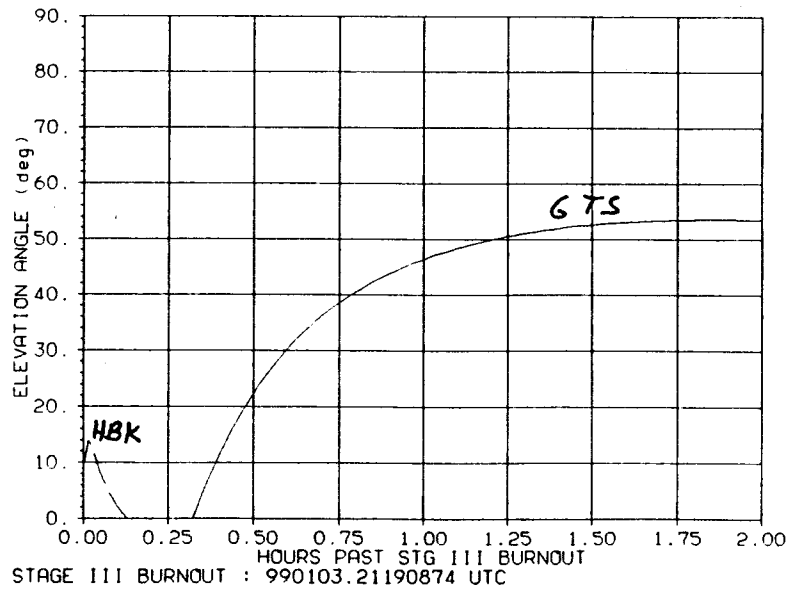
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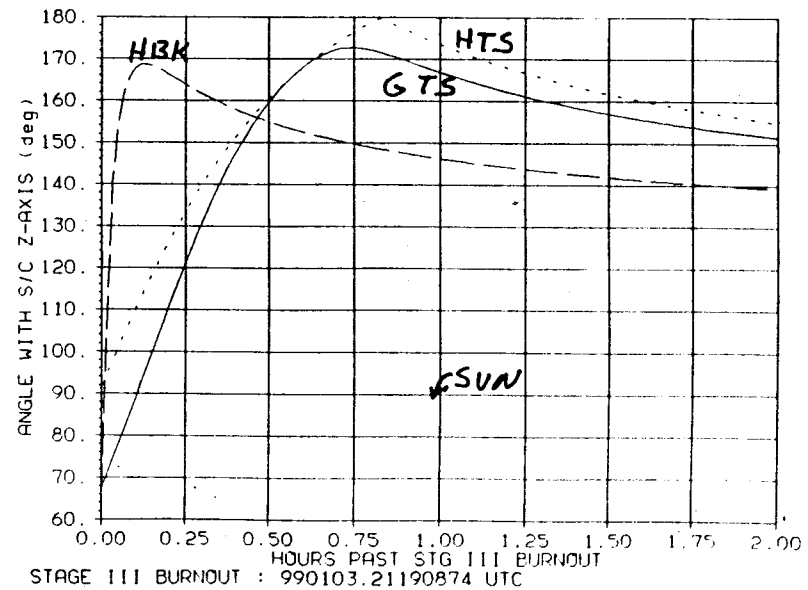
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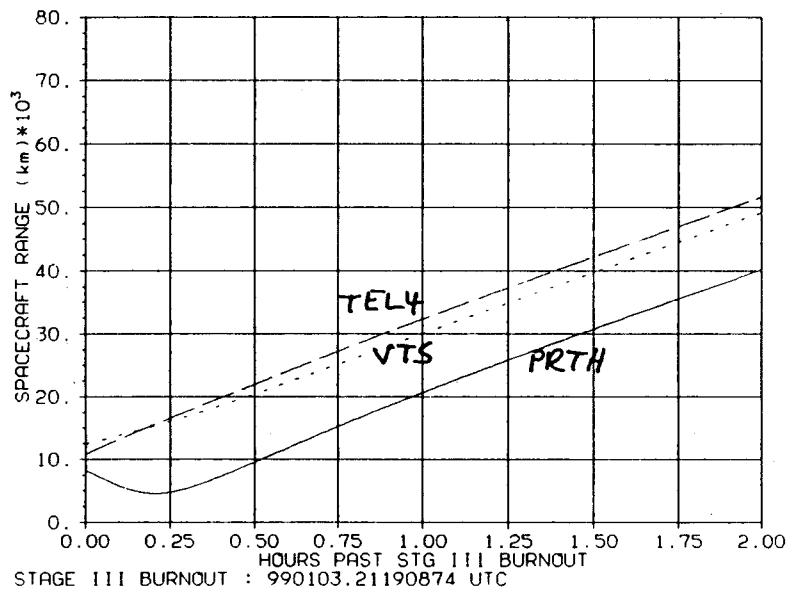


ASPECT ANGLE WITH S/C Z-AXIS

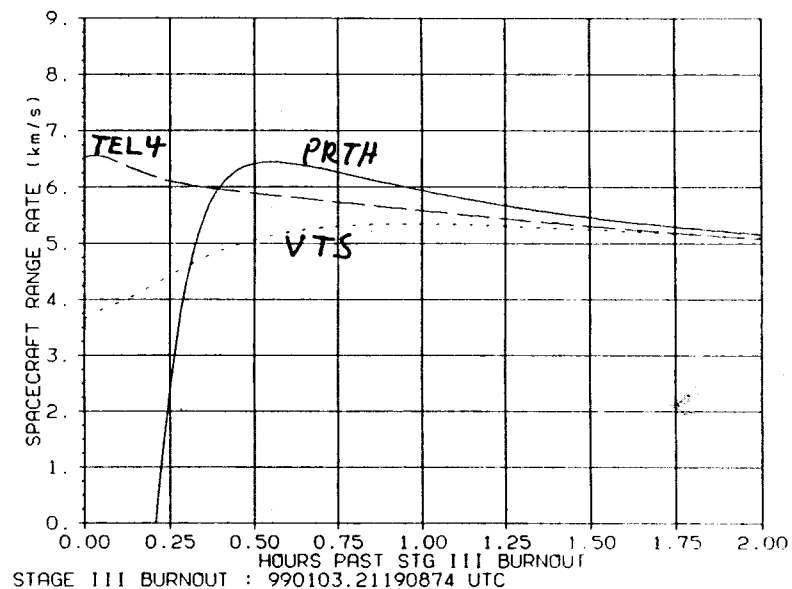


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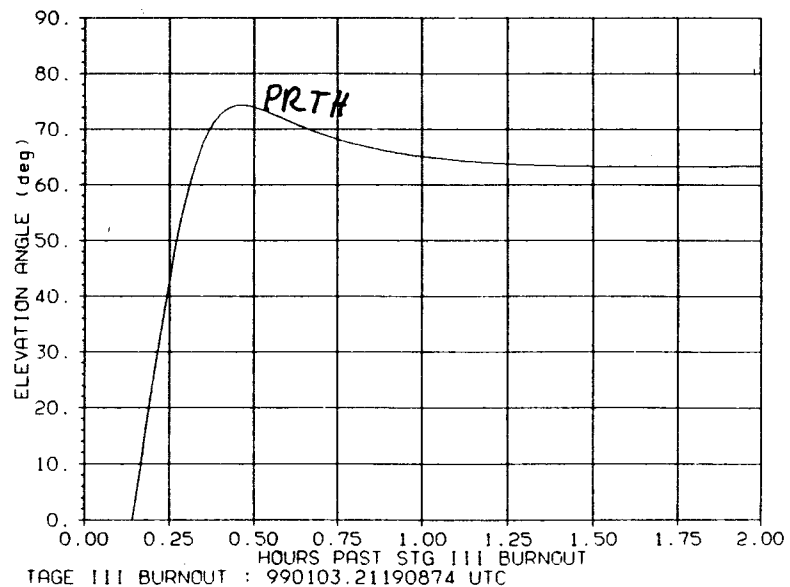
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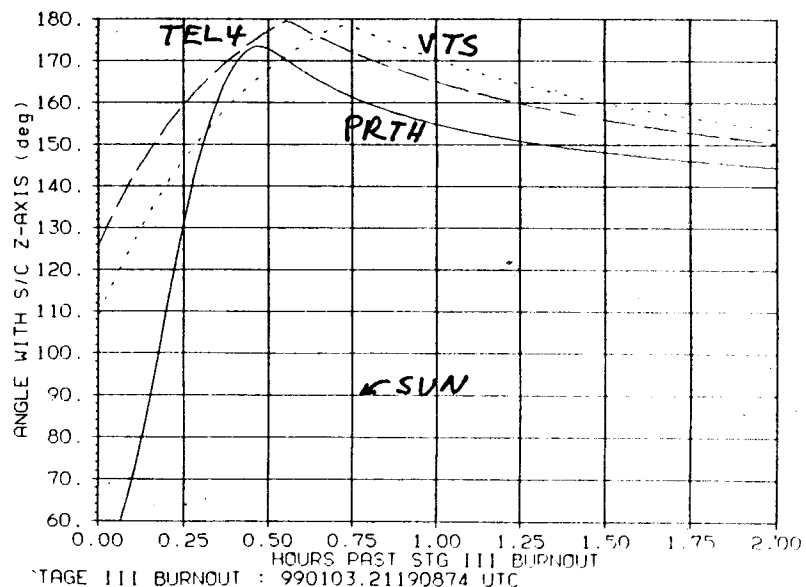
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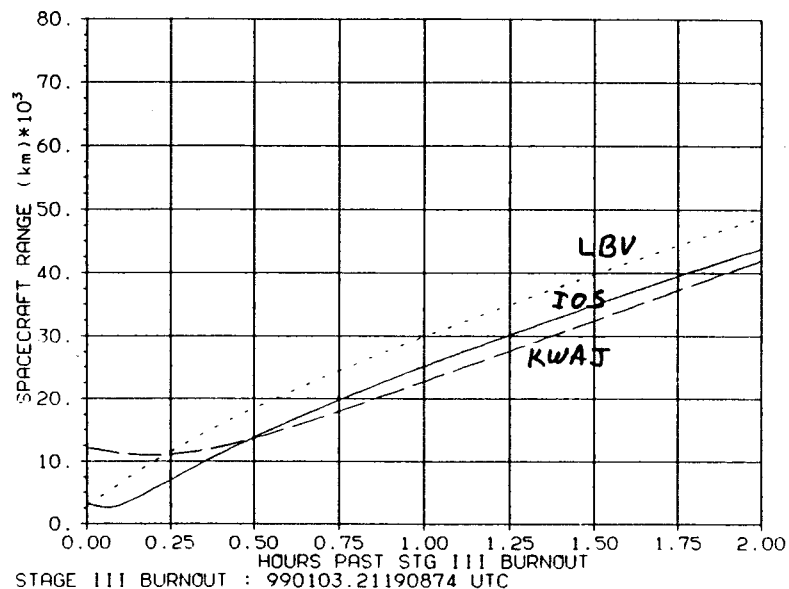


ASPECT ANGLE WITH S/C Z-AXIS

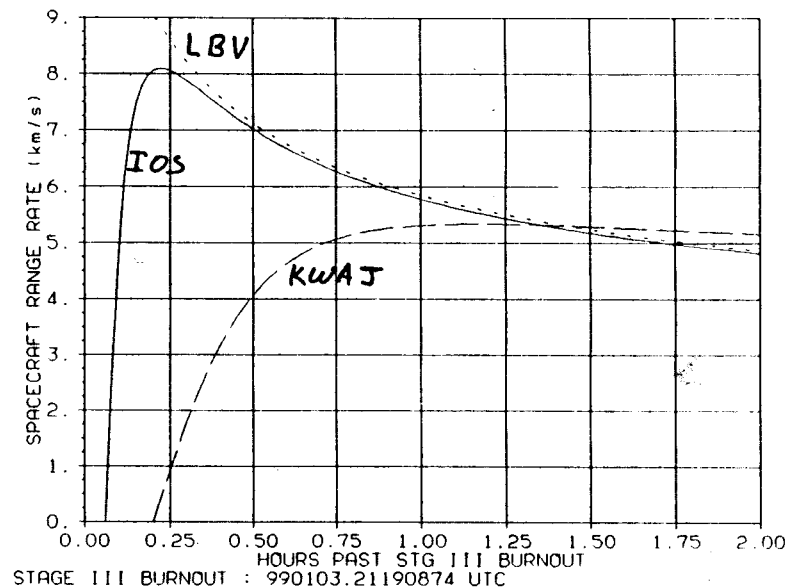


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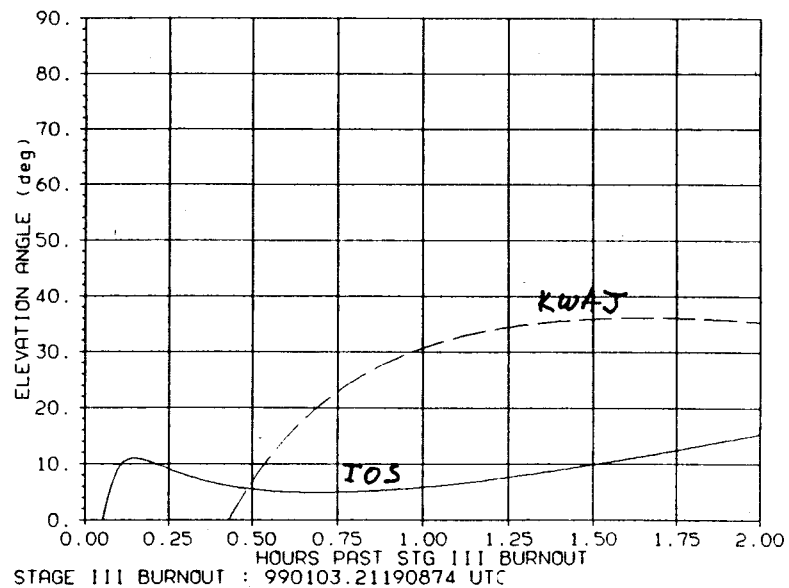
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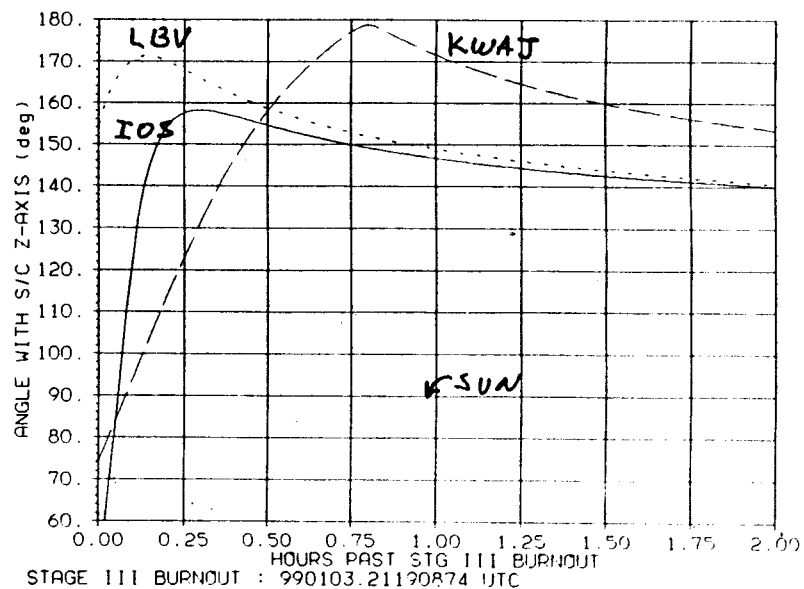
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SPACECRAFT ELEVATION ANGLE



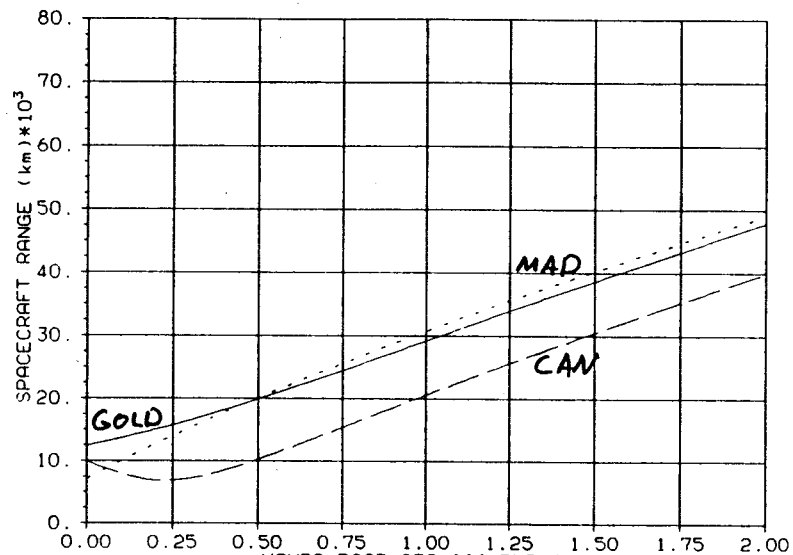
ASPECT ANGLE WITH S/C Z-AXIS



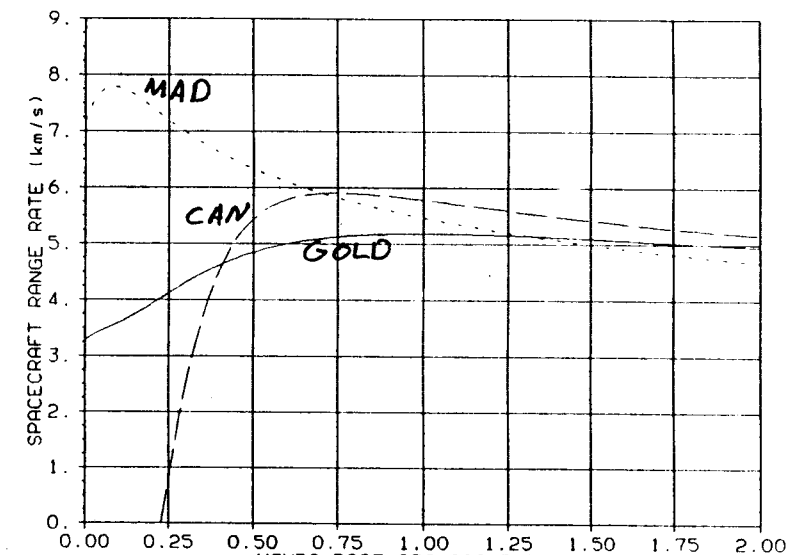
LANDER DAY 8 (1/10/99) SHORT COAST

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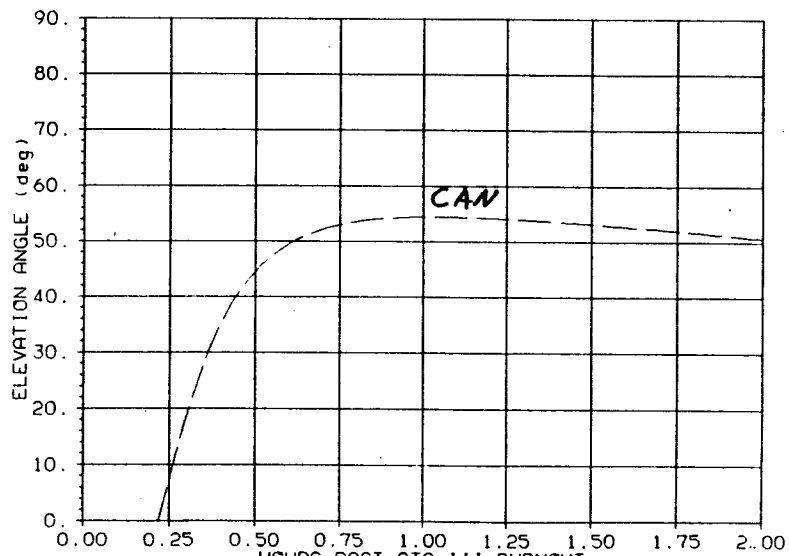
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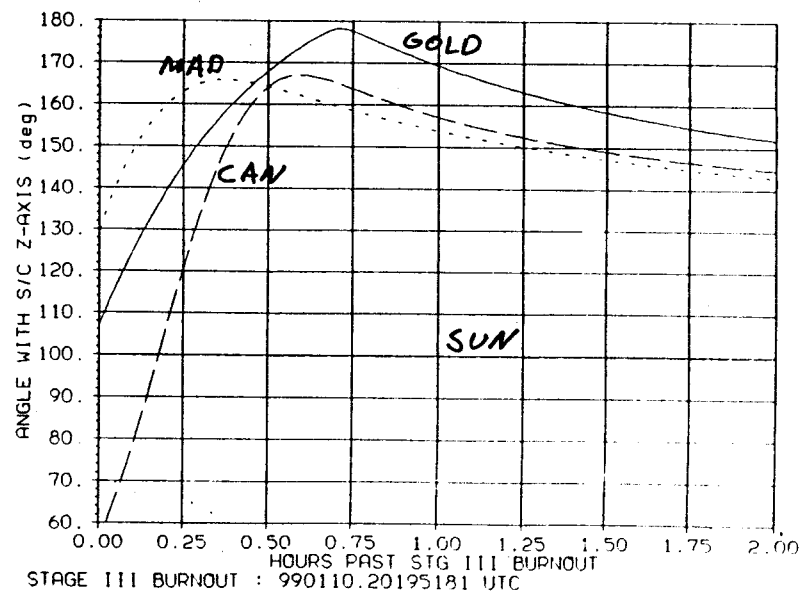
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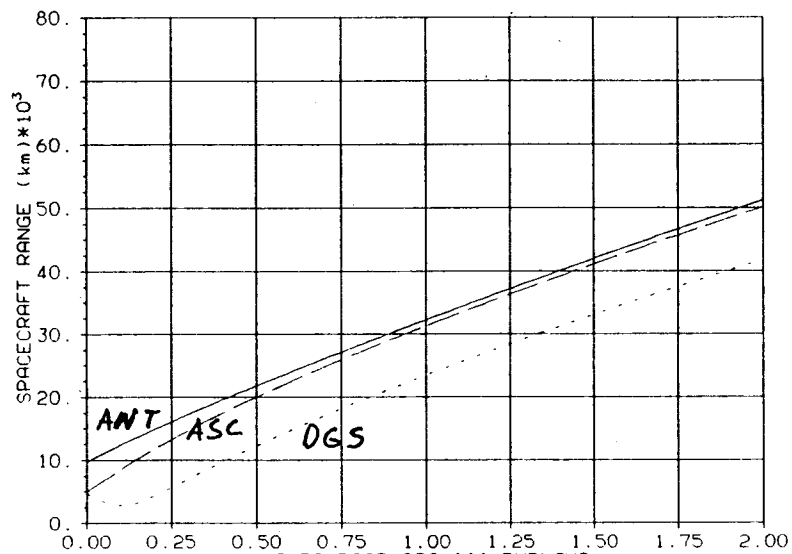


ASPECT ANGLE WITH S/C Z-AXIS



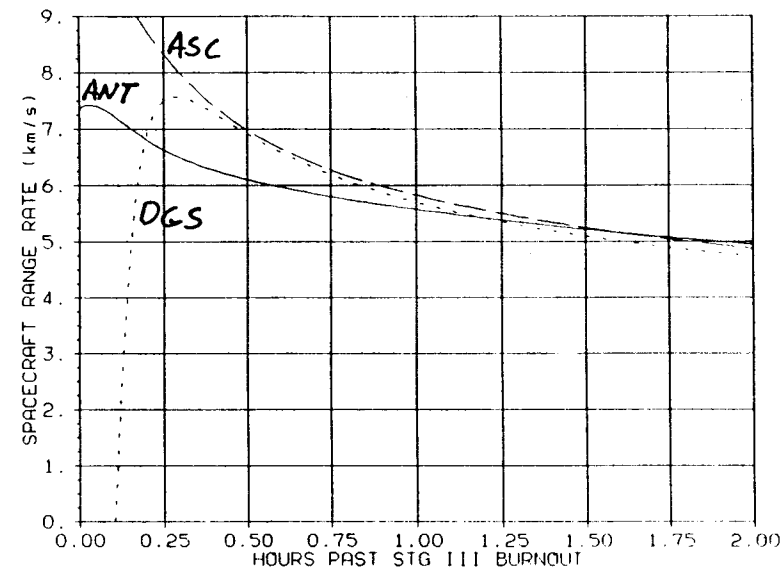
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SPACECRAFT RANGE



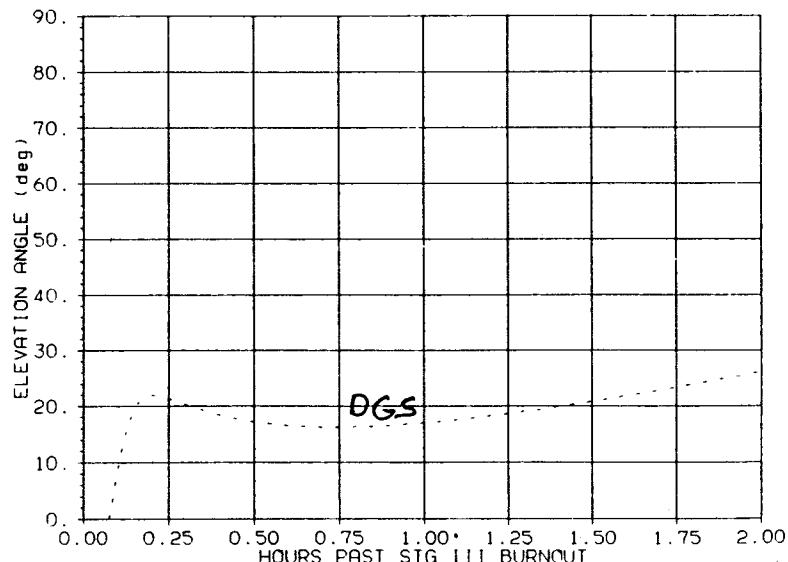
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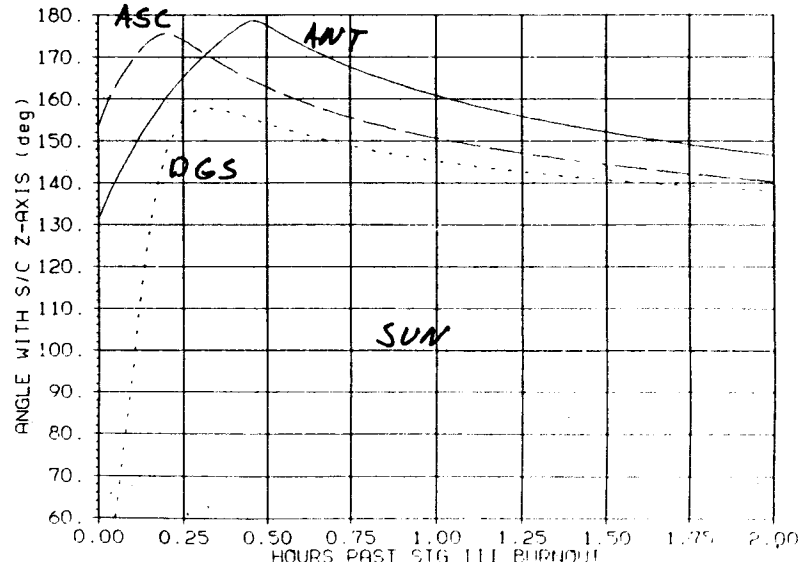
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SPACECRAFT ELEVATION ANGLE



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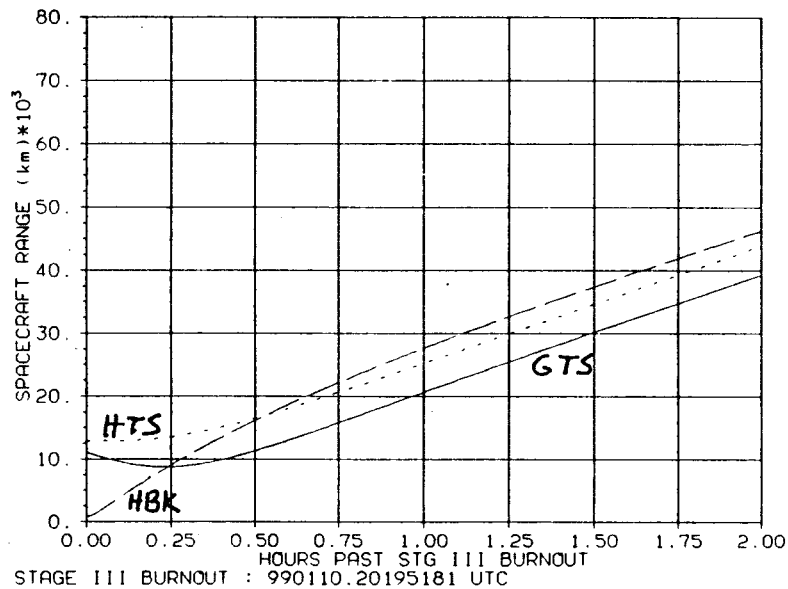
ASPECT ANGLE WITH S/C Z-AXIS



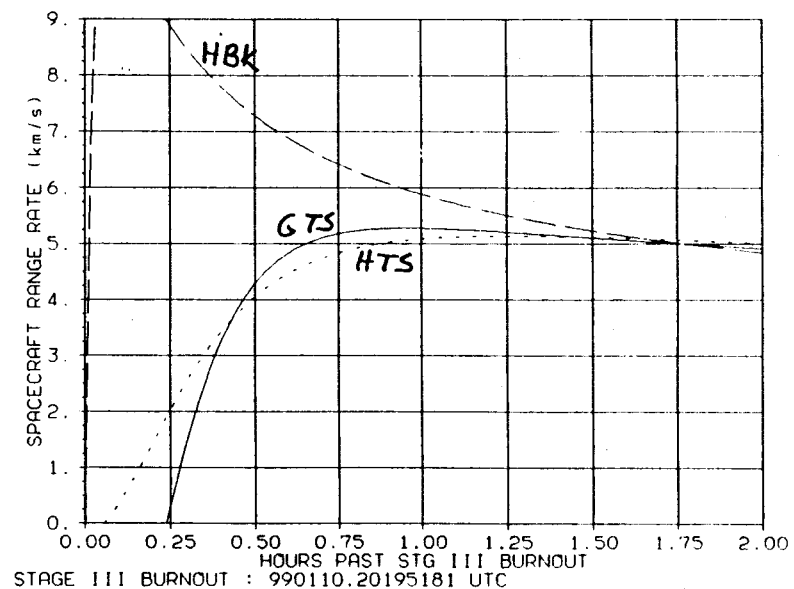
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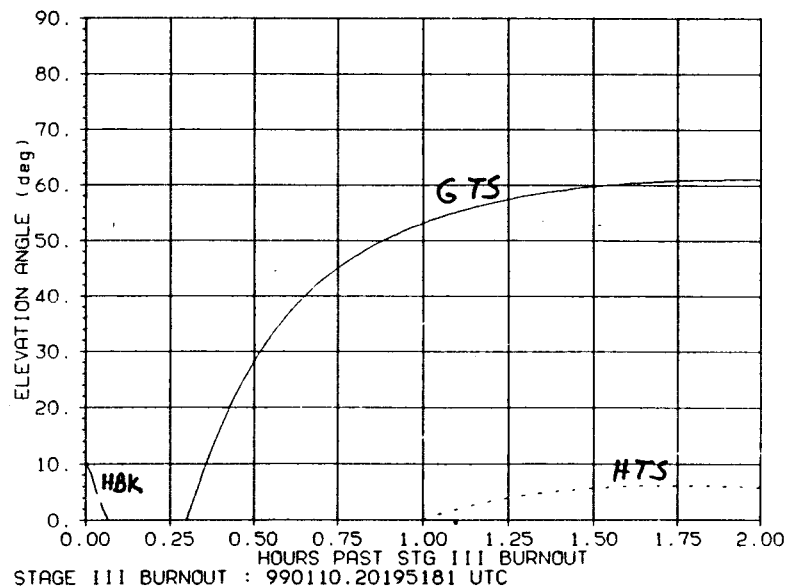
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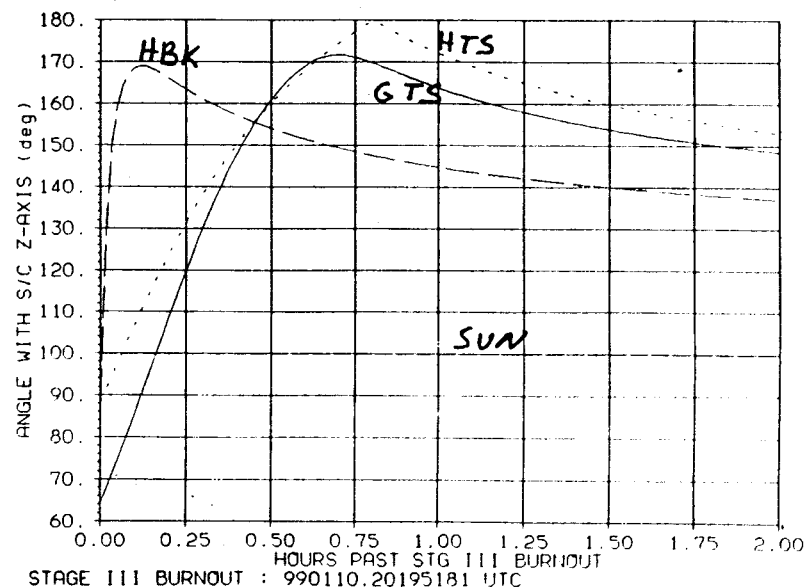
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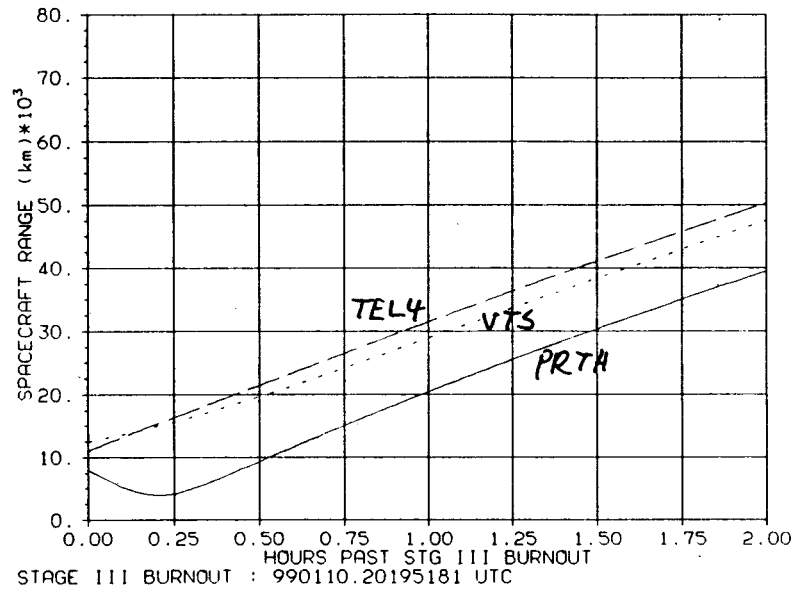


ASPECT ANGLE WITH S/C Z-AXIS

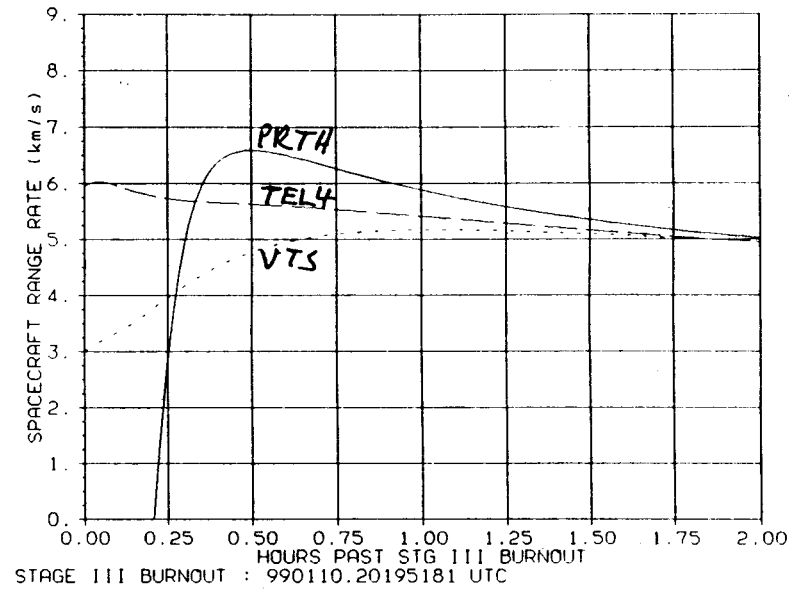


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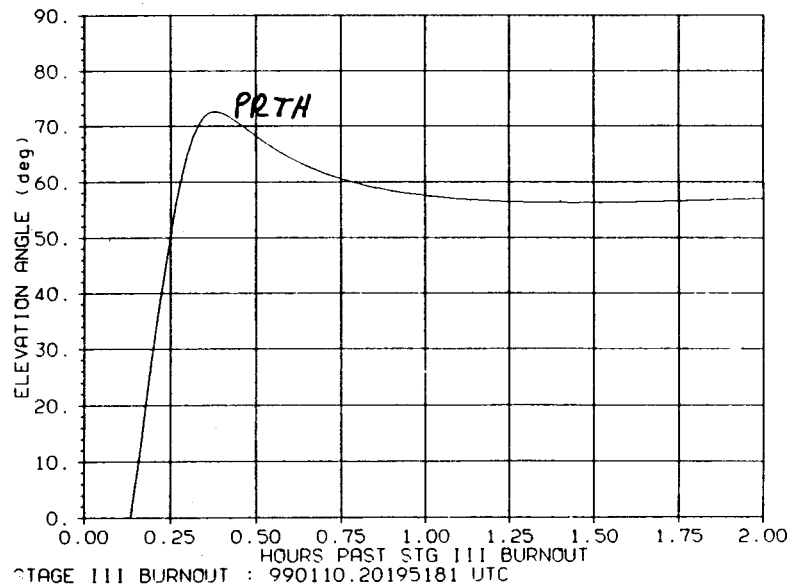
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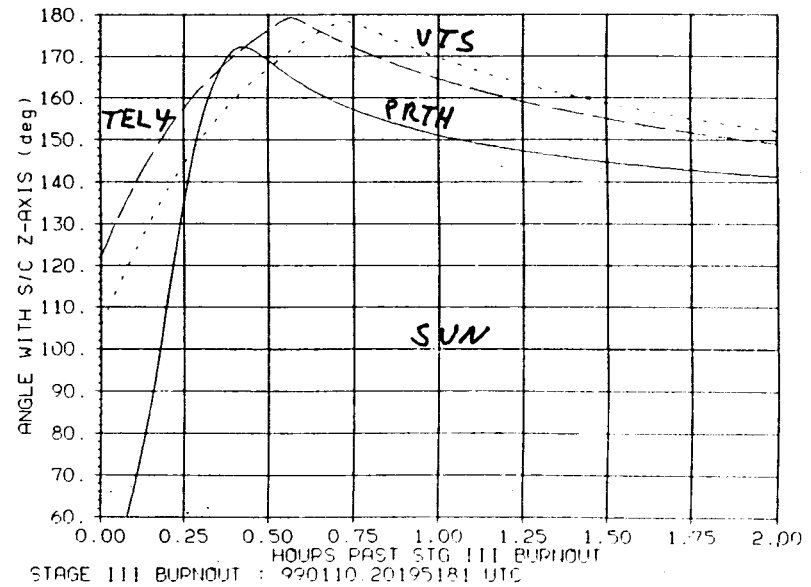
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SPACECRAFT ELEVATION ANGLE

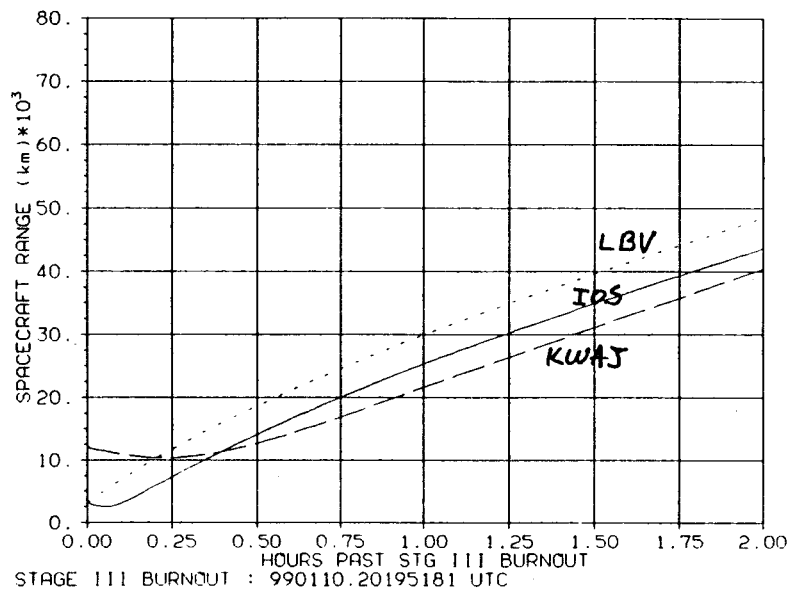


ASPECT ANGLE WITH S/C Z-AXIS

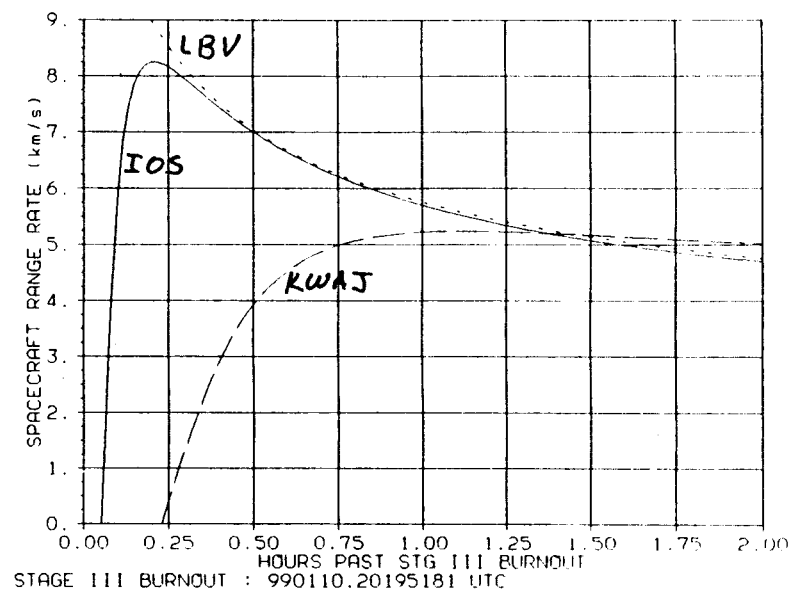


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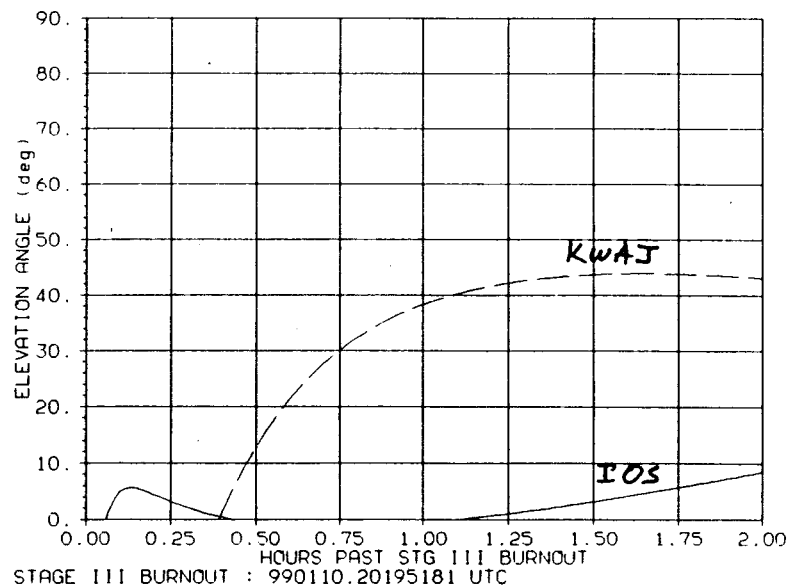
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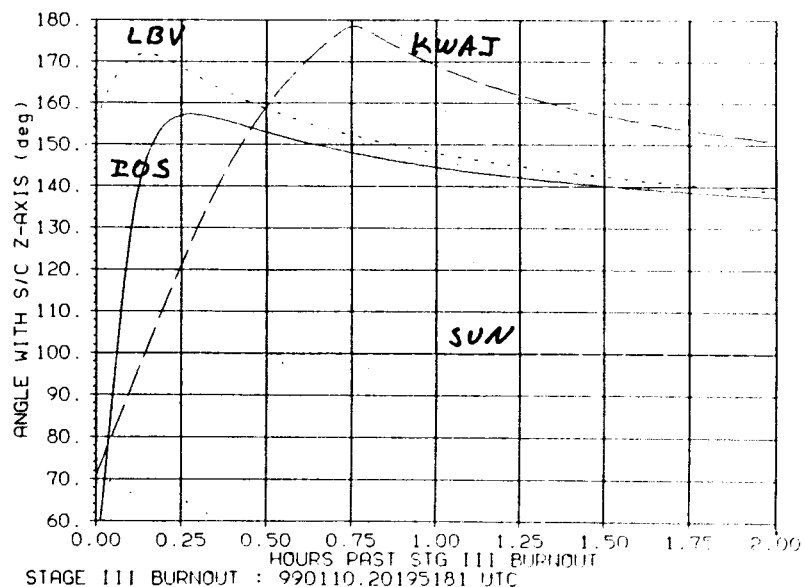
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SPACECRAFT ELEVATION ANGLE



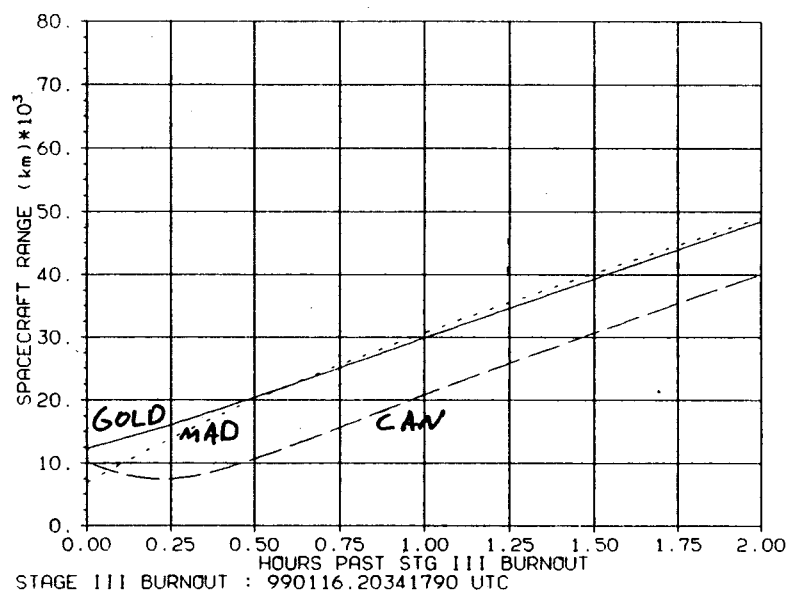
ASPECT ANGLE WITH S/C Z-AXIS



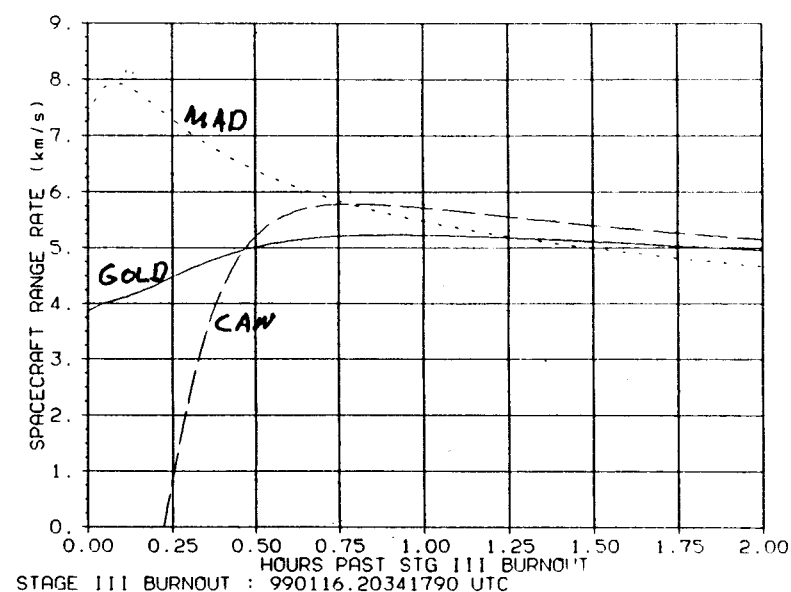
LANDER DAY 14 (1/16/99) SHORT COAST

TRACKING STATION GEOMETRY (LANDER) : DAY 14 SHORT COAST

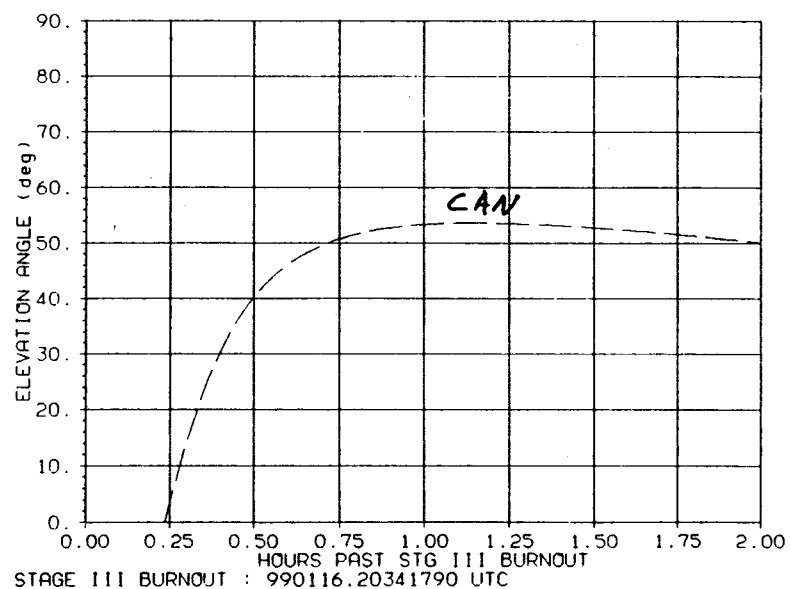
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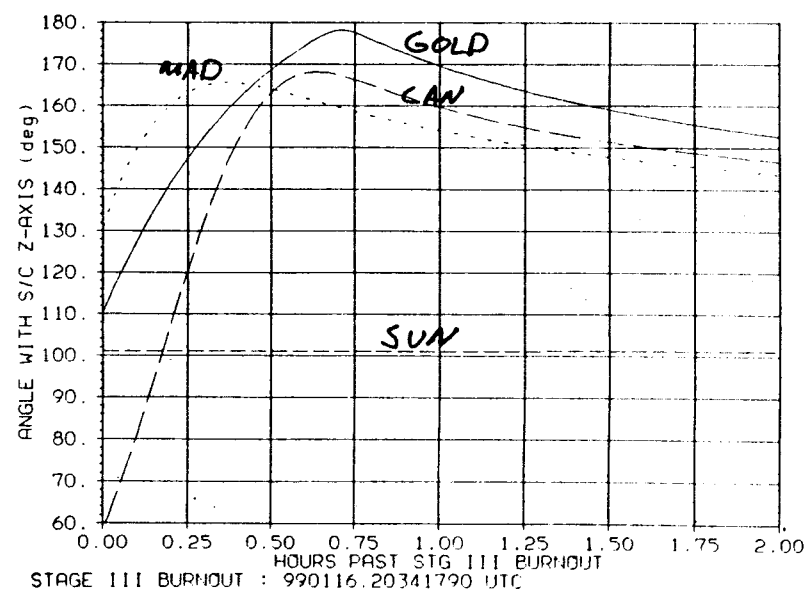
SPACECRAFT RANGE RATE



SPACECRAFT ELEVATION ANGLE

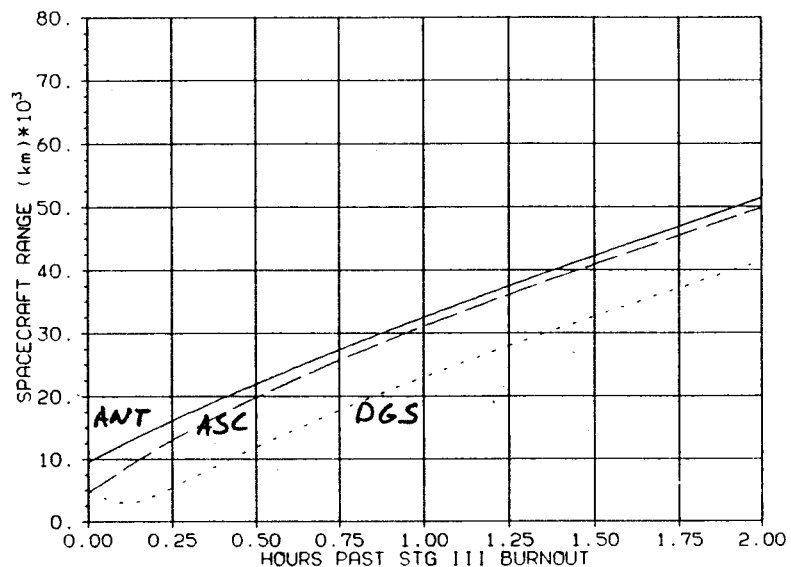


ASPECT ANGLE WITH S/C Z-AXIS

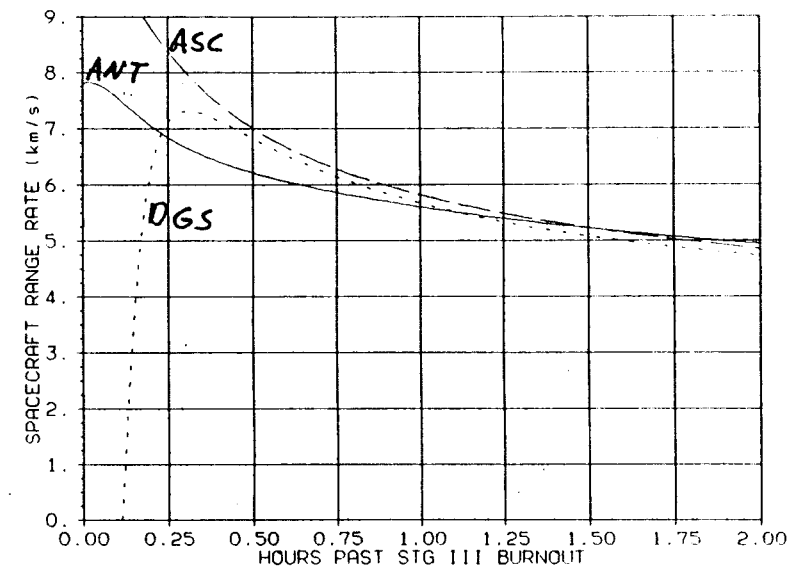


TRACKING STATION GEOMETRY (LANDER) : DAY 14 SHORT COAST

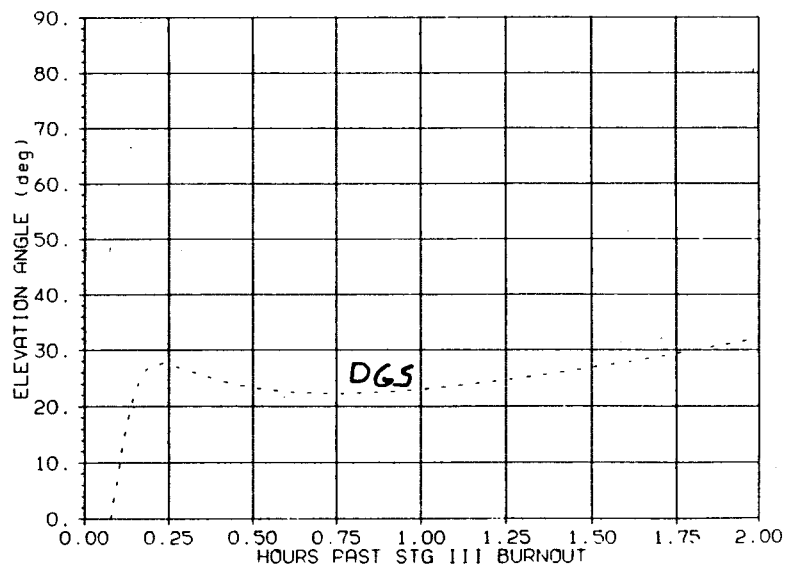
SPACECRAFT RANGE



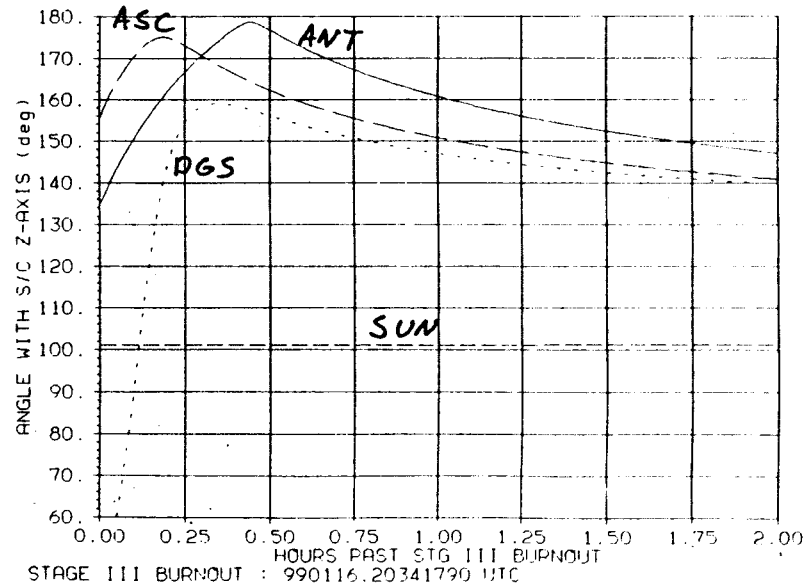
SPACECRAFT RANGE RATE



SPACECRAFT ELEVATION ANGLE

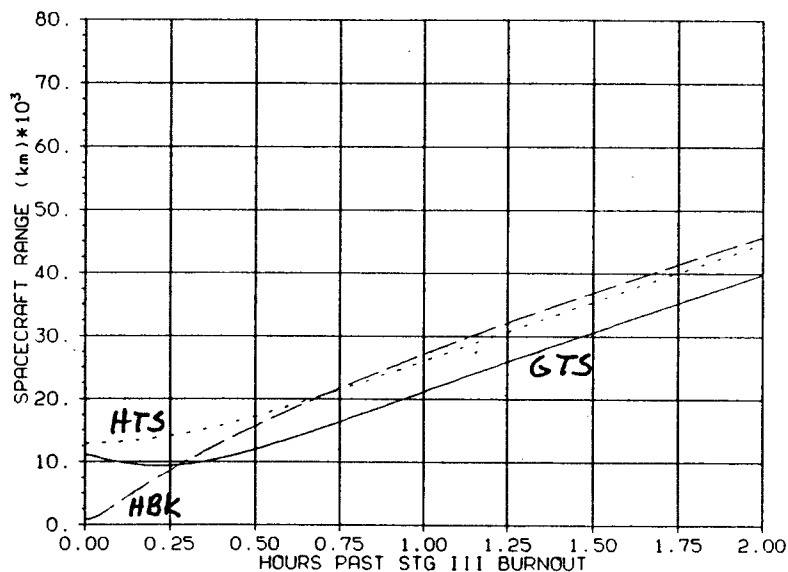


ASPECT ANGLE WITH S/C Z-AXIS

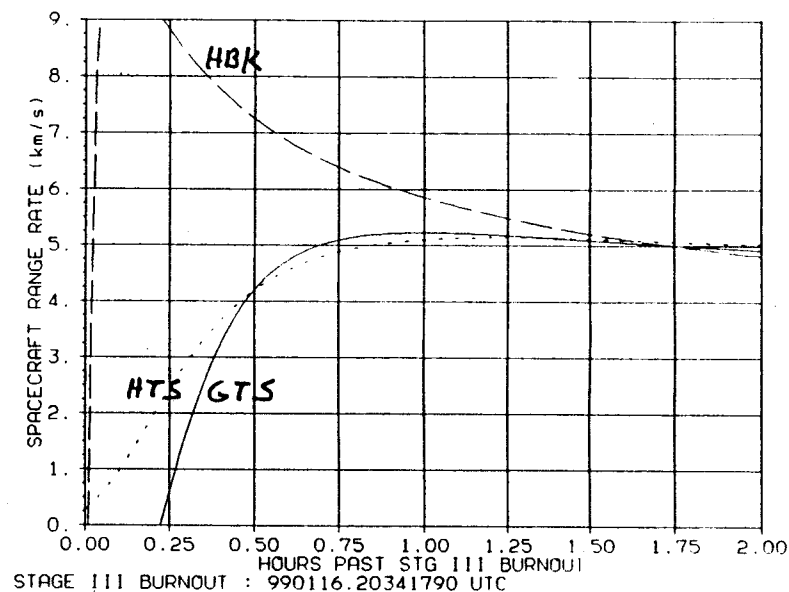


TRACKING STATION GEOMETRY (LANDER) : DAY 14 SHORT COAST

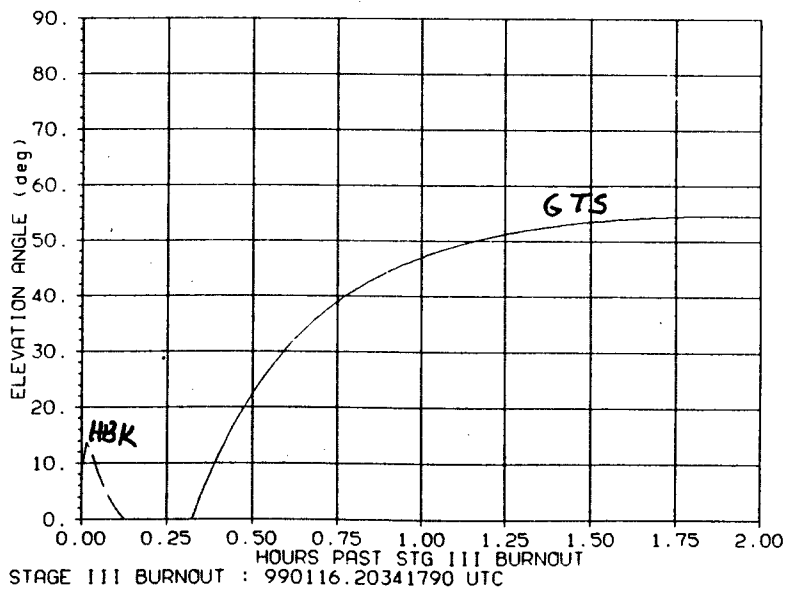
SPACECRAFT RANGE



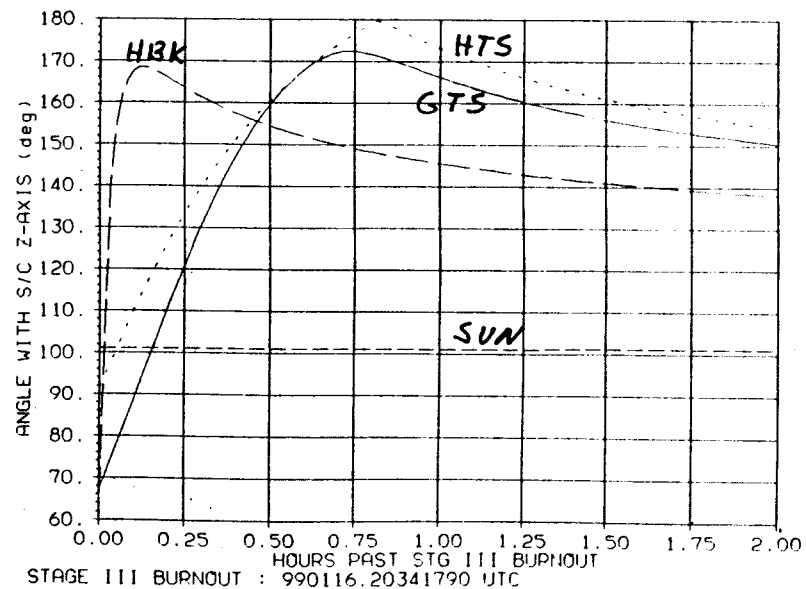
SPACECRAFT RANGE RATE



SPACECRAFT ELEVATION ANGLE

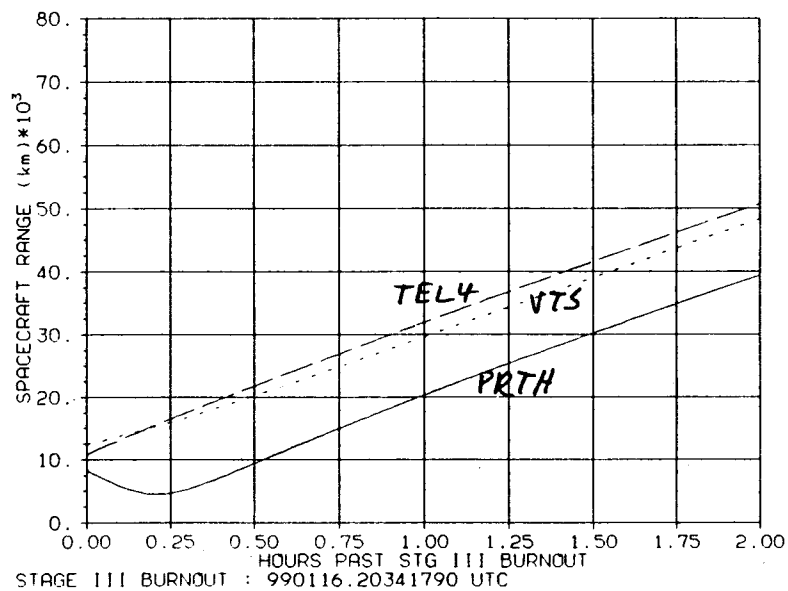


ASPECT ANGLE WITH S/C Z-AXIS

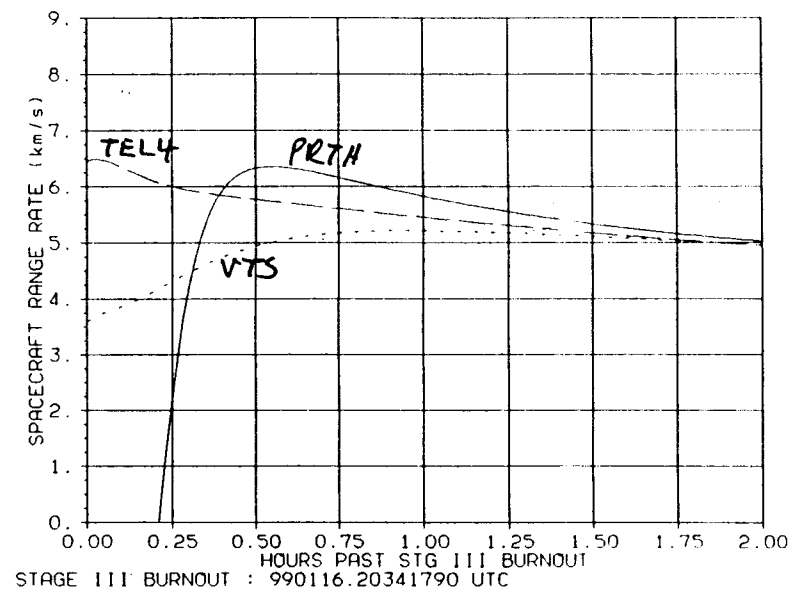


TRACKING STATION GEOMETRY (LANDER) : DAY 14 SHORT COAST

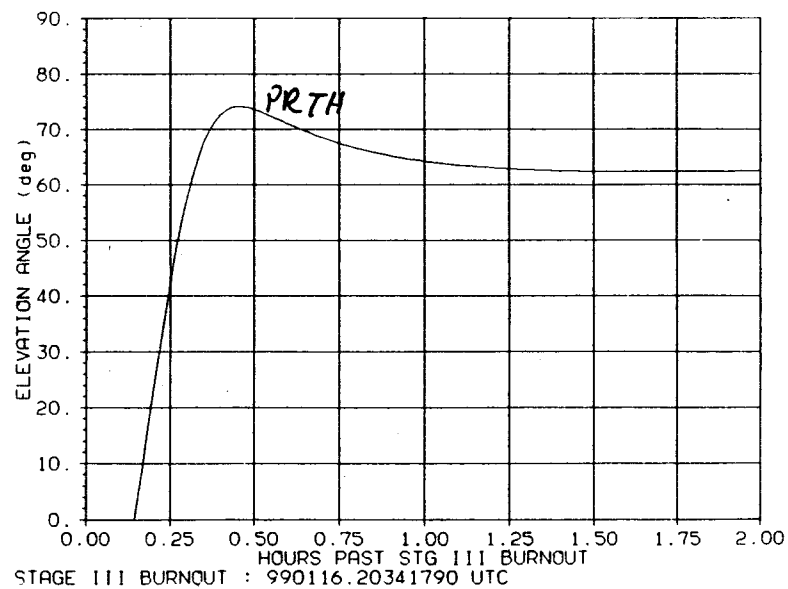
SPACECRAFT RANGE



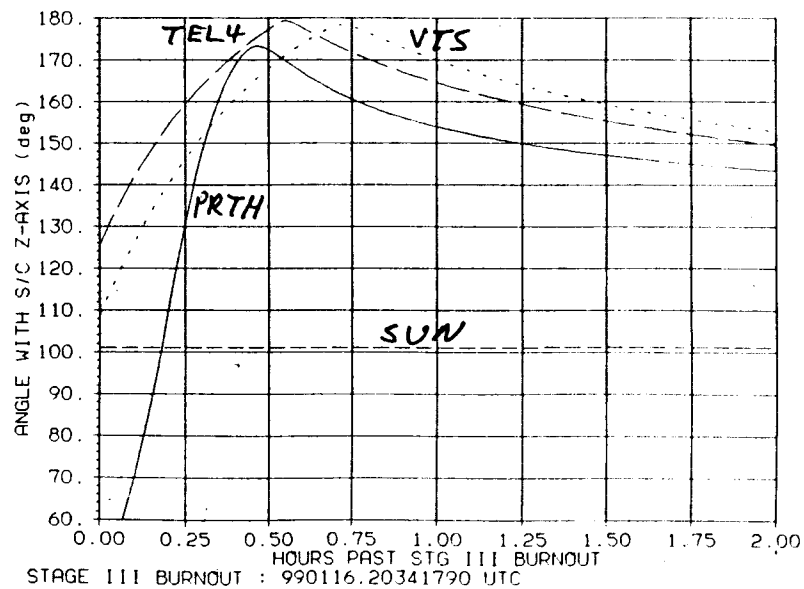
SPACECRAFT RANGE RATE



SPACECRAFT ELEVATION ANGLE

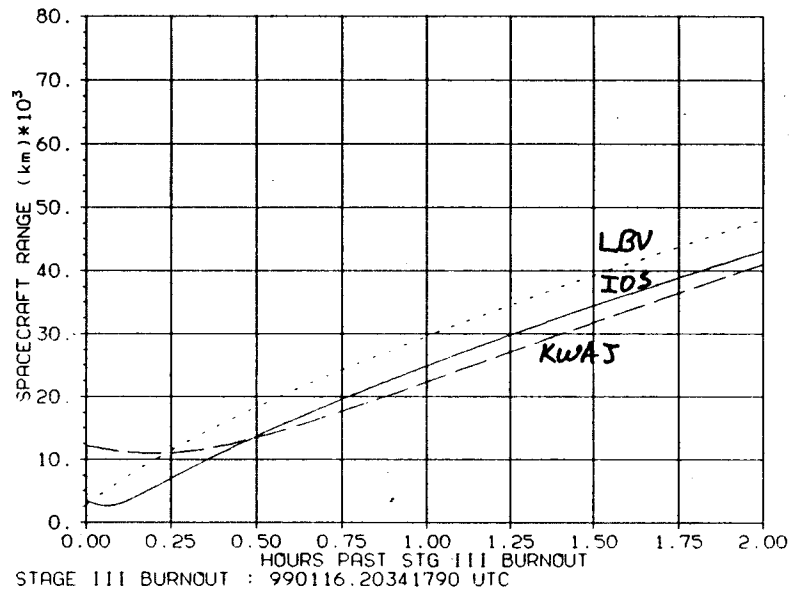


ASPECT ANGLE WITH S/C Z-AXIS

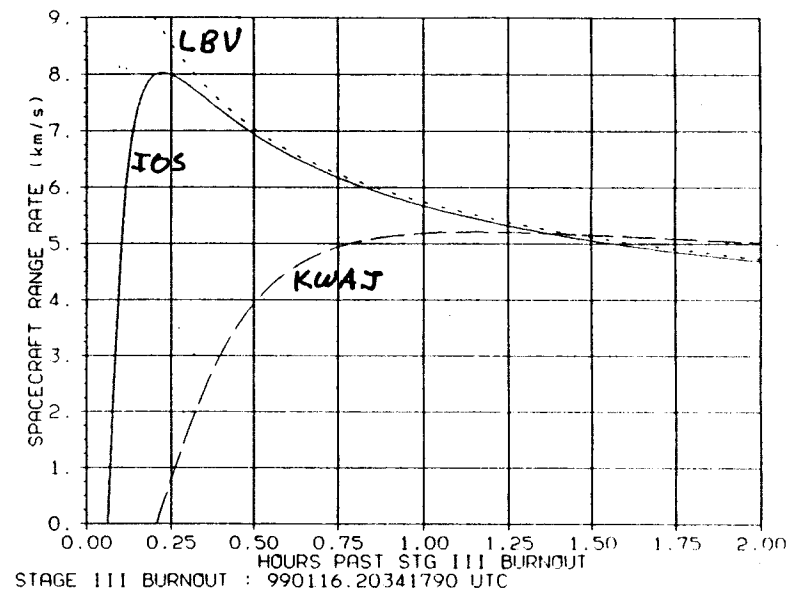


TRACKING STATION GEOMETRY (LANDER) : DAY 14 SHORT COAST

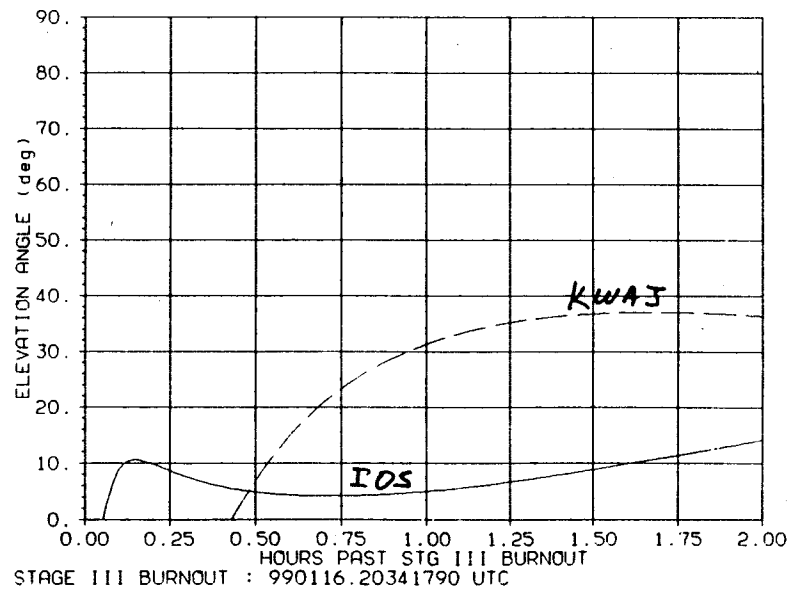
SPACECRAFT RANGE



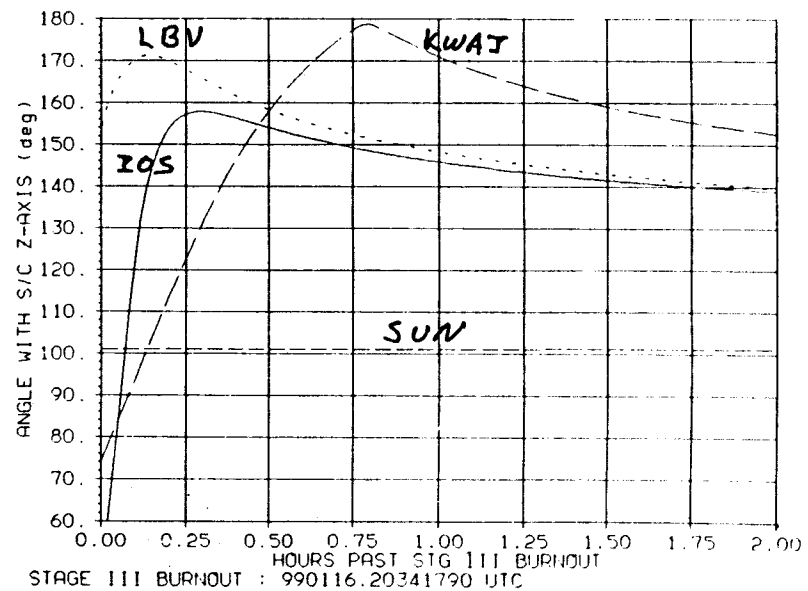
SPACECRAFT RANGE RATE



SPACECRAFT ELEVATION ANGLE



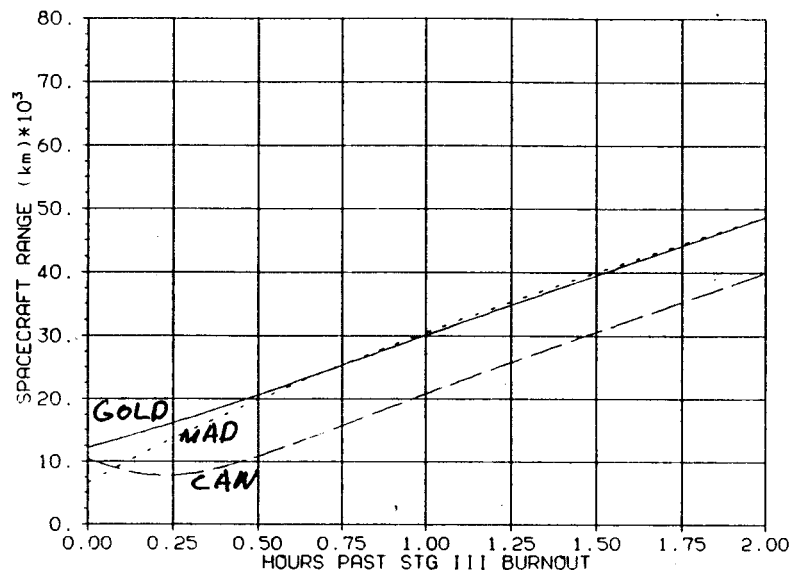
ASPECT ANGLE WITH S/C Z-AXIS



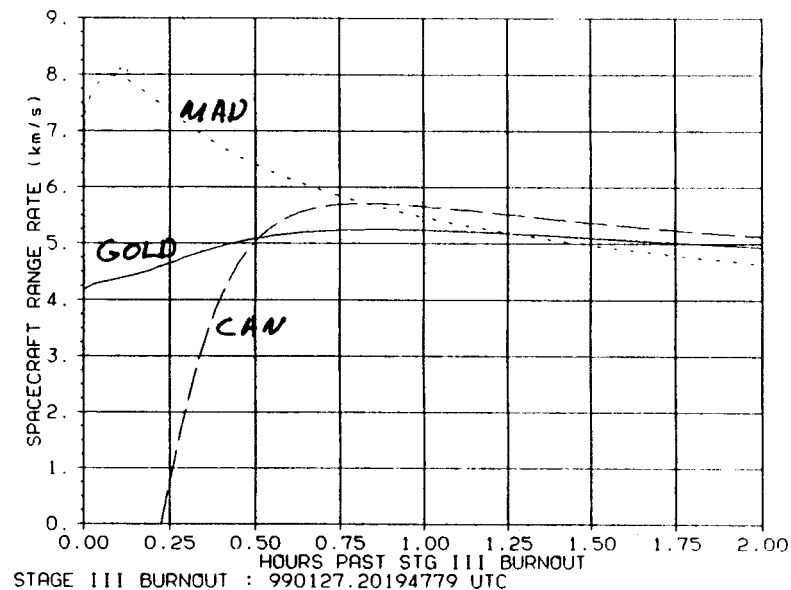
LANDER DAY 25 (1/27/99) SHORT COAST

TRACKING STATION GEOMETRY (LANDER) : DAY 25 SHORT COAST

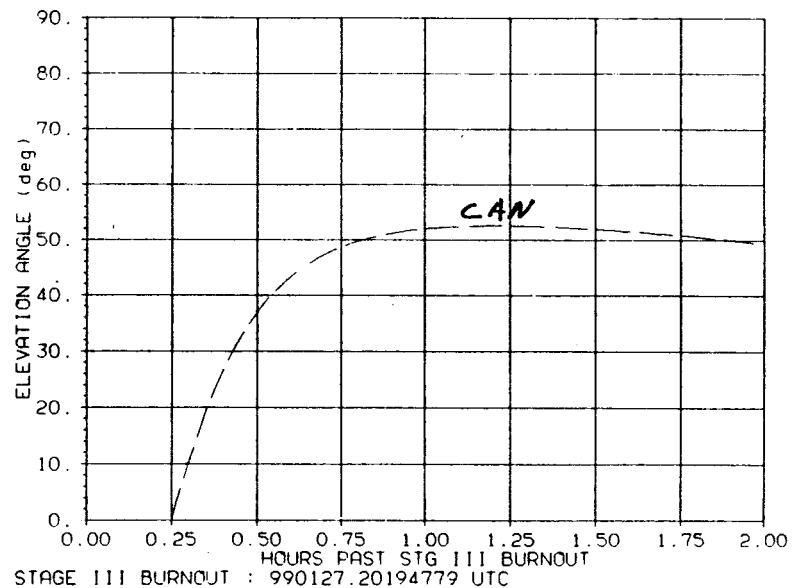
SPACECRAFT RANGE



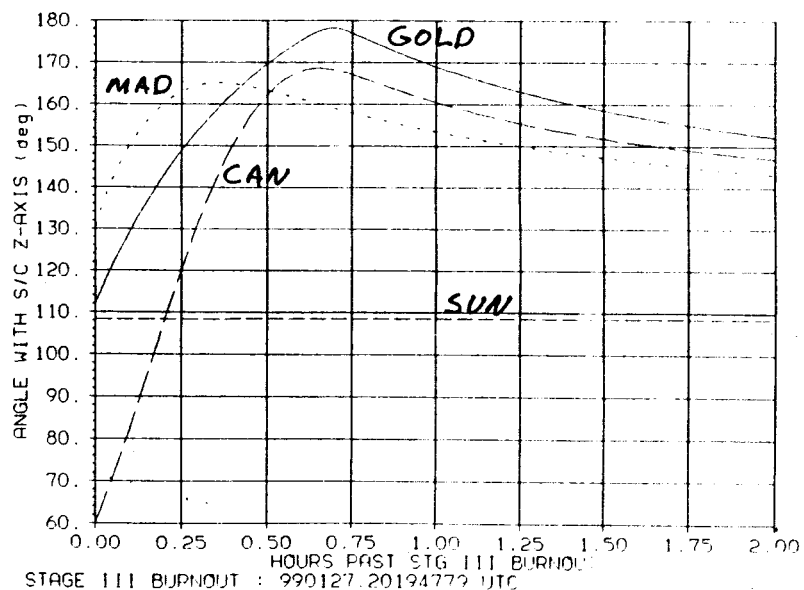
SPACECRAFT RANGE RATE



SPACECRAFT ELEVATION ANGLE

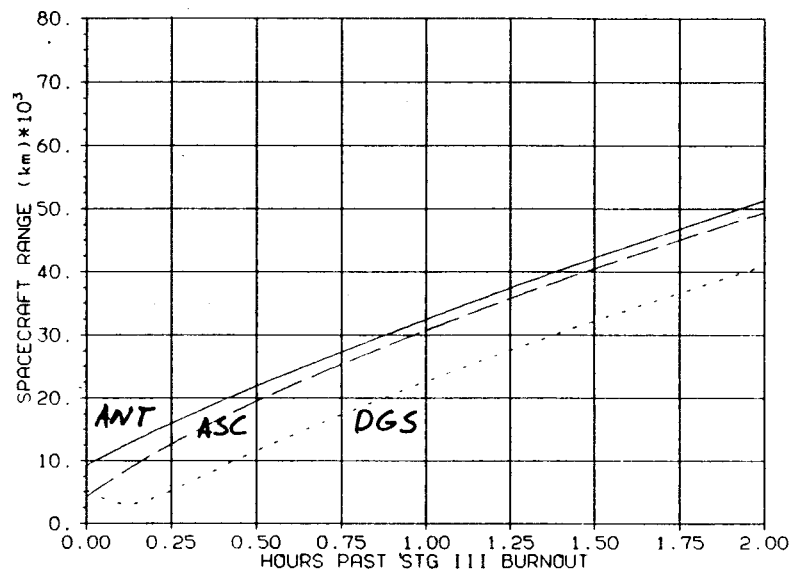


ASPECT ANGLE WITH S/C Z-AXIS

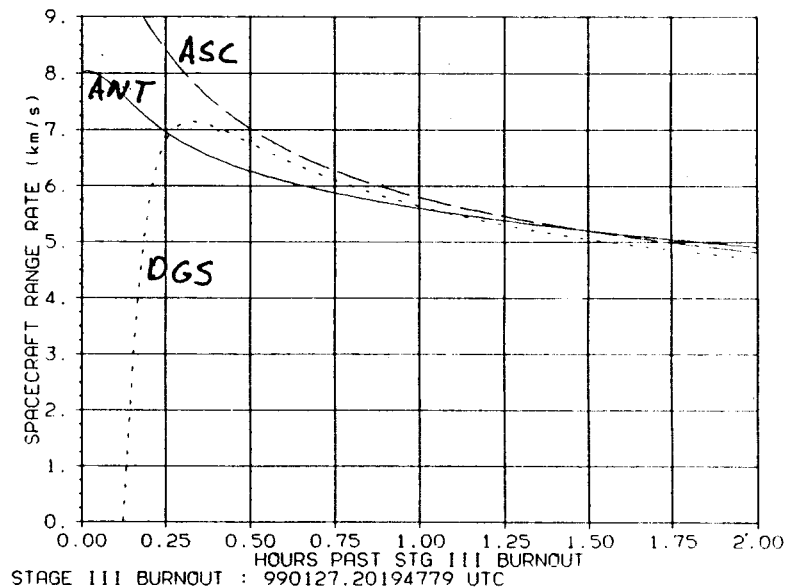


TRACKING STATION GEOMETRY (LANDER) : DAY 25 SHORT COAST

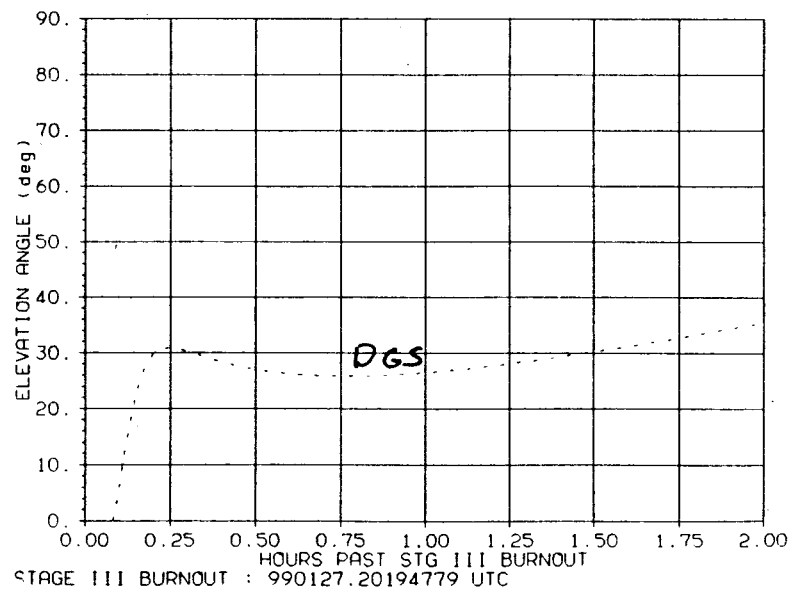
SPACECRAFT RANGE



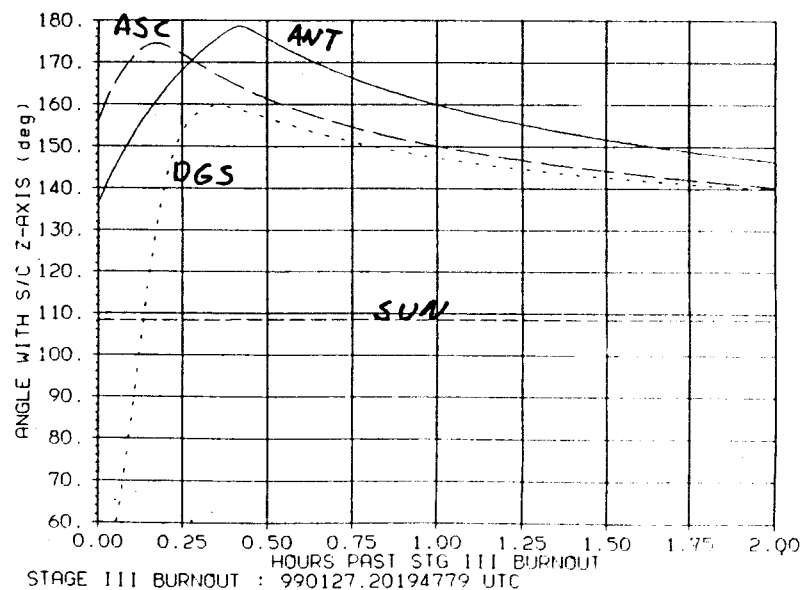
SPACECRAFT RANGE RATE



SPACECRAFT ELEVATION ANGLE

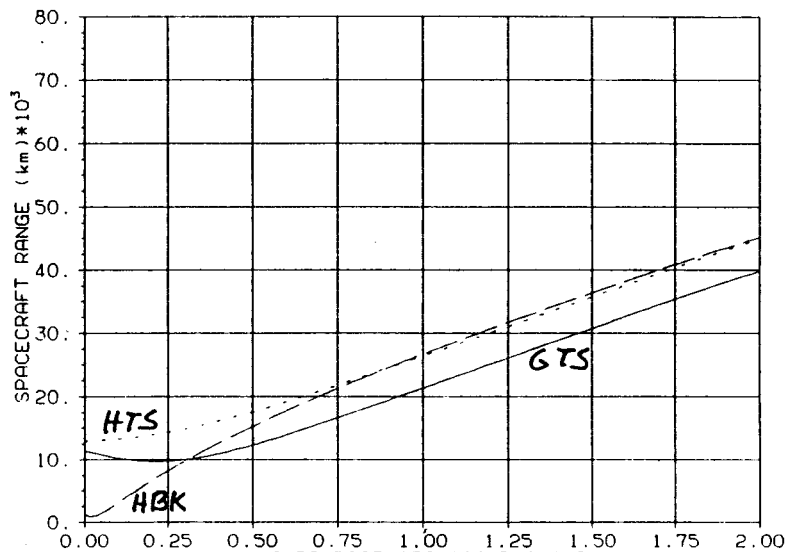


ASPECT ANGLE WITH S/C Z-AXIS

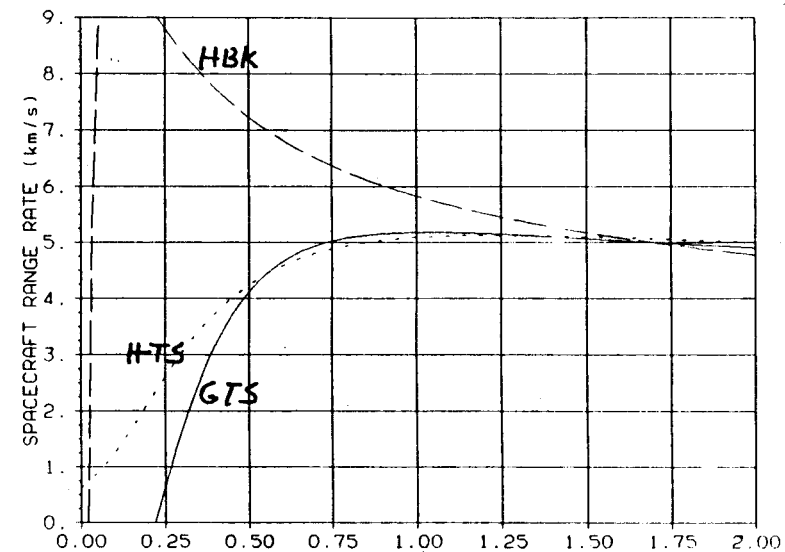


TRACKING STATION GEOMETRY (LANDER) : DAY 25 SHORT COAST

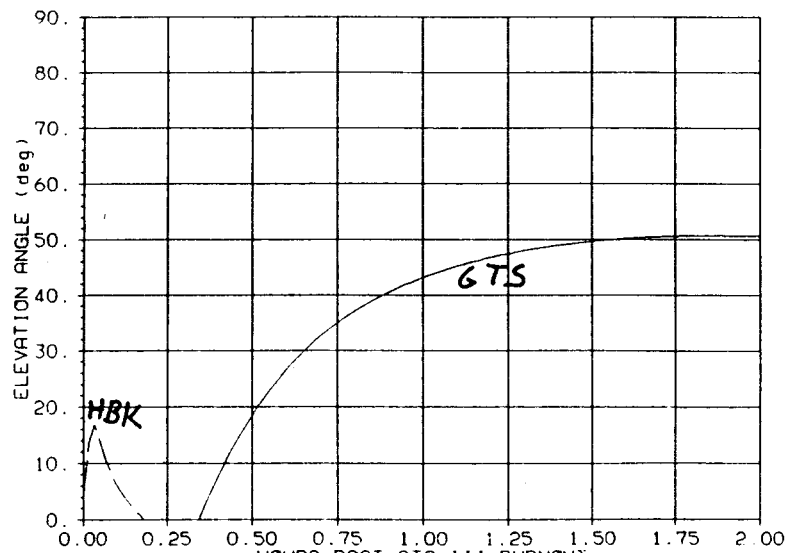
SPACECRAFT RANGE



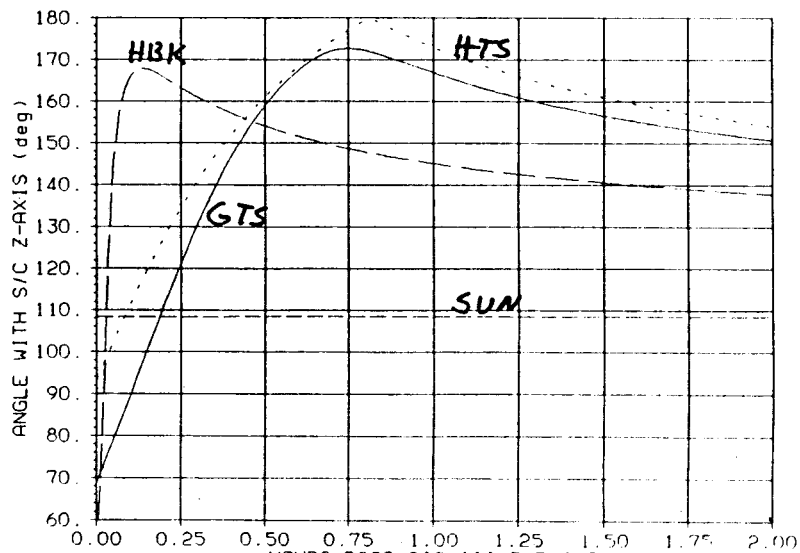
SPACECRAFT RANGE RATE



SPACECRAFT ELEVATION ANGLE

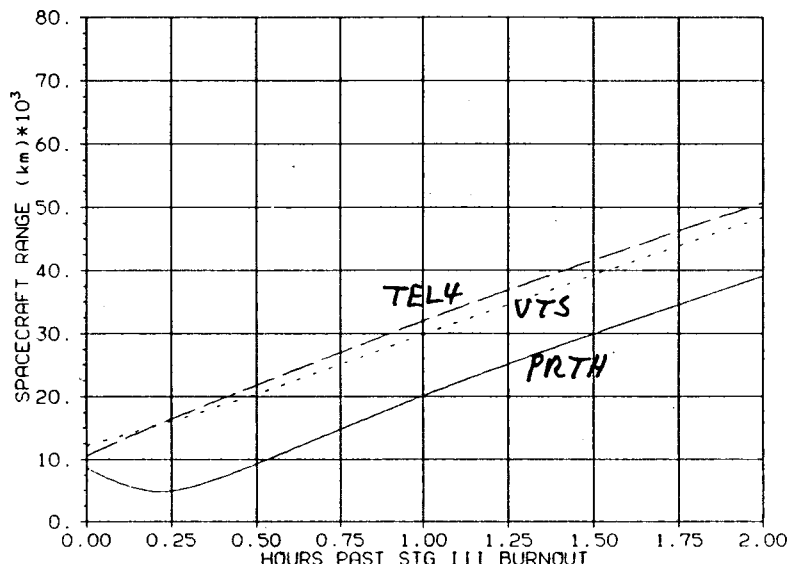


ASPECT ANGLE WITH S/C Z-AXIS



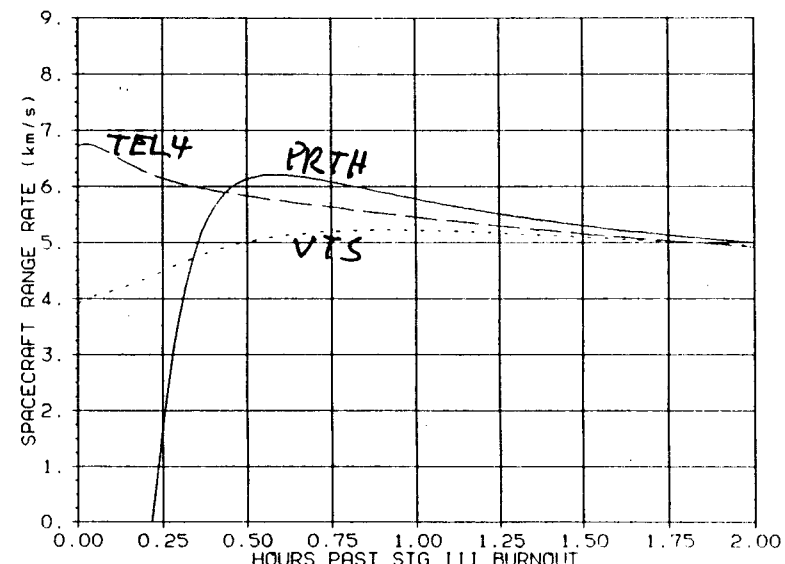
TRACKING STATION GEOMETRY (LANDER) : DAY 25 SHORT COAST

SPACECRAFT RANGE



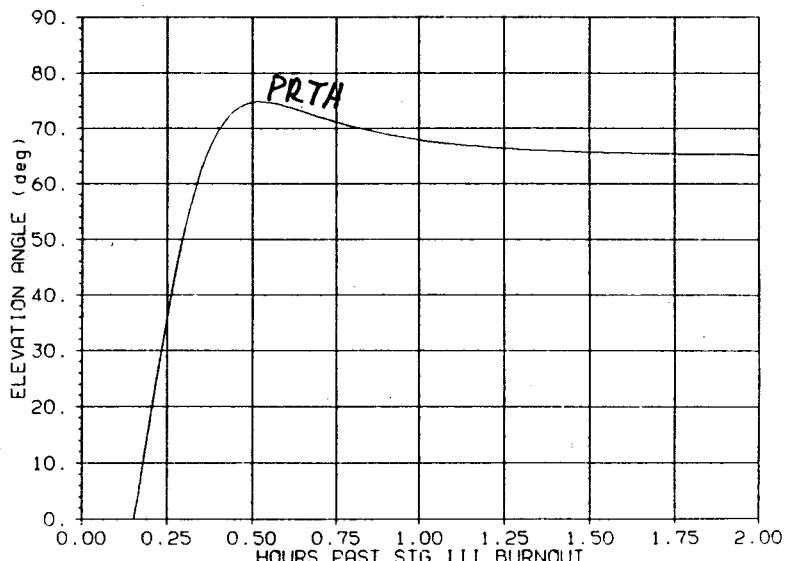
STAGE III BURNOUT : 990127.20194779 UTC

SPACECRAFT RANGE RATE



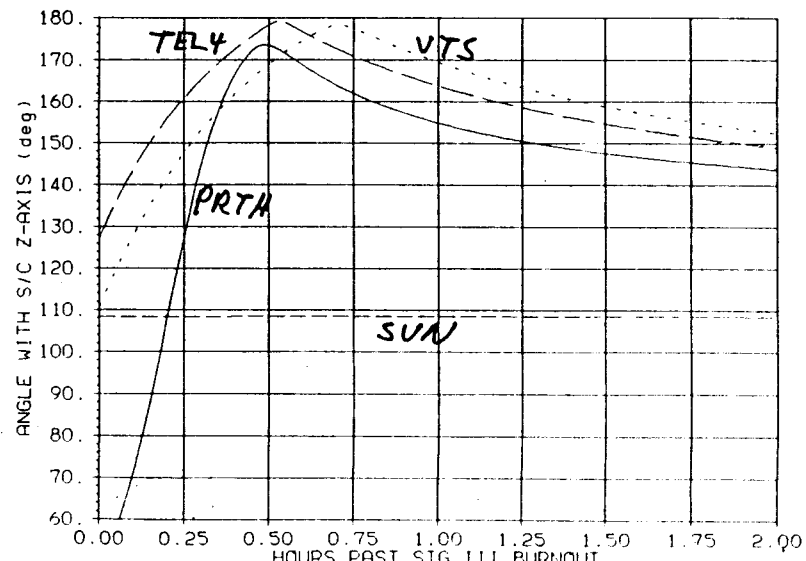
STAGE III BURNOUT : 990127.20194779 UTC

SPACECRAFT ELEVATION ANGLE



STAGE III BURNOUT : 990127.20194779 UTC

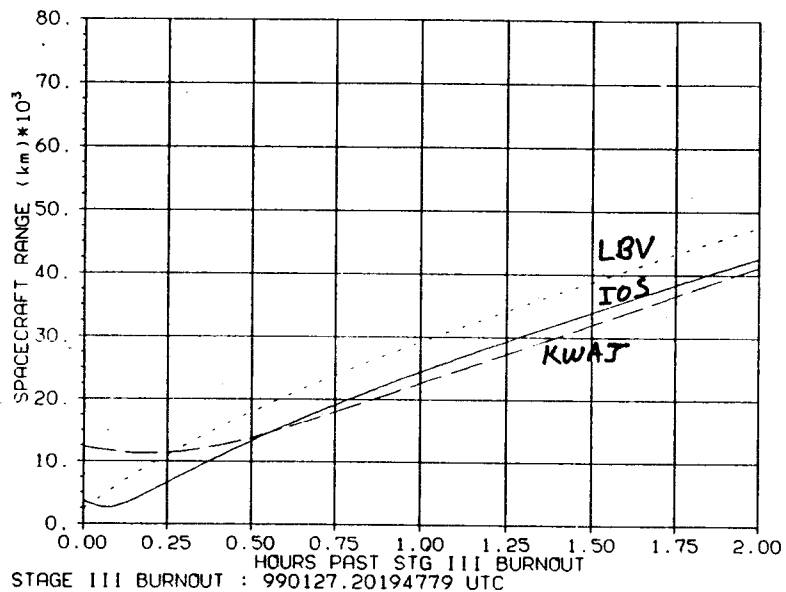
ASPECT ANGLE WITH S/C Z-AXIS



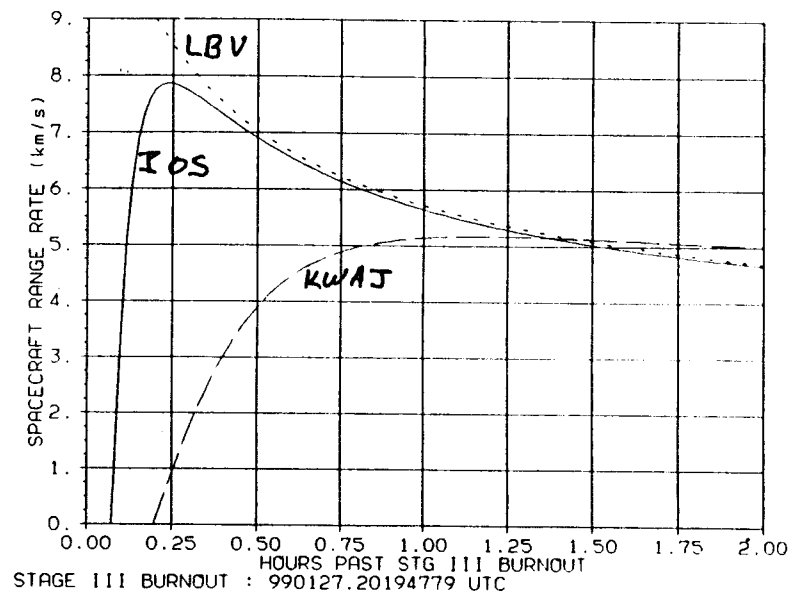
STAGE III BURNOUT : 990127.20194779 UTC

TRACKING STATION GEOMETRY (LANDER) : DAY 25 SHORT COAST

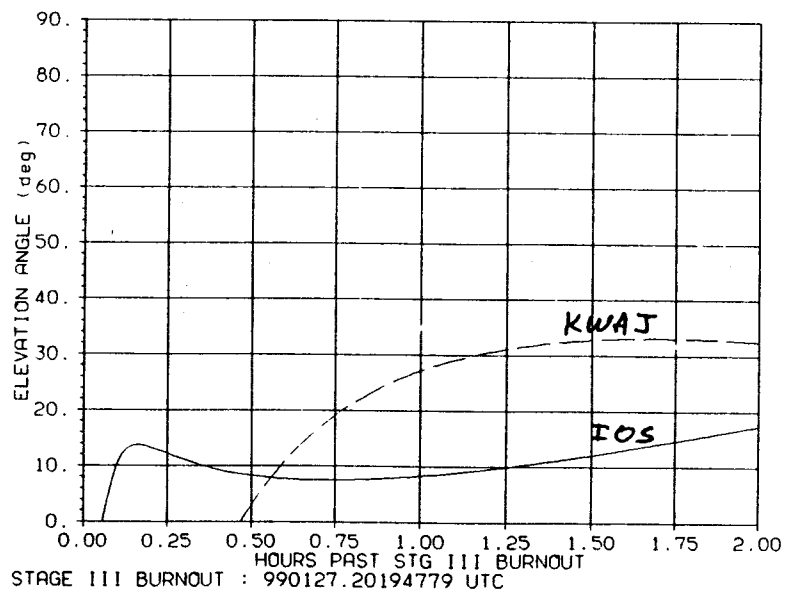
SPACECRAFT RANGE



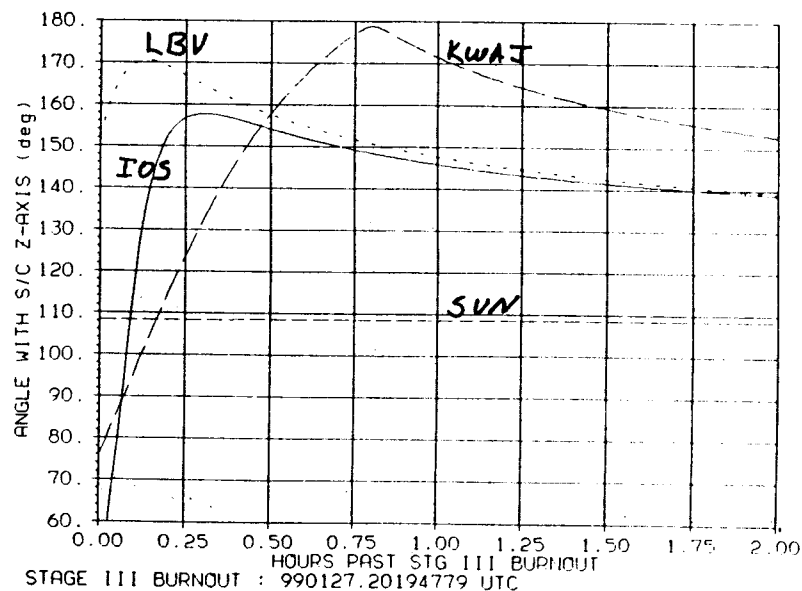
SPACECRAFT RANGE RATE



SPACECRAFT ELEVATION ANGLE

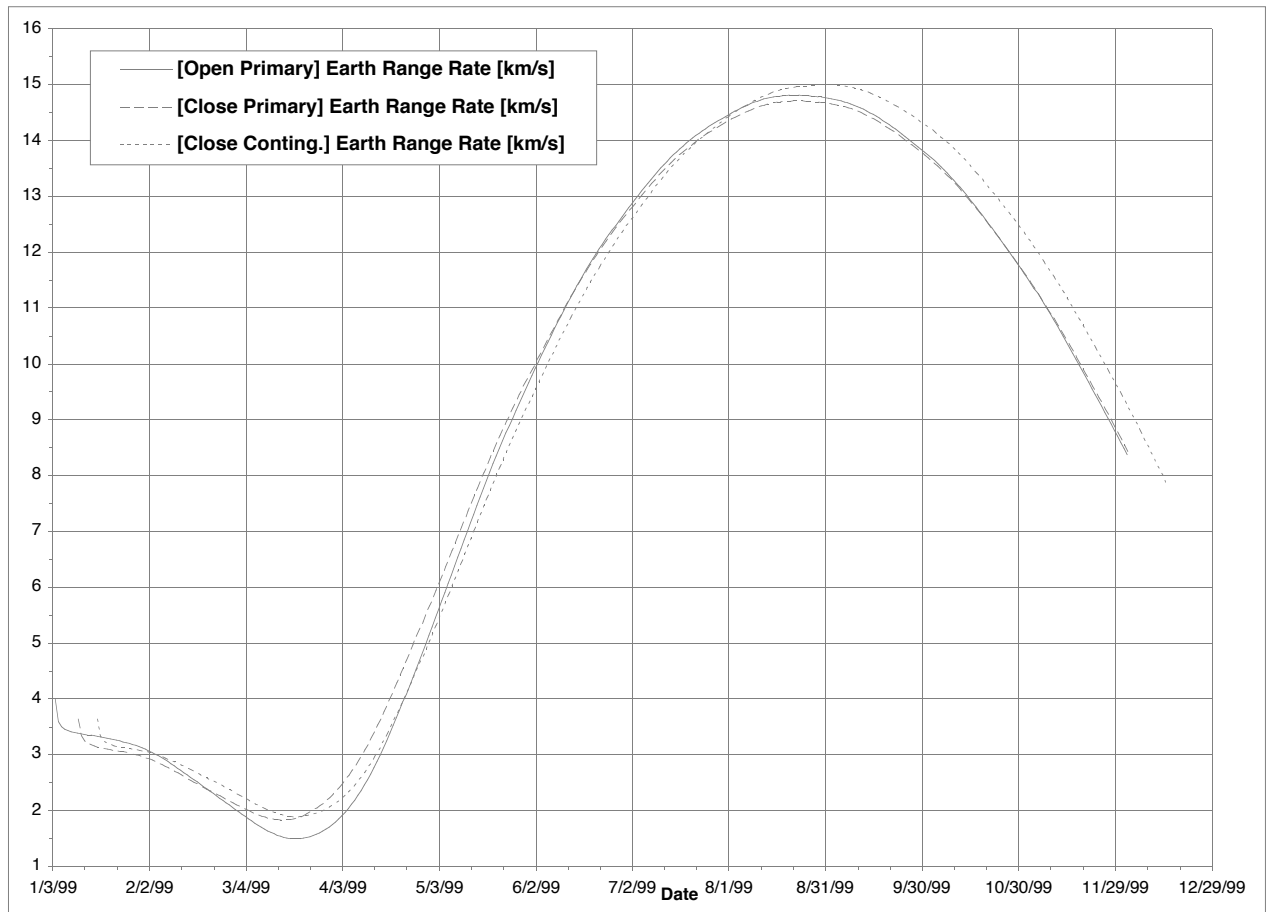
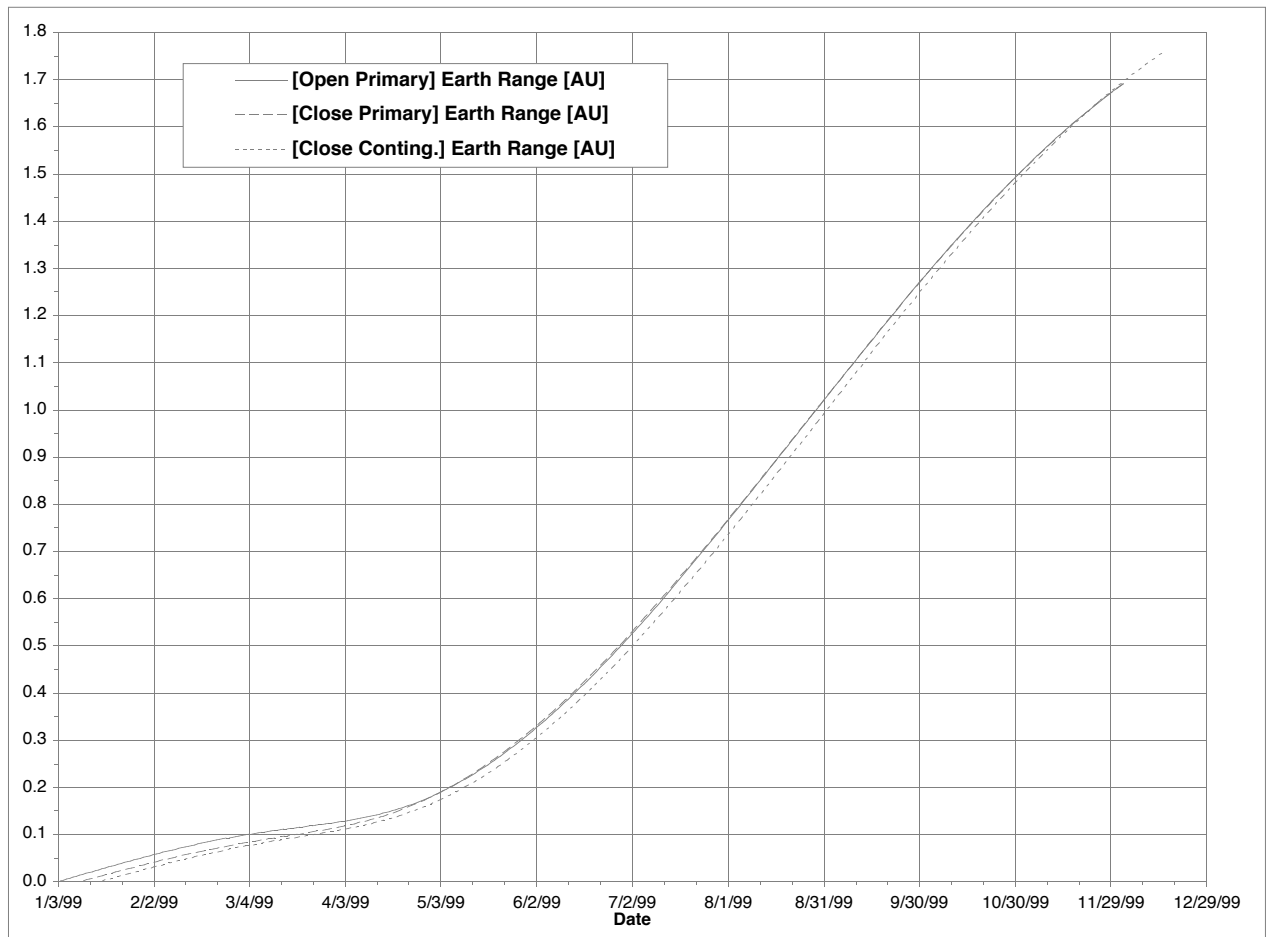


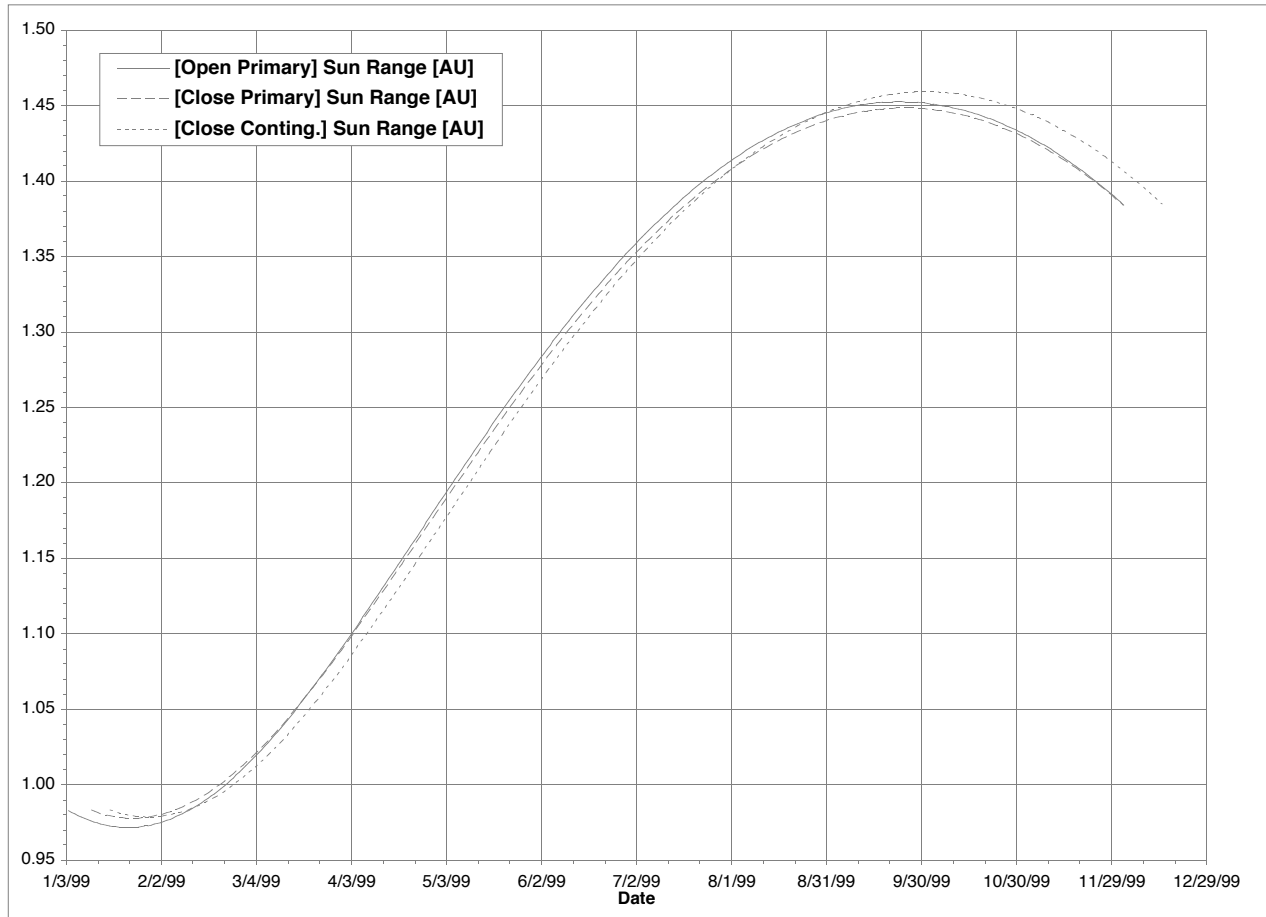
ASPECT ANGLE WITH S/C Z-AXIS

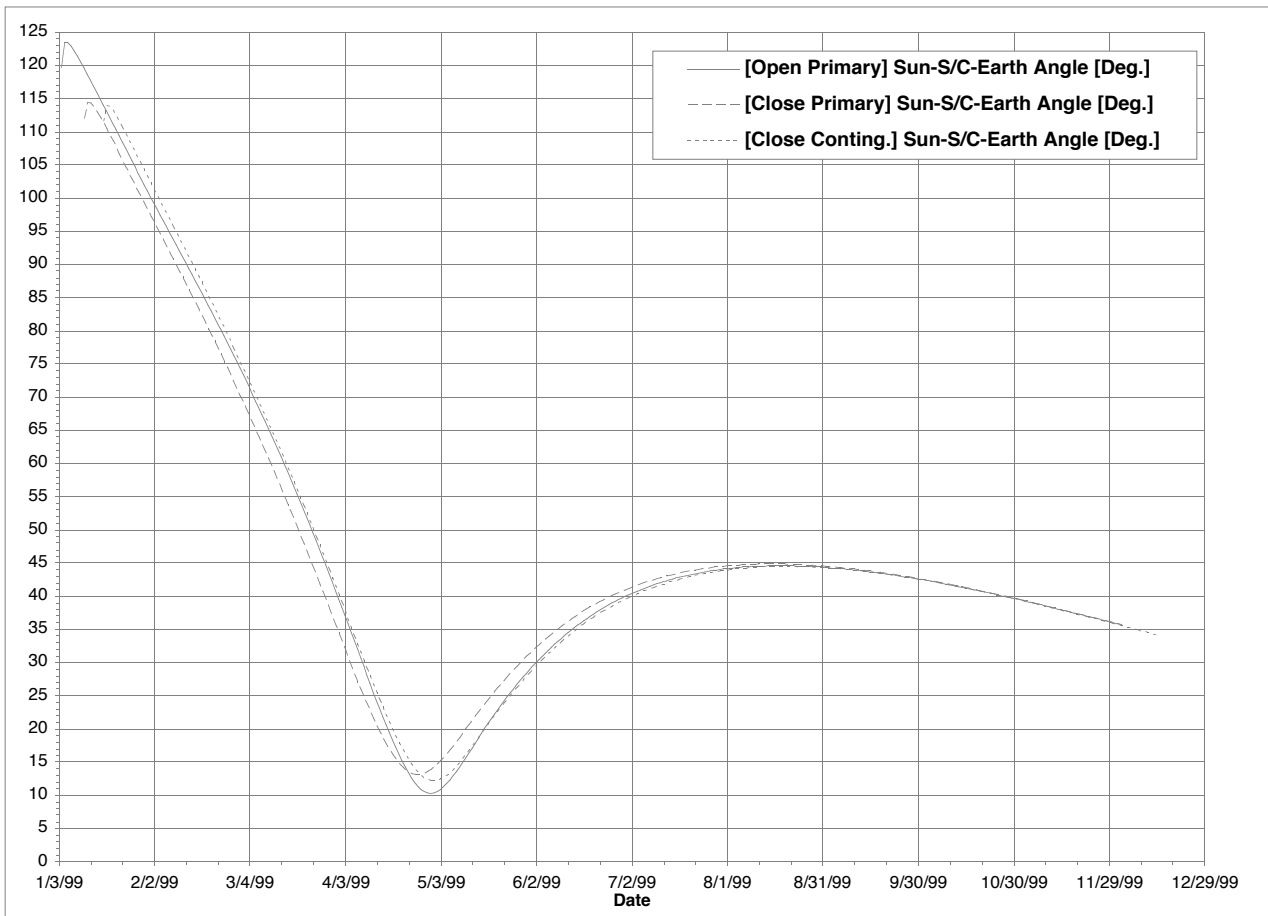
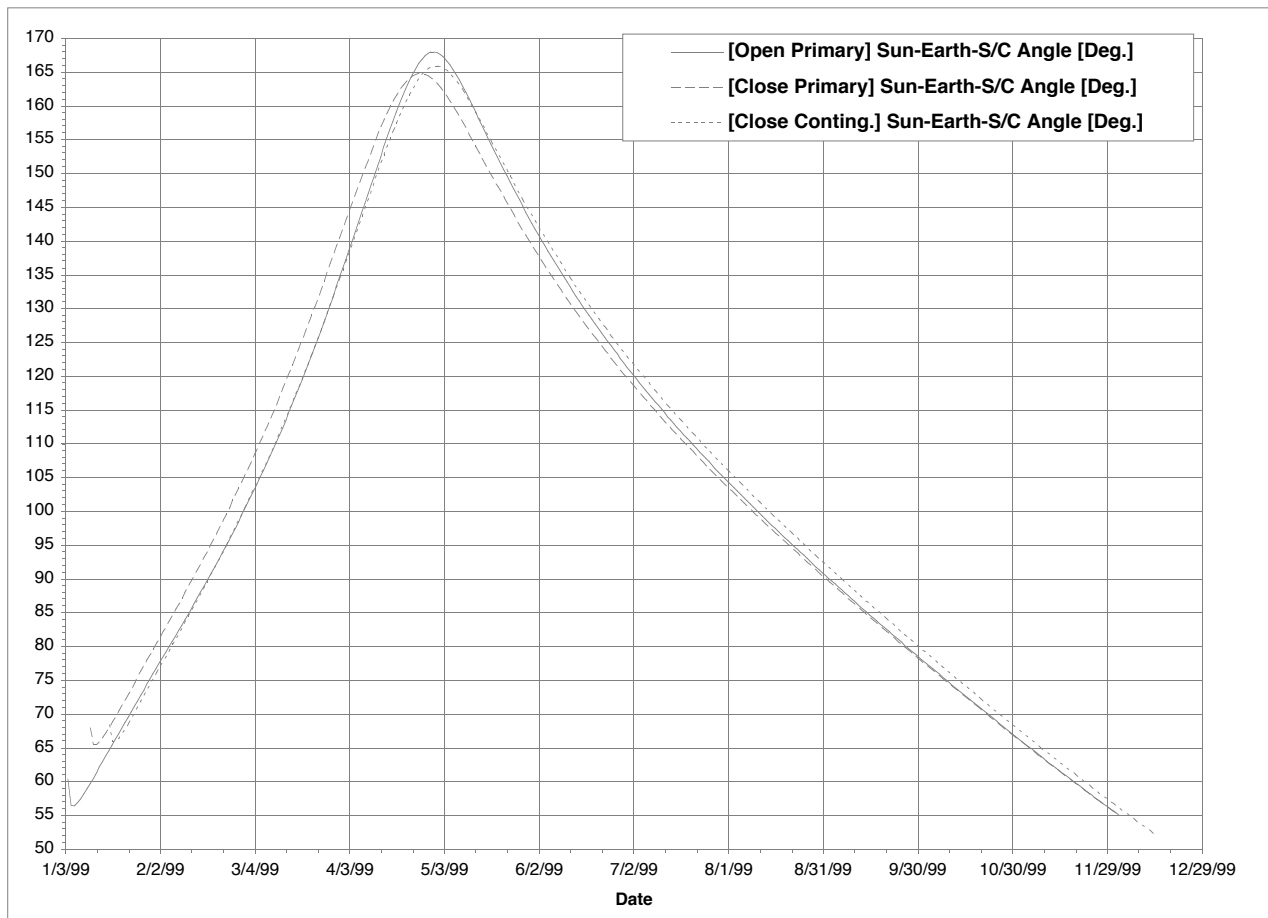


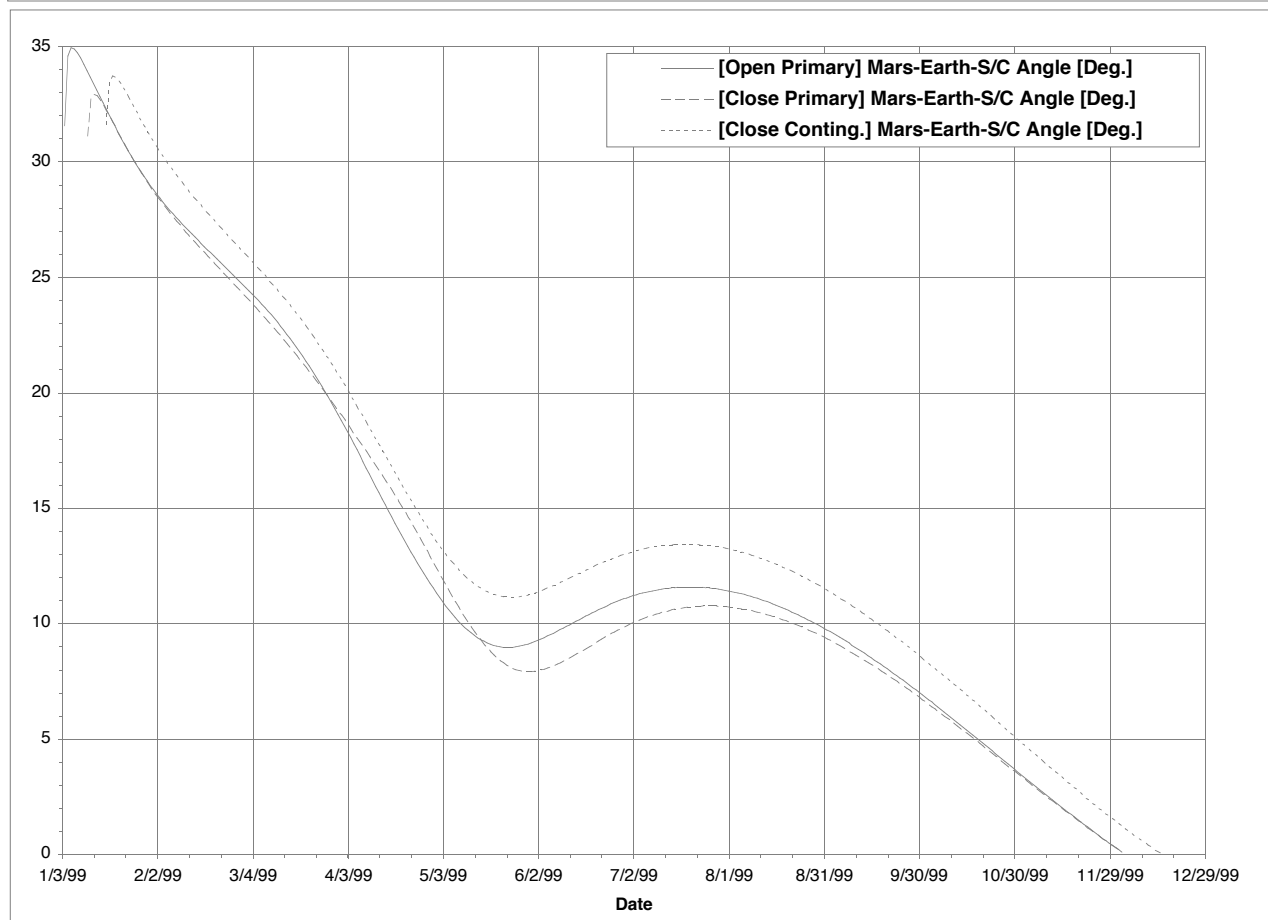
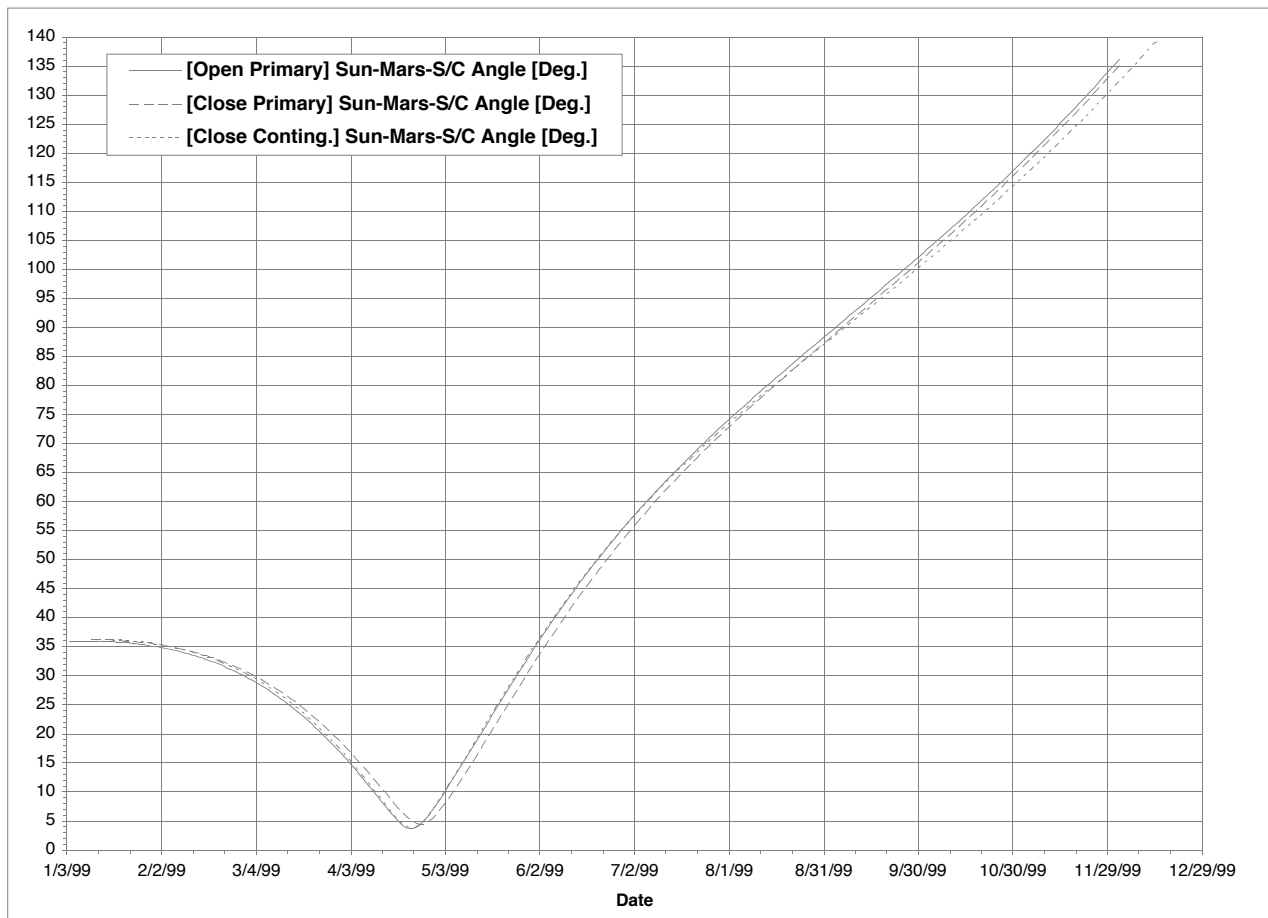
B.3 Lander Cruise Trajectory Characteristics

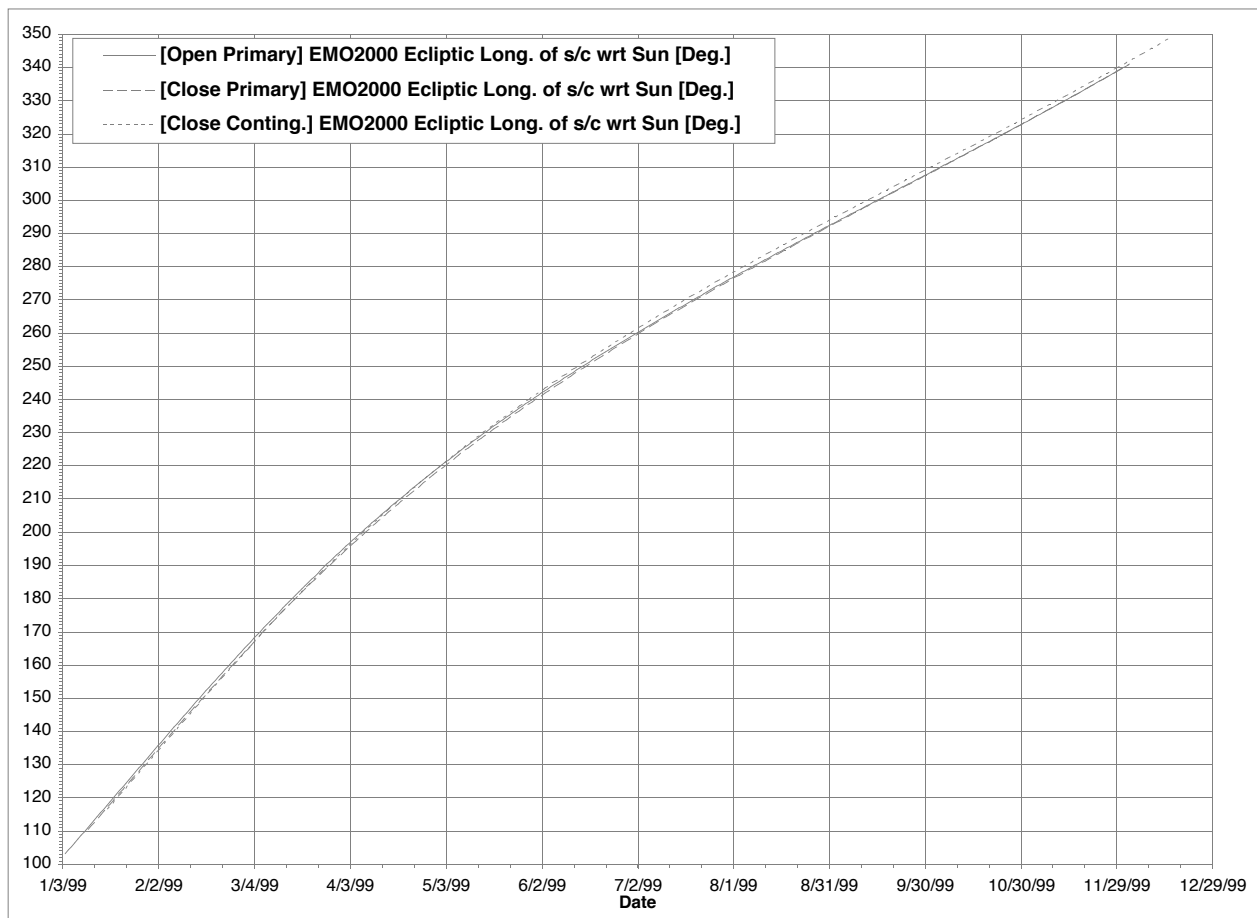
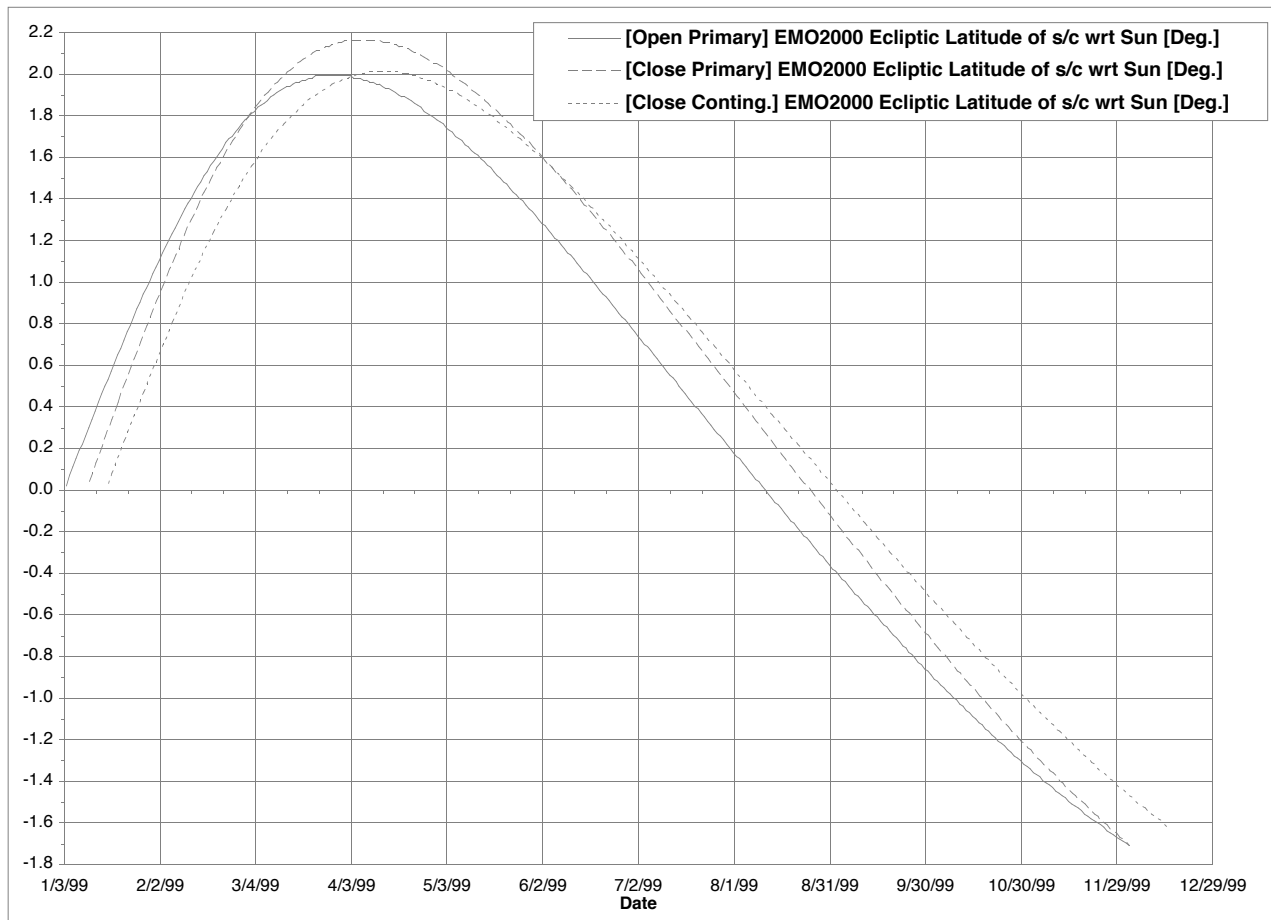
Data presented here are identical to the Lander cruise geometry data generated 5/8/96. The order of the plots has been changed to be consistent with the Orbiter cruise trajectory characteristics [Appendix A.3].

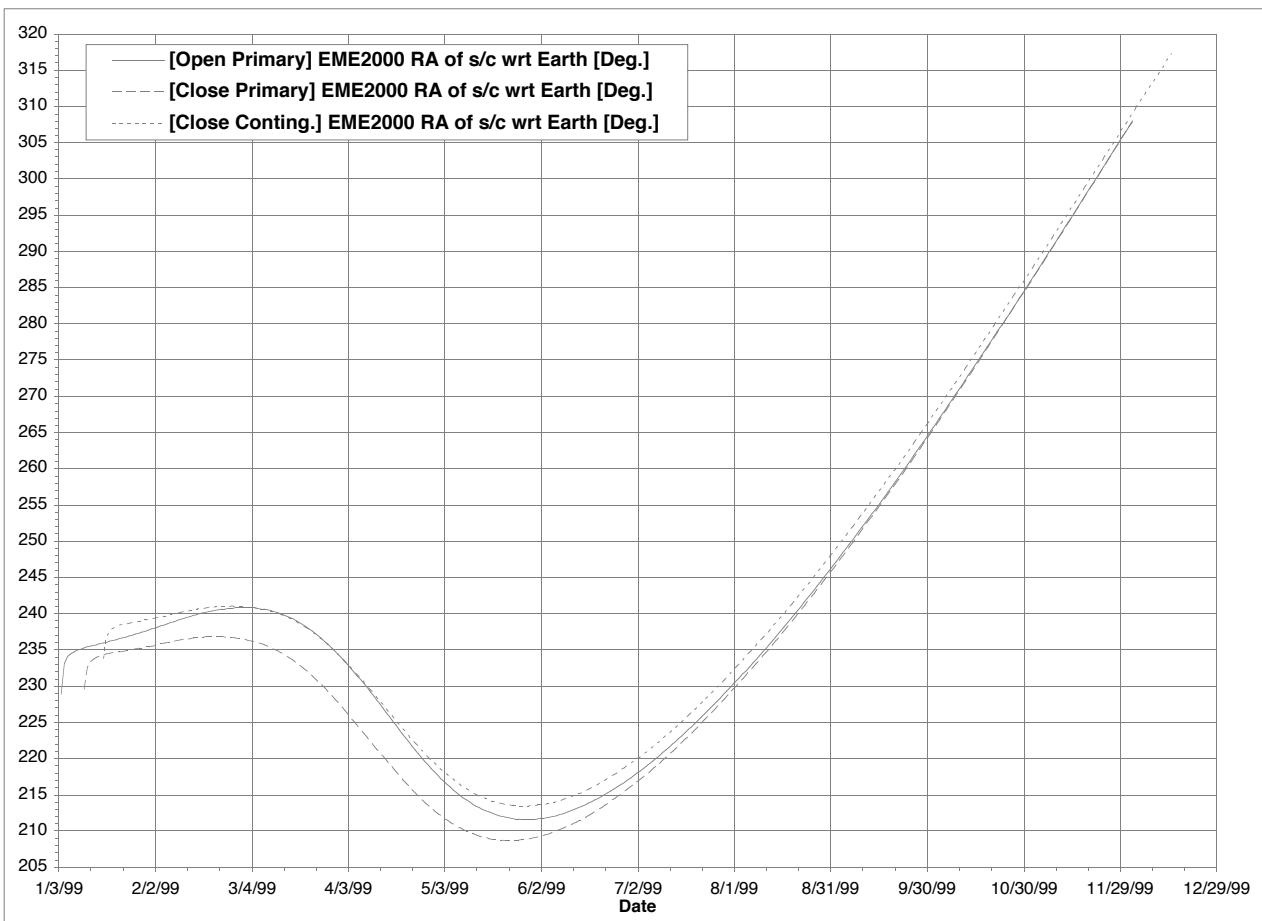
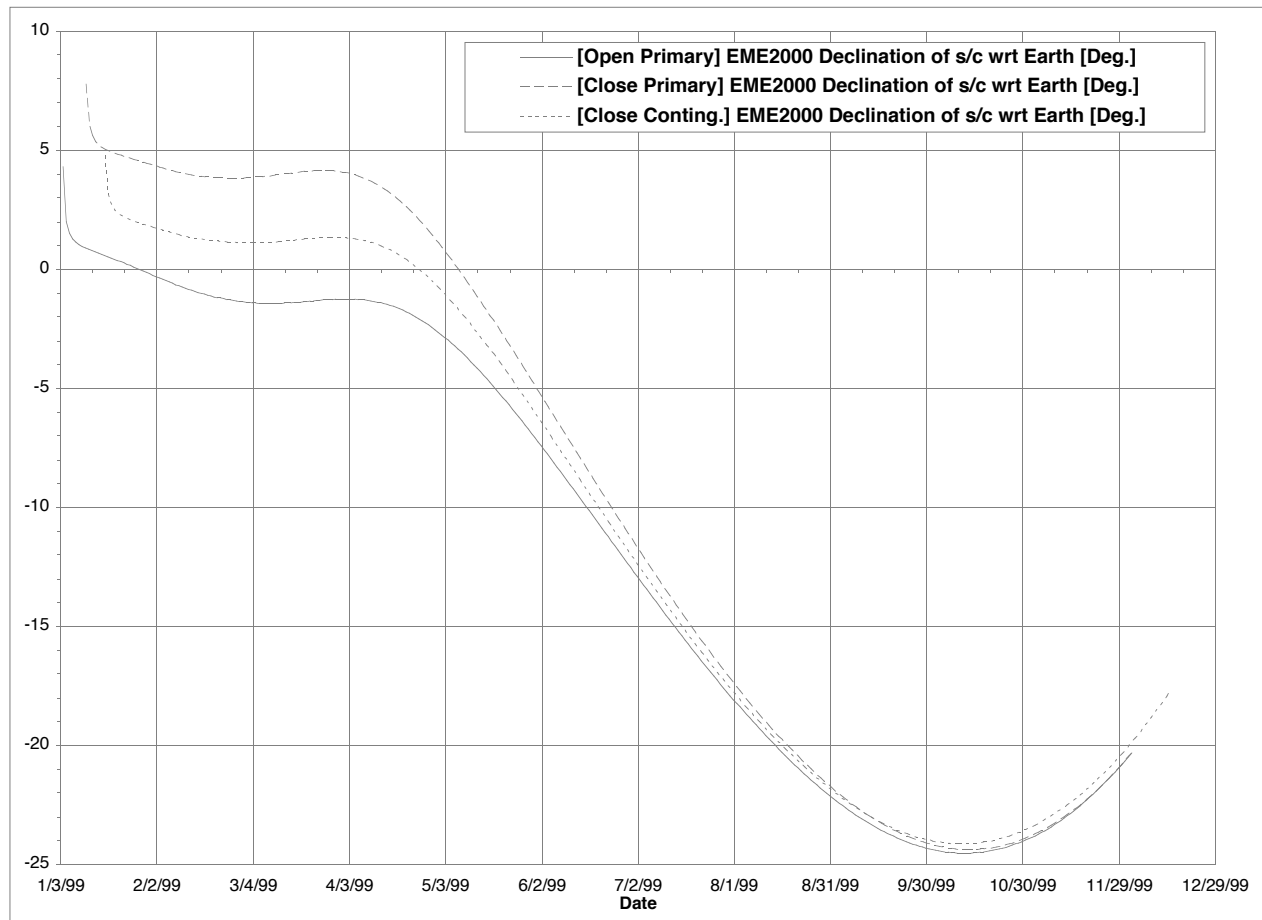












B.4 Approach/Entry Illustrations

Entry Interface 12/3/99: View from N. Trajectory Pole

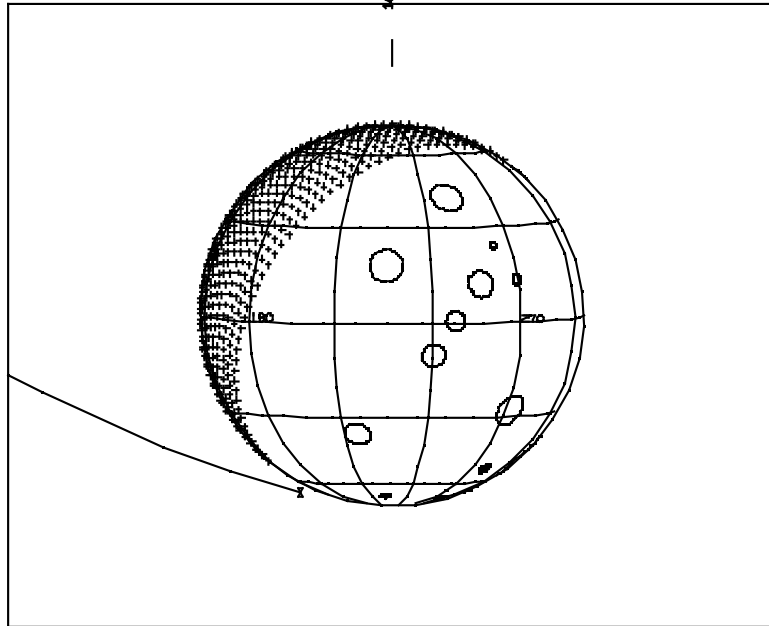


Fig 1

Entry Interface 12/3/99: View from Earth

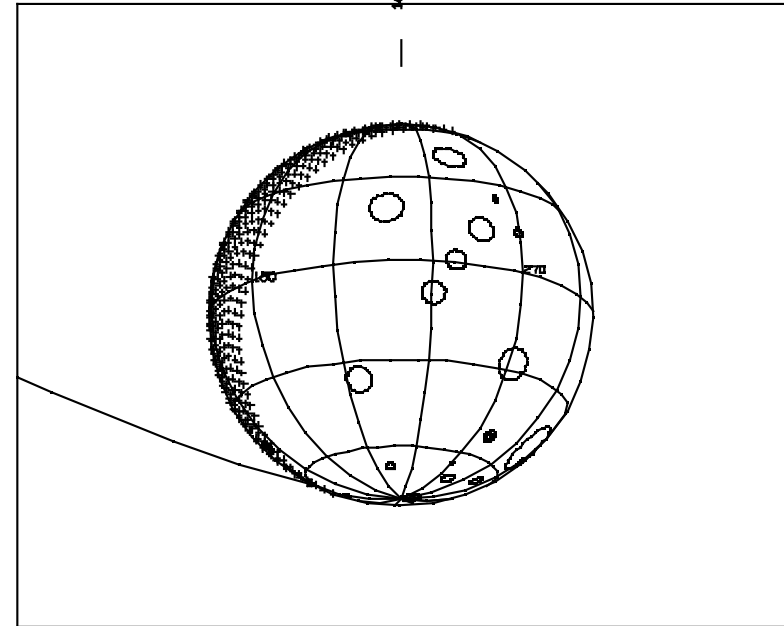


Fig 2

Entry Interface 12/3/99: View from Sun

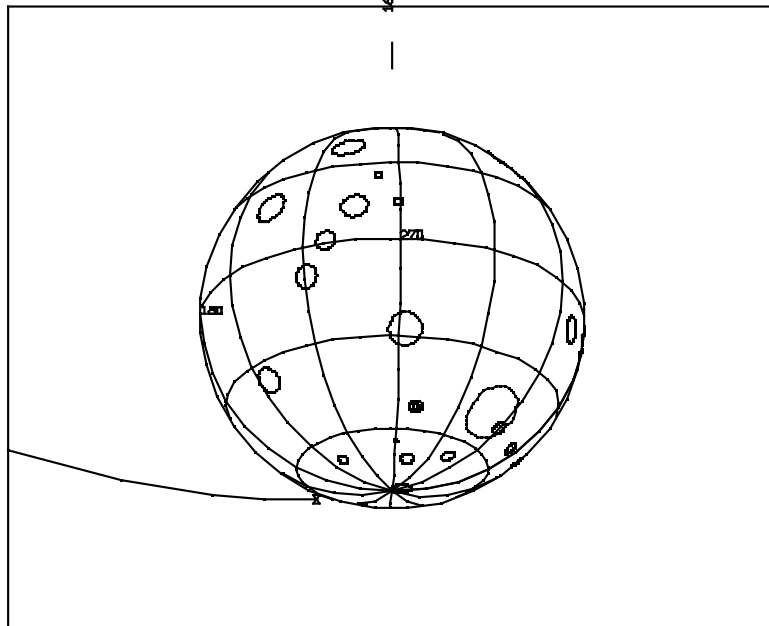


Fig 3

Entry Interface 12/3/99: View from Approach Asymptote

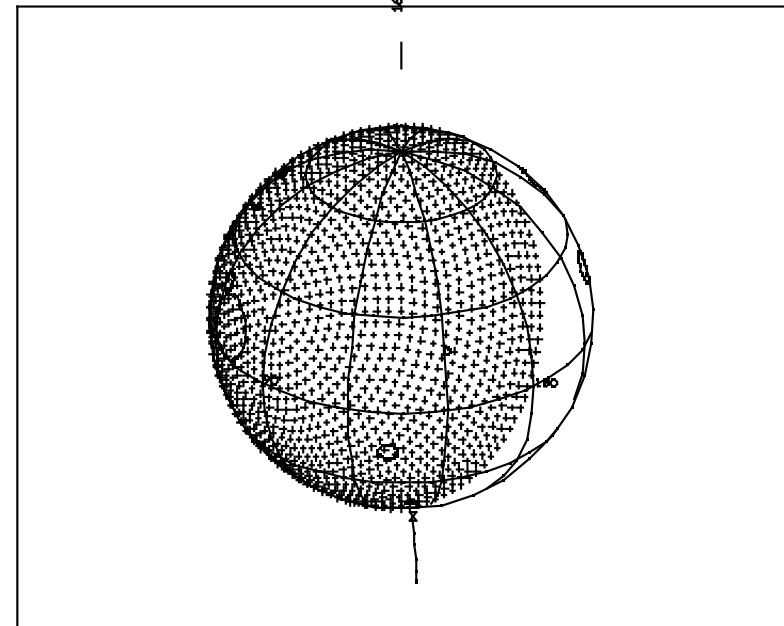


Fig 4

Entry Interface 12/3/99: View from South Pole

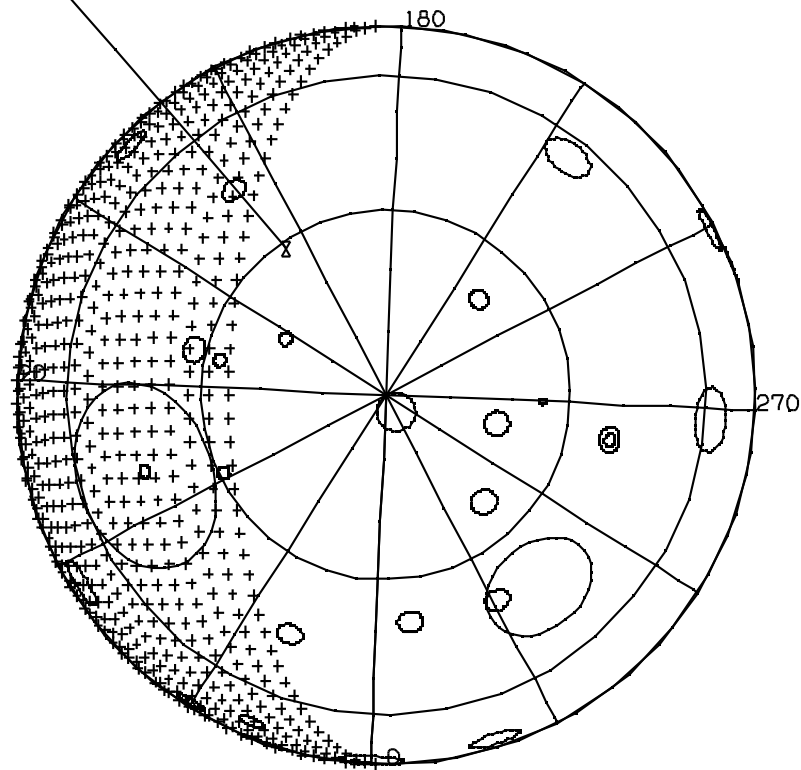


Fig 6

B.5 Post-Landing Data

B.5.1: First Pass after Landing - Variability with Landing Site and Orbiter Mean Anomaly

B.5.2: Orbiter/Lander Geometry Timelines

B.5.3: UHF Pass Information: Pass Durations, Data Volumes during Landed Science Mission

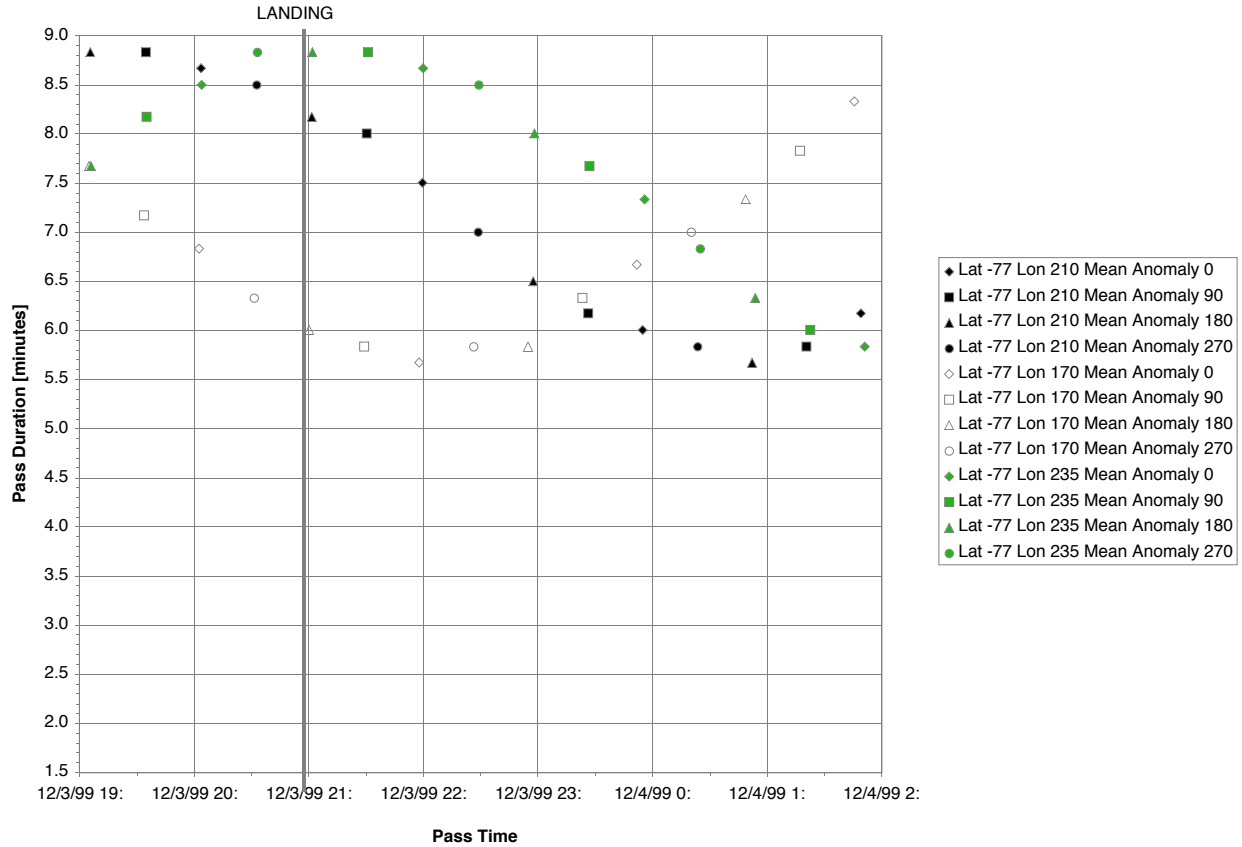
B.5.4: Earth and Sun Azimuth and Elevation during Landed Science Mission

B.5.5: Sun and Earth Geometry with Respect to Mars

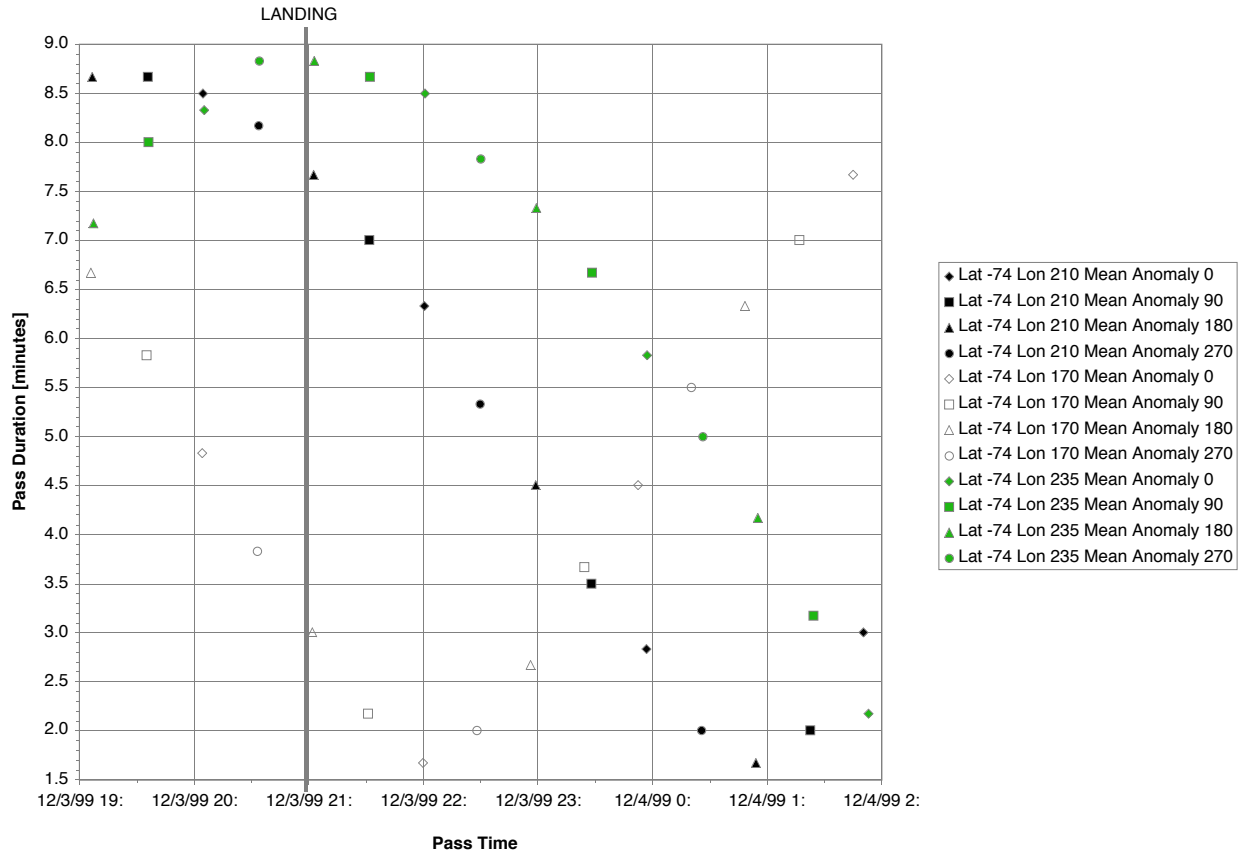
B.5.6: Design Reference Mission Power Profiles

B.5.7: Payload Scenarios

Pass Variability with Longitude and Mean Anomaly, Lat = -77°



Pass Variability with Longitude and Mean Anomaly, Lat = -74°



Orbiters/Lander Geometry Timelines

Shown below and on the next several pages are spacecraft timelines of geometric events during the Lander science period. Approximate timings of major events on both the MGS and Mars98 orbiters, and at the landing site are shown. For the orbiters, times of descending node passage, solar eclipse, earth occultation, and lander relay periods are indicated. For the Mars98 Orbiter, a candidate 10 hour Earth communication interval is shown for each sol. The DSN is requesting that Mars missions during this time share a common 10 hour Earth contact interval during operations at Mars. For this reason, and in order to facilitate orbiter support of Lander commanding and data relay, it is required that the 10 hour contact time be correlated with the lander operational day.

It is assumed the lander is located at the nominal landing site of 77S, 210W. Times when the Earth or Sun are above 10 degrees at this landing site are indicated by clear bars. Times when the Earth is above 20 degrees elevation are shown with a dark [or in color, blue] bar. Also indicated by the light gray [or yellow] bar is the Lander operational day, approximated in these graphics by intervals centered around local noon. [The duration of the Lander day is expected to shrink during the latter portion of the Landed science mission, as the Sun moves Northward and the maximum Solar elevation is reduced.] DSN view periods are also indicated, limited by 6 degree elevation masks at the DSN stations [G = Goldstone, C = Canberra, M = Madrid].

The absolute timing of events such as Sun and Earth rises and sets may differ from those presented below, depending on the actual landing site chosen. Also, at this point in time, the true anomalies of neither orbiter can be predicted, although their expected node locations are well established. As a result, the absolute timing of orbiter events, including lander relay periods, are uncertain to within one-half of the orbit period [i.e. approximately ± 1 hr]. However, it is expected that there will be approximately 8 relay opportunities per orbiter per day

Sol 0 Geometry Timeline: Shown on this graph is are geometric events on the day of landing. Landing occurs at 20:57 ET [approximately 04:14 Local True Solar Time]. Both the Sun and Earth are more than 18° above the horizon at landing. The Earth will rise above 20° elevation approximately 30 minutes later. At least one orbiter relay opportunity is expected to exist within 2 hours of landing. See Appendix A.1 [Lander Mission Database] for other arrival dates and data. A 9 hour Lander “day” is shown, as is the fact that the Sun remains above 10° continuously during this time.

Day 45 - 46 Geometry Timeline: Forty-five days into the mission, the geometry is similar to that at landing, but local noon has shifted because of the 40 minute difference in rotation rate between Earth and Mars.

Day 84 - 85 Geometry Timeline: Towards the end of the Lander mission, the Sun has moved Northward, and no longer remains above 10° throughout the day. The Lander day is expected to be reduced as a result of lower solar array output. This will also mean that fewer relay opportunities will be available during the Lander day, as the end of the mission is approached.

Sol 0

MGS ORBIT EVENTS

- Descending Node
- Solar Eclipse
- Earth Occultation
- Lander Relay Periods
- Downlink Periods

MARS 98 ORBIT

- Descending Node
- Solar Eclipse
- Earth Occultation
- Lander Relay Periods
- Downlink Periods

MARS 98 LANDER VIEW

- Sun View (10 deg elev mask)
- Earth View (10 & 20 deg mask)

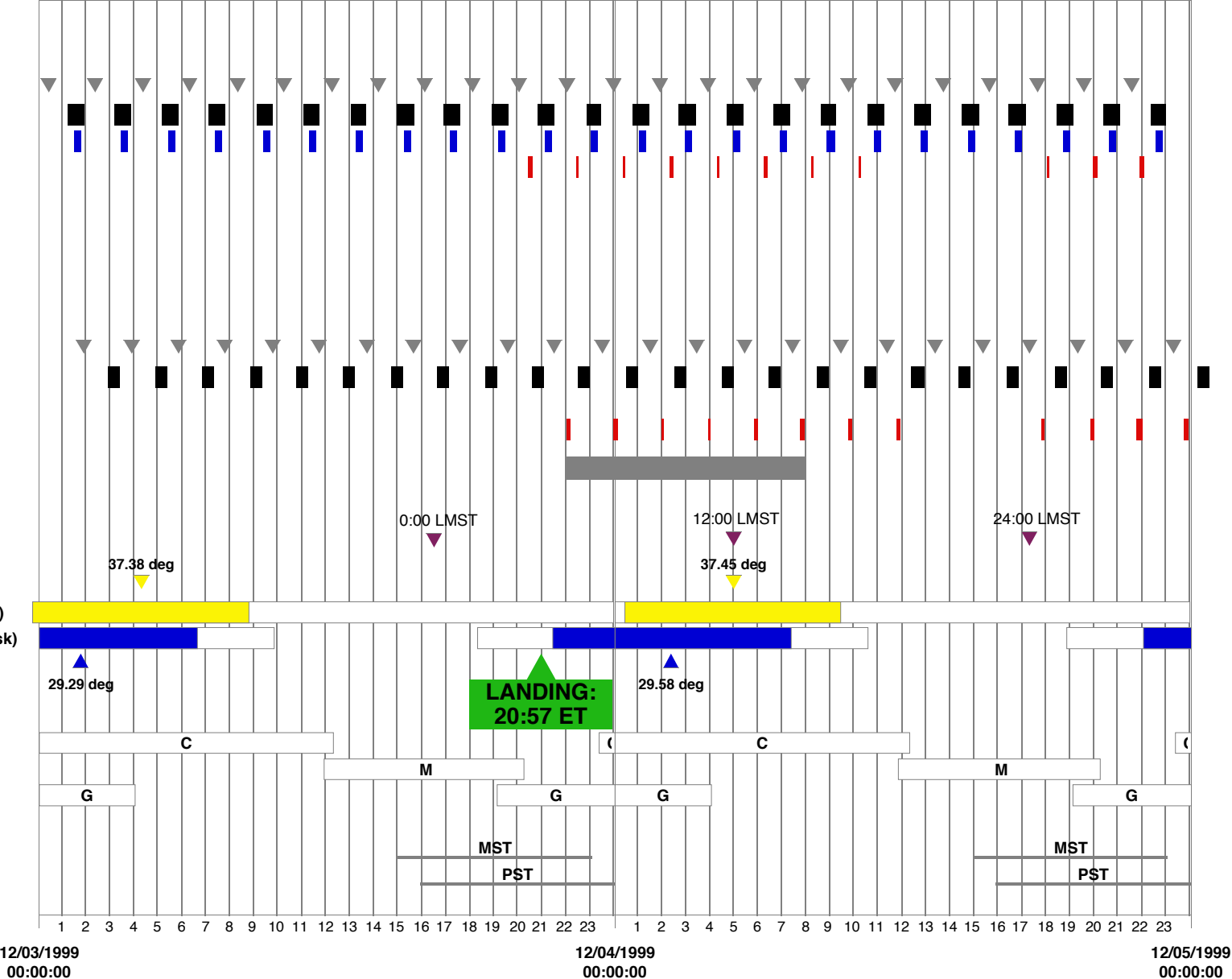
DSN VIEW PERIODS

(6 deg elev mask)

PRIME SHIFTS

TIME (UTC)

(time tics = 1 hrs)



Day 14 - 15

MGS ORBIT EVENTS

- Descending Node
- Solar Eclipse
- Earth Occultation
- Lander Relay Periods

Downlink Periods
(Data Rates in kbps)

MARS 98 ORBIT

- Descending Node
- Solar Eclipse
- Earth Occultation
- Lander Relay Periods

Downlink Periods
(Data Rates in kbps)

MARS 98 LANDER VIEW

- Sun View (10 deg elev mask)
- Earth View (10 & 20 deg mask)

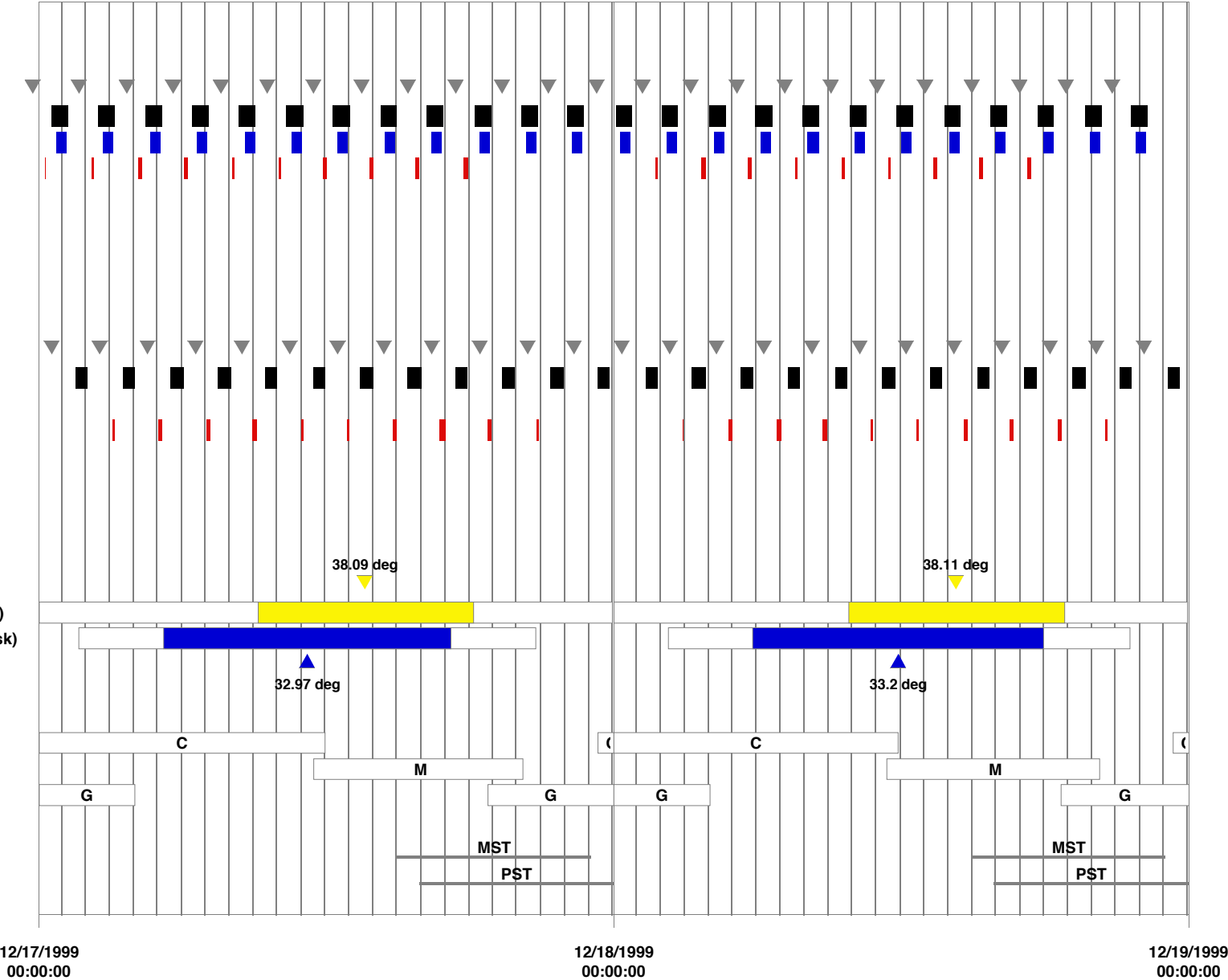
DSN VIEW PERIODS

(6 deg elev mask)

PRIME SHIFTS

TIME (UTC)

(time tics = 1 hrs)



Day 30 - 31

MGS ORBIT EVENTS

- Descending Node
- Solar Eclipse
- Earth Occultation
- Lander Relay Periods

Downlink Periods
(Data Rates in kbps)

MARS 98 ORBIT

- Descending Node
- Solar Eclipse
- Earth Occultation
- Lander Relay Periods

Downlink Periods
(Data Rates in kbps)

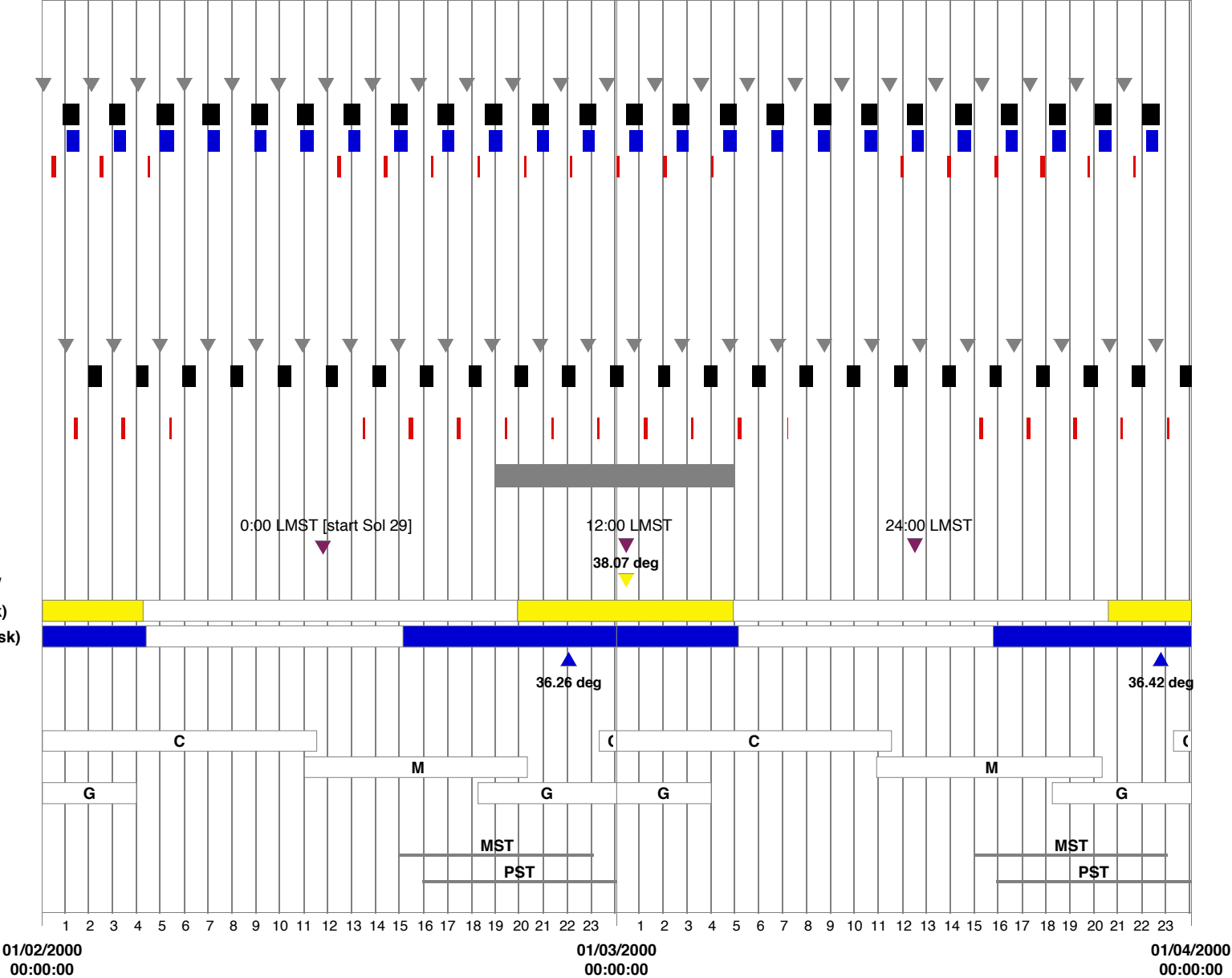
MARS 98 LANDER VIEW

- Sun View (10 deg elev mask)
- Earth View (10 & 20 deg mask)

DSN VIEW PERIODS
(6 deg elev mask)

PRIME SHIFTS

TIME (UTC)
(time tics = 1 hrs)



Day 45 - 46

MGS ORBIT EVENTS

- Descending Node
- Solar Eclipse
- Earth Occultation
- Lander Relay Periods

Downlink Periods
(Data Rates in kbps)

MARS 98 ORBIT

- Descending Node
- Solar Eclipse
- Earth Occultation
- Lander Relay Periods

Downlink Periods
(Data Rates in kbps)

MARS 98 LANDER VIEW

- Sun View (10 deg elev mask)
- Earth View (10 & 20 deg mask)

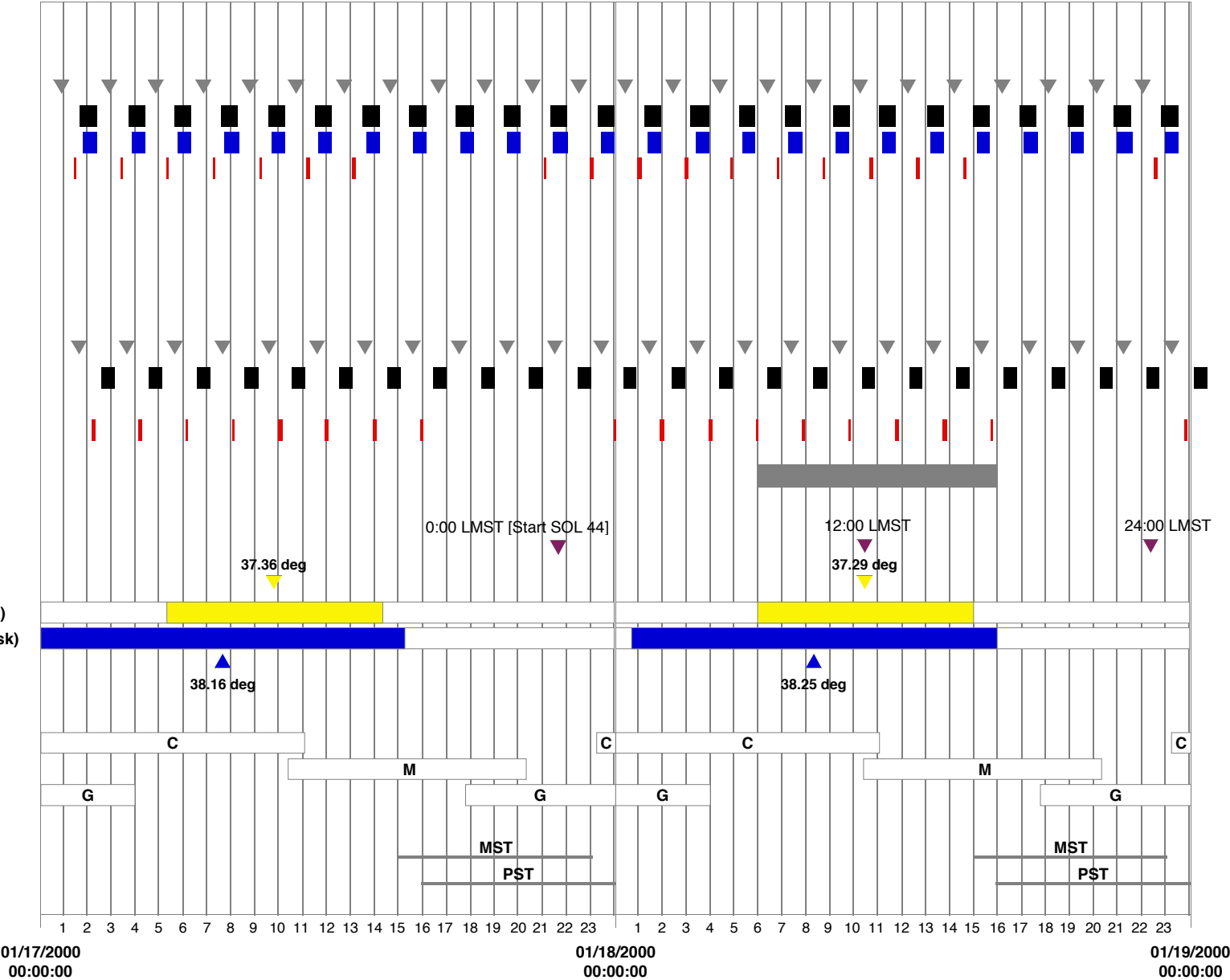
DSN VIEW PERIODS

(6 deg elev mask)

PRIME SHIFTS

TIME (UTC)

(time tics = 1 hrs)



Day 60 - 61

MGS ORBIT EVENTS

- Descending Node
- Solar Eclipse
- Earth Occultation
- Lander Relay Periods

Downlink Periods
(Data Rates in kbps)

MARS 98 ORBIT

- Descending Node
- Solar Eclipse
- Earth Occultation
- Lander Relay Periods

Downlink Periods
(Data Rates in kbps)

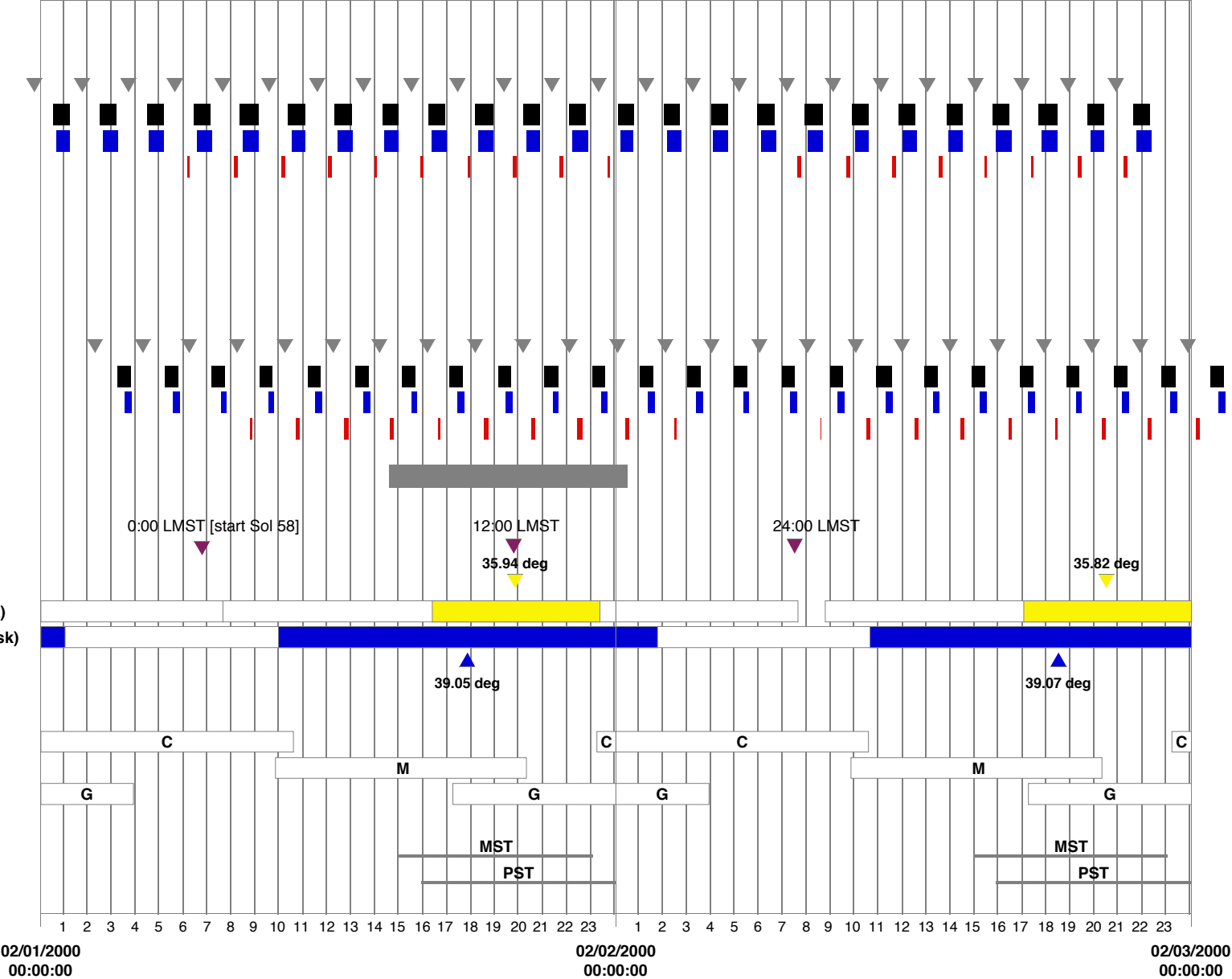
MARS 98 LANDER VIEW

- Sun View (10 deg elev mask)
- Earth View (10 & 20 deg mask)

DSN VIEW PERIODS
(6 deg elev mask)

PRIME SHIFTS

TIME (UTC)
(time tics = 1 hrs)



Day 75 - 76

MGS ORBIT EVENTS

- Descending Node
- Solar Eclipse
- Earth Occultation
- Lander Relay Periods

Downlink Periods
(Data Rates in kbps)

MARS 98 ORBIT

- Descending Node
- Solar Eclipse
- Earth Occultation
- Lander Relay Periods

Downlink Periods
(Data Rates in kbps)

MARS 98 LANDER VIEW

- Sun View (10 deg elev mask)
- Earth View (10 & 20 deg mask)

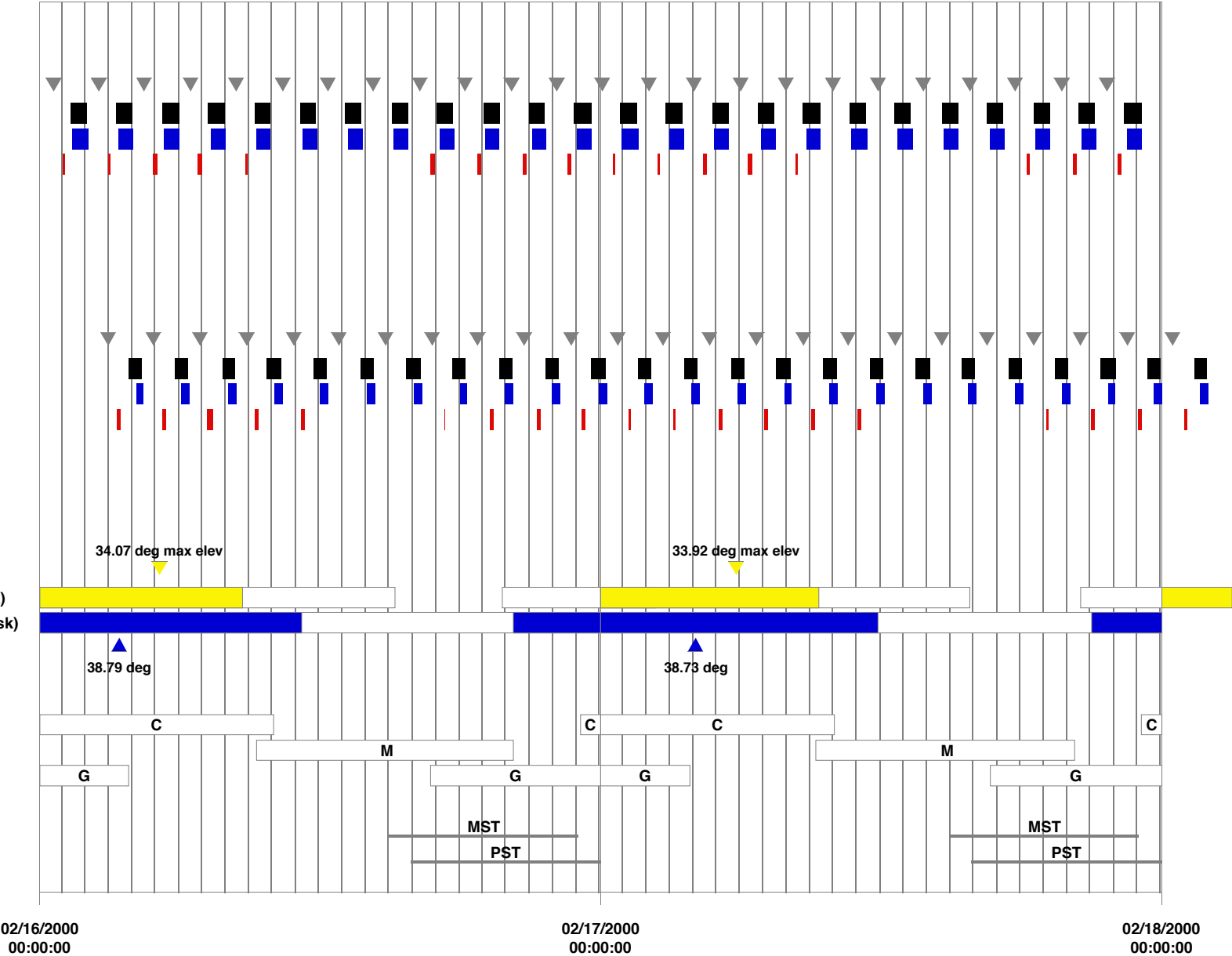
DSN VIEW PERIODS

(6 deg elev mask)

PRIME SHIFTS

TIME (UTC)

(time tics = 1 hrs)



Day 84 - 85

MGS ORBIT EVENTS

- Descending Node
- Solar Eclipse
- Earth Occultation
- Lander Relay Periods

Downlink Periods
(Data Rates in kbps)

MARS 98 ORBIT

- Descending Node
- Solar Eclipse
- Earth Occultation
- Lander Relay Periods

Downlink Periods
(Data Rates in kbps)

MARS 98 LANDER VIEW

- Sun View (10 deg elev mask)
- Earth View (10 & 20 deg mask)

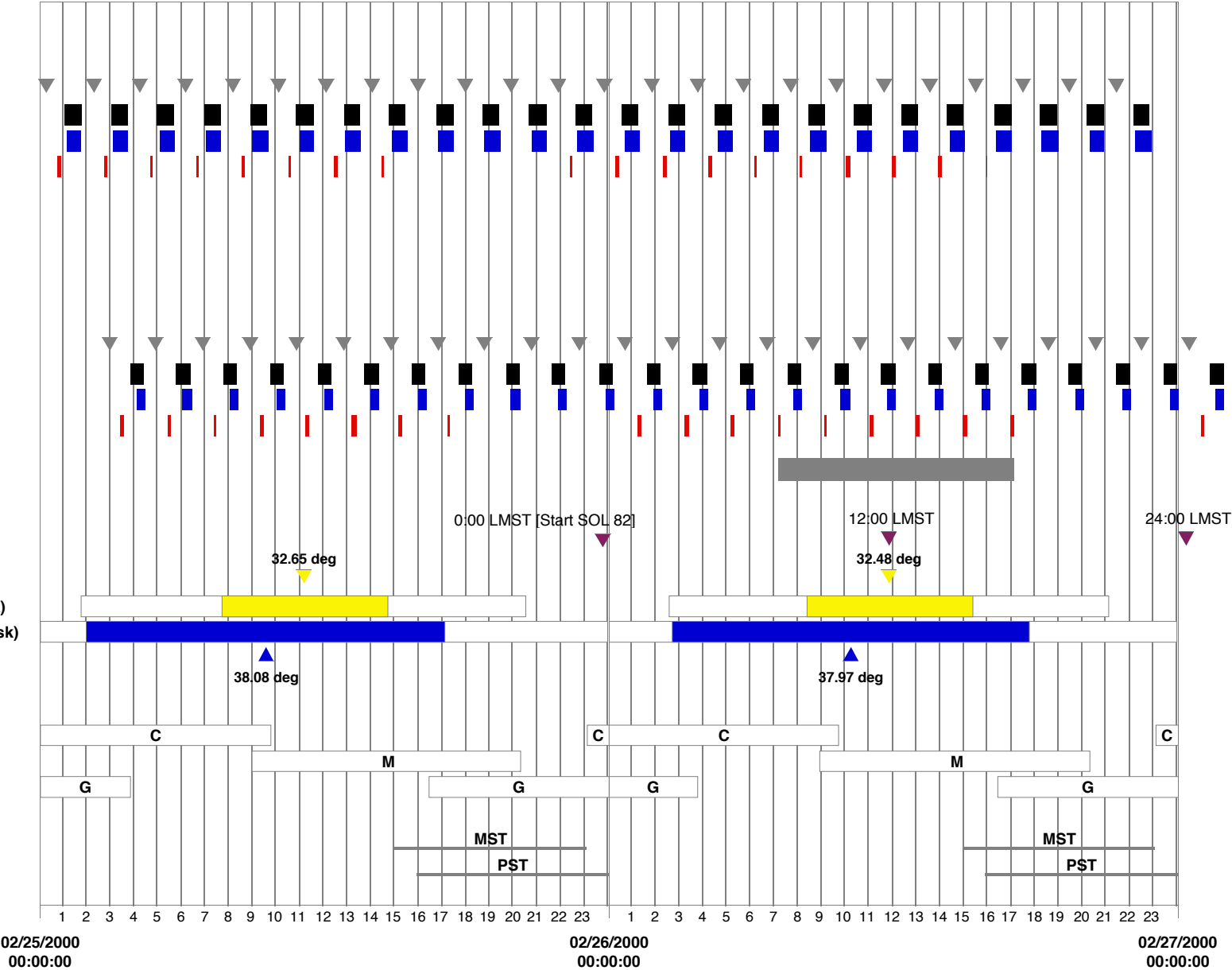
DSN VIEW PERIODS

(6 deg elev mask)

PRIME SHIFTS

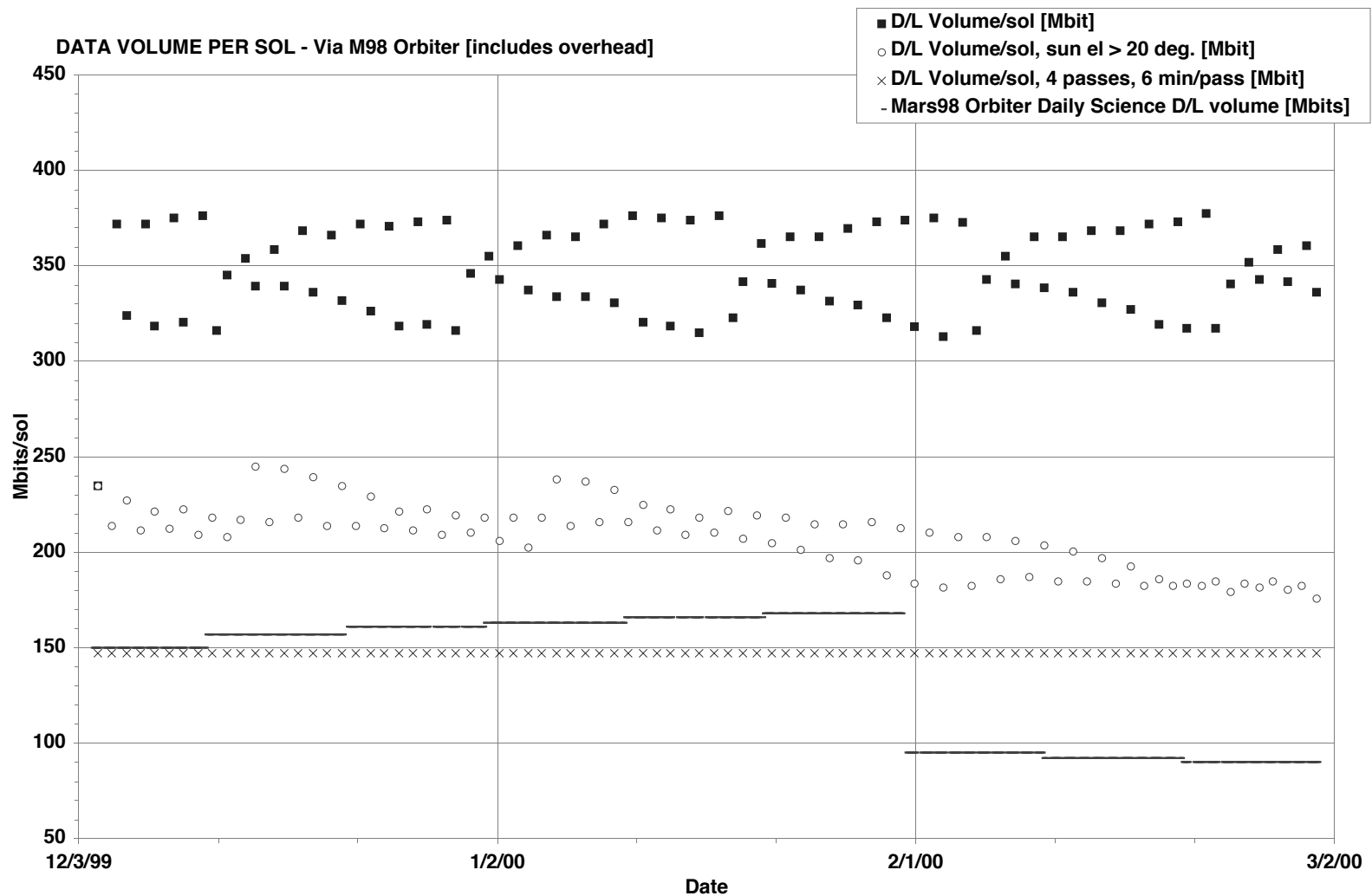
TIME (UTC)

(time tics = 1 hrs)

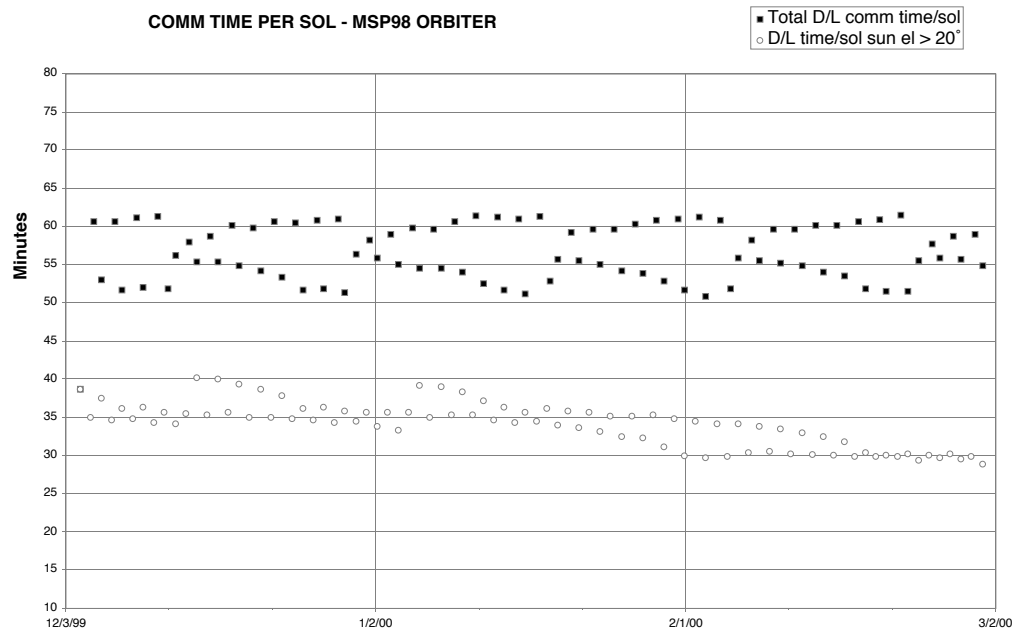


LANDER	UHF opportunities per day =	4
GEOMETRY	Average length =	6 min.
CMD LANDER	Command load time [in UHF pass] =	0.50 min.
	CMD data rate [Orb -> Lander] =	8 kbps
	Average daily U/L to Lander =	67.8 kbits/pass actual commands
CMD ORBITER	Number of times sent =	2.00
	U/L Data rate [Earth -> Orbiter]	0.5 kbps
	Overhead [Earth -> Orbiter]	1.77
	Time for Command U/L to Orbiter	8 min.
TLM	Telemetry time =	5.5 min.
	TLM data rate =	128 kbps
	MSP Overhead [Lander -> Orbiter -> Earth]	1.15
	Average daily D/L =	147 Megabits/day

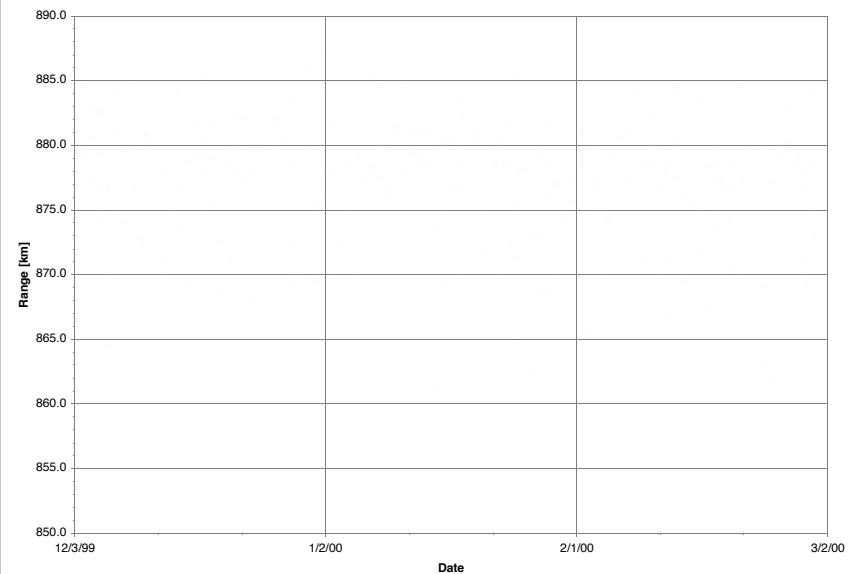
HYBRID PASSES
0.50 Minutes / pass for CMD



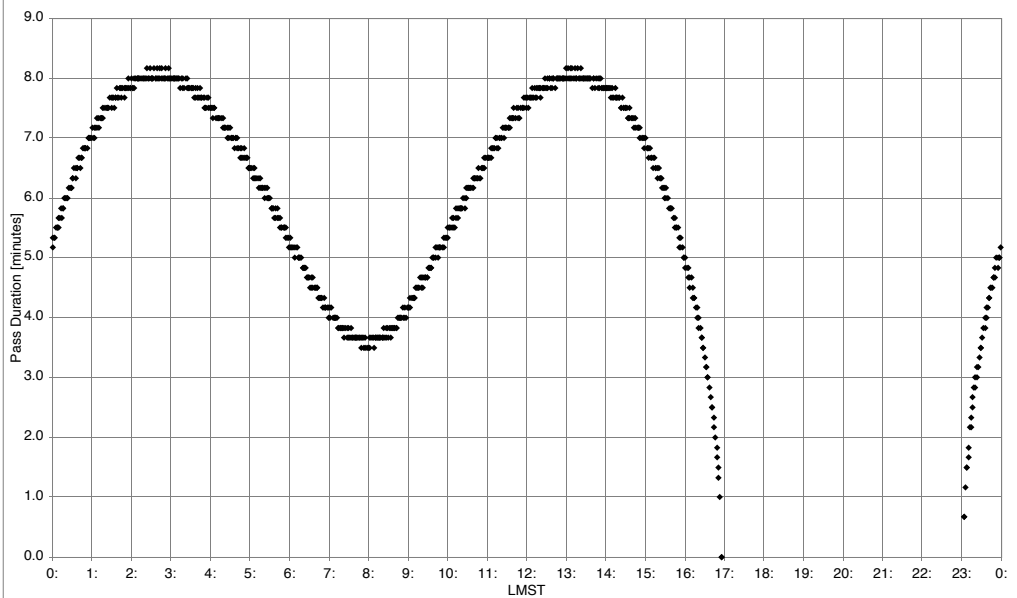
COMM TIME PER SOL - MSP98 ORBITER



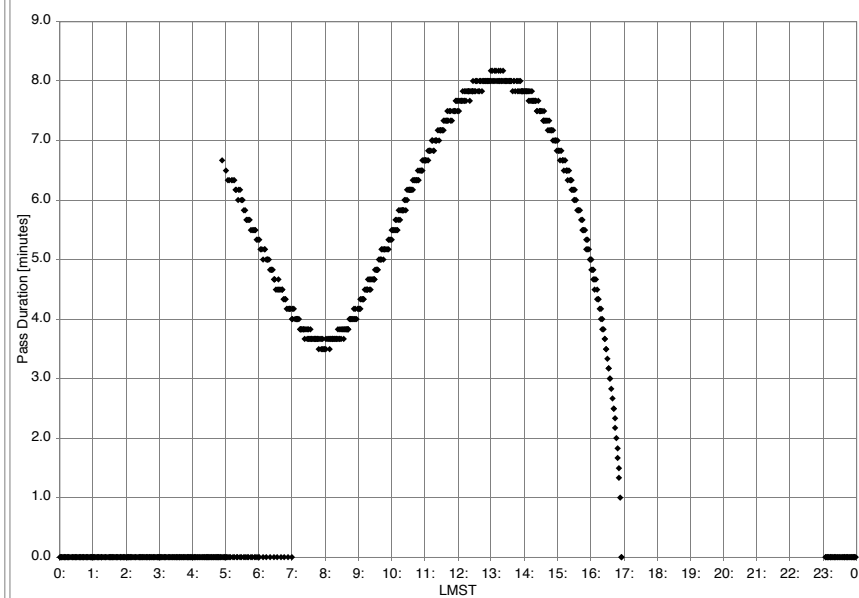
Max Range



Pass Duration vs LMST



Pass Duration [Sun above 20 deg.] vs LMST



Rise	Set	Pass Duration [min.]	Max.El at linder [deg.]	Max.Range [km]	Max.Sun.El [deg.]	Day # [ET]	Sol #	LMST	Pass # that Sol	D/L Pass duration [min.]	D/L Volume [Mbit]/pass w/ 0.50 min. CMD interval/pass	Max # passes that Sol	Cume D/L comm time that sol [min.]	Total D/L comm time/sol [min.]	D/L Volume/sol [Mbit]	Pass # sun el > 20°	Pass dur. sun el > 20° [min.]	D/L Volume [Mbit]/pass w/ 0.50 min. CMD interval/pass [sun el > 20°]	Max # passes sun el > 20°	Cume D/L time sun el > 20° [min.]	D/L time/sol sun el > 20° [min.]	D/L Volume/sol, sun el > 20 deg. [Mbit]	D/L Volume/sol, 4 passes, 6 min/pass [Mbit]	Mars98 Orbiter Daily Science D/L volume [Mbits]
12/3/99 22:02	12/3/99 22:08	6.3	34.8	879.4	21.5	1	0	5:15:30	1	6.3	38.9		6.3			1	6.3	38.9		6.3				150
12/4/99 0:00	12/4/99 0:04	4.0	24.5	878.9	28.3	1	0	7:10:10	2	4.0	23.4		10.3			2	4.0	23.4		10.3				150
12/4/99 1:56	12/4/99 2:00	4.3	25.2	882.2	34.4	2	0	9:03:14	3	4.3	25.6		14.7			3	4.3	25.6		14.7				150
12/4/99 3:51	12/4/99 3:58	6.5	38.0	865.9	38.1	2	0	10:55:48	4	6.5	40.1		21.2			4	6.5	40.1		21.2				150
12/4/99 5:48	12/4/99 5:56	8.0	78.9	877.5	38.2	2	0	12:49:21	5	8.0	50.1		29.2			5	8.0	50.1		29.2				150
12/4/99 7:47	12/4/99 7:54	7.3	44.5	884.8	34.6	2	0	14:45:00	6	7.3	45.6		36.5			6	7.3	45.6		36.5				150
12/4/99 9:49	12/4/99 9:51	2.2	21.2	879.7	28.2	2	0	16:43:54	7	2.2	11.2	7	38.7	38.66	234.8	7	2.2	11.2	7	38.7	38.66	234.8	146.92	150
12/4/99 17:50	12/4/99 17:56	6.3	34.4	880.7	10.5	2	1	0:31:32	1	6.3	38.9		6.3			0								150
12/4/99 19:48	12/4/99 19:56	8.0	80.5	877.1	13.2	2	1	2:26:23	2	8.0	50.1		14.3			0				0.0				150
12/4/99 21:46	12/4/99 21:53	7.2	46.4	875.5	18.5	2	1	4:21:23	3	7.2	44.5		21.5			0				0.0				150
12/4/99 23:44	12/4/99 23:49	5.0	27.6	883.0	25.1	2	1	6:16:14	4	5.0	30.1		26.5			1	5.0	30.1		5.0				150
12/5/99 1:41	12/5/99 1:44	3.7	23.7	880.5	31.7	3	1	8:10:06	5	3.7	21.2		30.2			2	3.7	21.2		8.7				150
12/5/99 3:36	12/5/99 3:42	5.5	29.9	877.7	36.8	3	1	10:02:40	6	5.5	33.4		35.7			3	5.5	33.4		14.2				150
12/5/99 5:32	12/5/99 5:40	7.5	54.3	871.5	38.7	3	1	11:55:34	7	7.5	46.7		43.2			4	7.5	46.7		21.7				150
12/5/99 7:30	12/5/99 7:38	7.8	67.2	864.2	36.8	3	1	13:50:15	8	7.8	49.0		51.0			5	7.8	49.0		29.5				150
12/5/99 9:30	12/5/99 9:36	5.5	29.3	884.2	31.6	3	1	15:47:12	9	5.5	33.4		56.5			6	5.5	33.4	6	35.0	35	213.7	146.92	150
12/5/99 17:34	12/5/99 17:38	4.2	24.4	879.3	10.4	3	1	23:37:36	10	4.2	24.5	10	60.7	60.67	371.8	10	4.2	24.5		0.0				150
12/5/99 19:31	12/5/99 19:39	7.7	53.6	882.7	11.6	3	2	1:32:07	1	7.7	47.9		7.7			0				0.0				150
12/5/99 21:29	12/5/99 21:37	7.8	66.5	877.1	15.8	3	2	3:27:07	2	7.8	49.0		15.5			0				0.0				150
12/5/99 23:28	12/5/99 23:34	6.0	33.8	869.9	21.9	3	2	5:22:07	3	6.0	36.7		21.5			1	6.0	36.7		6.0				150
12/6/99 1:25	12/6/99 1:29	3.8	24.2	874.0	28.7	4	2	7:16:38	4	3.8	22.2		25.3			2	3.8	22.2		9.8				150
12/6/99 3:21	12/6/99 3:26	4.3	25.6	874.5	34.8	4	2	9:09:42	5	4.3	25.6		29.7			3	4.3	25.6		14.2				150
12/6/99 5:17	12/6/99 5:24	6.7	39.3	876.7	38.4	4	2	11:02:07	6	6.7	41.2		36.3			4	6.7	41.2		20.8				150
12/6/99 7:14	12/6/99 7:22	8.0	82.3	879.4	38.3	4	2	12:55:49	7	8.0	50.1		44.3			5	8.0	50.1		28.8				150
12/6/99 9:13	12/6/99 9:20	7.2	42.4	882.4	34.5	4	2	14:51:38	8	7.2	44.5		51.5			6	7.2	44.5		36.0				150
12/6/99 11:15	12/6/99 11:17	1.5	20.5	882.7	28.0	4	2	16:50:51	9	1.5	6.7	9	53.0	53	323.9	7	1.5	6.7	7	37.5	37.5	227.1	146.92	150
12/6/99 19:15	12/6/99 19:22	6.5	36.0	876.8	10.7	4	3	0:38:00	1	6.5	40.1		6.5			0				0.0				150
12/6/99 21:13	12/6/99 21:21	8.0	84.3	869.6	13.5	4	3	2:32:51	2	8.0	50.1		14.5			0				0.0				150
12/6/99 23:11	12/6/99 23:18	7.0	44.7	864.6	18.9	4	3	4:27:51	3	7.0	43.4		21.5			0				0.0				150
12/7/99 1:09	12/7/99 1:14	4.8	27.1	878.3	25.5	5	3	6:22:42	4	4.8	28.9		26.3			1	4.8	28.9		4.8				150
12/7/99 3:06	12/7/99 3:10	3.7	23.7	876.5	32.1	5	3	8:16:34	5	3.7	21.2		30.0			2	3.7	21.2		8.5				150
12/7/99 5:02	12/7/99 5:08	5.7	30.7	876.7	37.1	5	3	10:08:59	6	5.7	34.5		35.7			3	5.7	34.5		14.2				150
12/7/99 6:58	12/7/99 7:06	7.5	56.7	864.5	38.8	5	3	12:02:02	7	7.5	46.7		43.2			4	7.5	46.7		21.7				150
12/7/99 8:56	12/7/99 9:04	7.8	64.0	877.7	36.8	5	3	13:56:43	8	7.8	49.0		51.0			5	7.8	49.0		29.5				150
12/7/99 10:56	12/7/99 11:02	5.2	28.1	875.2	31.4	5	3	15:53:59	9	5.2	31.2		56.2			6	5.2	31.2	6	34.7	34.67	211.5	146.92	150
12/7/99 18:59	12/7/99 19:04	4.5	25.4	881.2	10.5	5	3	23:44:04	10	4.5	26.7	10	60.7	60.67	371.8	10	4.5	26.7		0.0				150
12/7/99 20:57	12/7/99 21:05	7.7	56.3	870.9	11.9	5	4	1:38:35	1	7.7	47.9		7.7			0				0.0				150
12/7/99 22:55	12/7/99 23:03	7.8	63.5	880.6	16.1	5	4	3:33:35	2	7.8	49.0		15.5			0				0.0				150
12/8/99 0:53	12/8/99 0:59	6.0	32.8	884.0	22.3	6	4	5:28:35	3	6.0	36.7		21.5			1	6.0	36.7		6.0				150
12/8/99 2:51	12/8/99 2:55	3.7	24.1	869.9	29.1	6	4	7:23:07	4	3.7	21.2		25.2			2	3.7	21.2		9.7				150
12/8/99 4:47	12/8/99 4:52	4.5	25.9	875.2	35.1	6	4	9:16:00	5	4.5	26.7		29.7			3	4.5	26.7		14.2				150
12/8/99 6:43	12/8/99 6:50	6.8	40.7	879.3	38.6	6	4	11:08:35	6	6.8	42.3		36.5			4	6.8	42.3		21.0				150
12/8/99 8:40	12/8/99 8:48	8.2	85.6	882.5	38.3	6	4	13:02:17	7	8.2	51.2		44.7			5	8.2	51.2		29.2				150
12/8/99 10:39	12/8/99 10:46	7.0	40.5	881.5	34.4	6	4	14:58:16	8	7.0	43.4	8	51.7	51.67	318.4	6	7.0	43.4	6	36.2	36.17	221.5	146.92	150
12/8/99 20:41	12/8/99 20:48	6.7	37.7	874.1	10.9	6	5	0:44:29	1	6.7	41.2		6.7			0				0.0				150
12/8/99 22:39	12/8/99 22:47	8.0	88.0	867.5	13.8	6	5	2:39:19	2	8.0	50.1		14.7			0				0.0				150
12/9/99 0:37	12/9/99 0:44	7.0	43.0	872.0	19.2	7	5	4:34:19	3	7.0	43.4		21.7			0				0.0				150
12/9/99 2:35	12/9/99 2:40	4.7	26.6	873.9	25.9	7	5	6:29:10	4	4.7	27.8		26.3			1	4.7	27.8		4.7				150
12/9/99 4:32	12/9/99 4:36	3.8	23.8	880.1	32.5	7	5	8:22:52	5	3.8	22.2		30.2			2	3.8	22.2		8.5				150
12/9/99 6:28	12/9/99 6:33	5.8	31.5	883.1	37.4	7	5	10:15:17	6	5.8	35.6		36.0			3	5.8	35.6		14.3				150
12/9/99 8:24	12/9/99 8:32	7.8	59.2	885.8	38.9	7	5	12:08:20	7	7.8	49.0		43.8			4	7.8	49.0		22.2				150
12/9/99 10:22	12/9/99 10:30	7.8	60.9	879.8	36.7	7	5	14:03:21	8	7.8	49.0		51.7			5	7.8	49.0		30.0				150
12/9/99 12:23	12/9/99 12:27	4.8	27.0	870.4	31.2	7	5	16:00:47	9	4.8	28.9		56.5			6	4.8	28.9	6	34.8	34.82	212.5	146.92	150
12/9/99 20:25	12/9/99 20:30	4.7	26.4	871.0	10.6	7	5	23:50:32	10	4.7	27.8	10	61.2	61.16	375.1	10	4.7	27.8		0.0				150
12/9/99 22:23	12/9/99 22:31	7.8	59.1	875.6	12.1	7	6	1:45:03	1	7.8	49.0		7.8			0				0.0				150
12/10/99 0:21	12/10/99 0:29	7.8	60.7	885.1	16.5	8	6	3:40:03	2	7.8	49.0		15.7			0				0.0				150
12/10/99 2:19	12/10/99 2:25	5.8	31.9	876.9	22.7	8	6	5:35:04	3	5.8	35.6		21.5			1	5.8	35.6		5.8				150
12/10/99 4:17	12/10/99 4:21	3.8	23.9	880.7	29.5	8	6	7:29:25	4	3.8	22.2		25.3			2	3.8	22.2		9.7				150
12/10/99 6:13	12/10/99 6:17	4.7	26.4	879.5	35.4	8	6	9:22:19	5	4.7	27.8		30.0			3	4.7	27.8		14.3				150
12/10/99 8:08	12/10/99 8:15	7.0	42.2	876.5	38.7	8	6	11:14:53	6	7.0	43.4		3											

Rise	Set	Pass Duration [min]	Max.El at lندر [deg]	Max.Range [km]	Max.Sun.El [deg]	Day # [ET]	Sol #	LMST	Pass # that Sol	D/L Pass duration [min.]	D/L Volume [Mbit]/pass w/ 0.50 min.CMD interval/pass	Max # passes that Sol	Cume D/L comm time that sol [min.]	Total D/L comm time/sol [min.]	D/L Volume/sol [Mbit]	Pass # sun el > 20°	Pass dur. sun el > 20° [min.]	D/L Volume [Mbit]/pass w/ 0.50 min.CMD interval/pass [sun el > 20°]	Max # passes sun el > 20°	Cume D/L time sun el > 20° [min.]	D/L time/sol sun el > 20° [min.]	D/L Volume/sol, sun el > 20 deg. [Mbit]	D/L Volume/sol, 4 passes, 6 min/pass [Mbit]	Mars98 Orbiter Daily Science D/L volume [Mbits]	
12/12/99 21:36	12/12/99 21:37	0.7	20.1	882.5	11.2	10	8	23:04:02	9	0.7	1.1	9	51.9	51.85	316.2	0					0.0				157
12/12/99 23:33	12/12/99 23:40	7.0	41.3	872.7	11.2	10	9	0:57:25	1	7.0	43.4		7.0			0									157
12/13/99 1:31	12/13/99 1:39	8.2	84.1	883.2	14.4	11	9	2:52:15	2	8.2	51.2		15.2			0					0.0				157
12/13/99 3:29	12/13/99 3:36	6.8	40.0	879.5	20.0	11	9	4:47:16	3	6.8	42.3		22.0			0					0.0				157
12/13/99 5:27	12/13/99 5:31	4.5	25.8	881.7	26.7	11	9	6:42:06	4	4.5	26.5		26.5			1	4.5	26.7			4.5				157
12/13/99 7:24	12/13/99 7:27	3.8	24.1	877.7	33.2	11	9	8:35:39	5	3.8	22.2		30.3			2	3.8	22.2			8.3				157
12/13/99 9:19	12/13/99 9:25	6.0	33.2	876.0	37.9	11	9	10:28:03	6	6.0	36.7		36.3			3	6.0	36.7			14.3				157
12/13/99 11:15	12/13/99 11:23	7.8	64.8	876.8	39.1	11	9	12:21:17	7	7.8	49.0		44.2			4	7.8	49.0			22.2				157
12/13/99 13:14	12/13/99 13:21	7.7	55.1	871.1	36.5	11	9	14:16:27	8	7.7	47.9		51.8			5	7.7	47.9			29.8				157
12/13/99 15:15	12/13/99 15:19	4.3	25.0	877.9	30.8	11	9	16:14:12	9	4.3	25.6	9	56.2	56.16	345.0	6	4.3	25.6	6	34.2	34.16	208.1	146.92		157
12/13/99 23:17	12/13/99 23:22	5.3	28.6	882.2	10.8	11	10	0:03:28	1	5.3	32.3		5.3			0									157
12/14/99 1:15	12/14/99 1:23	7.8	65.4	873.7	12.6	12	10	1:58:09	2	7.8	49.0		13.2			0					0.0				157
12/14/99 3:13	12/14/99 3:20	7.5	55.6	869.6	17.1	12	10	3:53:09	3	7.5	46.7		20.7			0					0.0				157
12/14/99 5:11	12/14/99 5:16	5.5	30.3	874.7	23.5	12	10	5:48:00	4	5.5	33.4		26.2			1	5.5	33.4			5.5				157
12/14/99 7:08	12/14/99 7:12	3.7	23.7	878.0	30.3	12	10	7:42:21	5	3.7	21.2		29.8			2	3.7	21.2			9.2				157
12/14/99 9:04	12/14/99 9:09	4.8	27.3	871.6	36.0	12	10	9:35:05	6	4.8	28.9		34.7			3	4.8	28.9			14.0				157
12/14/99 11:00	12/14/99 11:07	7.2	45.5	879.3	39.0	12	10	11:27:39	7	7.2	44.5		41.8			4	7.2	44.5			21.2				157
12/14/99 12:57	12/14/99 13:05	8.0	82.7	870.6	38.3	12	10	13:21:51	8	8.0	49.8		50.1			5	8.0	50.1			29.2				157
12/14/99 14:57	12/14/99 15:03	6.3	35.3	867.2	33.9	12	10	15:18:19	9	6.3	38.9		56.2			6	6.3	38.9			35.5		146.92		157
12/14/99 23:02	12/14/99 23:03	1.8	20.8	880.7	11.2	12	10	23:10:01	10	1.8	58.0	10	57.99	57.99	353.9	0			6	0.0	35.5	217.0	146.92		157
12/15/99 0:59	12/15/99 1:06	7.2	43.3	874.0	11.4	13	11	1:03:53	1	7.2	44.5		7.2			0									157
12/15/99 2:57	12/15/99 3:05	8.0	80.7	880.6	14.7	13	11	2:58:53	2	8.0	50.1		15.2			0					0.0				157
12/15/99 4:55	12/15/99 5:02	6.7	38.7	884.3	20.3	13	11	4:53:53	3	6.7	41.2		21.8			1	6.7	41.2			6.7				157
12/15/99 6:53	12/15/99 6:57	4.3	25.4	877.3	27.1	13	11	6:48:34	4	4.3	25.6		26.2			2	4.3	25.6			11.0				157
12/15/99 8:49	12/15/99 8:53	3.8	24.3	873.8	33.6	13	11	8:42:07	5	3.8	22.2		30.0			3	3.8	22.2			14.8				157
12/15/99 10:45	12/15/99 10:51	6.2	34.2	884.0	38.1	13	11	10:34:22	6	6.2	37.9		36.2			4	6.2	37.9			21.0				157
12/15/99 12:41	12/15/99 12:49	7.8	67.8	873.8	39.1	13	11	12:27:45	7	7.8	49.0		44.0			5	7.8	49.0			28.8				157
12/15/99 14:40	12/15/99 14:47	7.5	52.4	867.2	36.4	13	11	14:23:04	8	7.5	46.7		51.5			6	7.5	46.7			36.3				157
12/15/99 16:41	12/15/99 16:45	3.8	24.0	876.7	30.6	13	11	16:21:00	9	3.8	22.2	9	55.3	55.33	339.5	7	3.8	22.2	7	40.2	40.16	244.8	146.92		157
12/16/99 0:43	12/16/99 0:48	5.5	29.8	873.2	10.9	14	12	0:09:56	1	5.5	33.4		5.5			0									157
12/16/99 2:41	12/16/99 2:48	7.8	68.7	861.6	12.8	14	12	2:04:37	2	7.8	49.0		13.3			0					0.0				157
12/16/99 4:39	12/16/99 4:46	7.5	53.3	876.9	17.5	14	12	3:59:37	3	7.5	46.7		20.8			0					0.0				157
12/16/99 6:37	12/16/99 6:42	5.5	29.6	878.8	23.8	14	12	5:54:28	4	5.5	33.4		26.3			1	5.5	33.4			5.5				157
12/16/99 8:34	12/16/99 8:38	3.5	23.6	871.3	30.6	14	12	7:48:49	5	3.5	20.0		29.8			2	3.5	20.0			9.0				157
12/16/99 10:30	12/16/99 10:35	5.0	27.8	875.6	36.3	14	12	9:41:23	6	5.0	30.1		34.8			3	5.0	30.1			14.0				157
12/16/99 12:26	12/16/99 12:33	7.2	47.3	868.9	39.1	14	12	11:34:07	7	7.2	44.5		42.0			4	7.2	44.5			21.2				157
12/16/99 14:23	12/16/99 14:31	8.0	78.9	878.7	38.2	14	12	13:28:19	8	8.0	50.1		50.0			5	8.0	50.1			29.2				157
12/16/99 16:23	12/16/99 16:29	6.2	33.8	869.3	33.7	14	12	15:24:57	9	6.2	37.9		56.2			6	6.2	37.9	6	35.3	35.34	216.0	146.92		157
12/17/99 0:27	12/17/99 0:30	2.5	21.6	877.9	11.2	15	12	23:16:19	10	2.5	13.4	10	58.7	58.67	368.4	0					0.0				157
12/17/99 2:24	12/17/99 2:32	7.3	45.5	876.9	11.5	15	13	1:10:21	1	7.3	45.6		7.3			0									157
12/17/99 4:23	12/17/99 4:31	8.0	77.3	879.2	15.0	15	13	3:05:21	2	8.0	50.1		15.3			0					0.0				157
12/17/99 6:21	12/17/99 6:27	6.5	37.4	873.7	20.7	15	13	5:00:21	3	6.5	40.1		21.8			1	6.5	40.1			6.5				157
12/17/99 8:19	12/17/99 8:23	4.2	25.1	873.0	27.4	15	13	6:55:02	4	4.2	24.5		26.0			2	4.2	24.5			10.7				157
12/17/99 10:15	12/17/99 10:19	4.0	24.6	875.3	33.9	15	13	8:48:25	5	4.0	23.4		30.0			3	4.0	23.4			14.7				157
12/17/99 12:11	12/17/99 12:17	6.3	35.2	879.4	38.3	15	13	10:40:50	6	6.3	38.9		36.3			4	6.3	38.9			21.0				157
12/17/99 14:07	12/17/99 14:15	8.0	71.0	881.3	39.1	15	13	12:34:13	7	8.0	50.1		44.3			5	8.0	50.1			29.0				157
12/17/99 16:06	12/17/99 16:13	7.5	49.9	881.7	36.3	15	13	14:29:32	8	7.5	46.7		51.8			6	7.5	46.7			36.5				157
12/17/99 18:07	12/17/99 18:11	3.5	23.1	878.1	30.3	15	13	16:27:47	9	3.5	20.0	9	55.3	55.33	339.5	7	3.5	20.0	7	40.0	40	243.8	146.92		157
12/18/99 2:09	12/18/99 2:14	5.8	31.1	884.9	11.0	16	14	0:16:24	1	5.8	35.6		5.8			0									157
12/18/99 4:06	12/18/99 4:14	8.0	72.2	877.1	13.0	16	14	2:11:05	2	8.0	50.1		13.8			0					0.0				157
12/18/99 6:05	12/18/99 6:12	7.5	51.1	885.1	17.8	16	14	4:06:05	3	7.5	46.7		21.3			0					0.0				157
12/18/99 8:03	12/18/99 8:08	5.3	29.0	879.6	24.2	16	14	6:00:56	4	5.3	32.3		26.7			1	5.3	32.3			5.3				157
12/18/99 10:00	12/18/99 10:04	3.7	23.6	878.0	31.0	16	14	7:55:07	5	3.7	21.2		30.3			2	3.7	21.2			9.0				157
12/18/99 11:56	12/18/99 12:01	5.2	28.4	880.5	36.6	16	14	9:47:42	6	5.2	31.2		35.5			3	5.2	31.2			14.2				157
12/18/99 13:51	12/18/99 13:59	7.5	49.2	885.5	39.2	16	14	11:40:26	7	7.5	46.7		43.0			4	7.5	46.7			21.7				157
12/18/99 15:49	12/18/99 15:57	8.0	75.3	879.3	38.1	16	14	13:34:57	8	8.0	50.1		51.0			5	8.0	50.1			29.7				157
12/18/99 17:49	12/18/99 17:55	6.0	32.3	875.1	33.5	16	14	15:31:34	9	6.0	36.7		57.0			6	6.0	36.7	6	35.7	35.67	218.2	146.92		157
12/19/99 1:53	12/19/99 1:56	3.2	22.4	881.8	11.2	17	14	23:22:37	10	3.2	17.8	10													

Rise	Set	Pass Duration [min.]	Max.El at lندر [deg.]	Max.Range [km]	Max.Sun.El [deg.]	Day # [ET]	Sol #	LMST	Pass # that Sol	D/L Pass duration [min.]	D/L Volume [Mbit]/pass w/ 0.50 min.CMD interval/pass	Max # passes that Sol	Cume D/L comm time that sol [min.]	Total D/L comm time/sol [min.]	D/L Volume/sol [Mbit]	Pass # sun el > 20°	Pass dur. sun el > 20° [min.]	D/L Volume [Mbit]/pass w/ 0.50 min.CMD interval/pass [sun el > 20°]	Max # passes sun el > 20°	Cume D/L time sun el > 20° [min.]	D/L time/sol sun el > 20° [min.]	D/L Volume/sol, sun el > 20 deg. [Mbit]	D/L Volume/sol, 4 passes, 6 min/pass [Mbit]	Mars98 Orbiter Daily Science D/L volume [Mbits]
12/21/99 11:10	12/21/99 11:14	4.0	24.5	878.6	28.1	19	17	707:58	4	4.0	23.4		25.8			2	4.0	23.4		10.3				157
12/21/99 13:07	12/21/99 13:11	4.2	25.1	877.3	34.4	19	17	901:12	5	4.2	24.5		30.0			3	4.2	24.5		14.5				157
12/21/99 15:02	12/21/99 15:09	6.5	37.5	871.0	38.6	19	17	1053:36	6	6.5	40.1		36.5			4	6.5	40.1		21.0				157
12/21/99 16:59	12/21/99 17:07	8.0	77.7	871.3	39.1	19	17	1247:09	7	8.0	44.5		44.5			5	8.0	50.1		29.0				157
12/21/99 18:58	12/21/99 19:05	7.2	45.2	872.0	35.9	19	17	1442:48	8	7.2	44.5		51.7			6	7.2	44.5		36.2				157
12/21/99 21:00	12/21/99 21:02	2.5	21.5	881.2	29.7	19	17	1641:32	9	2.5	13.4	9	54.2	54.17	331.7	7	2.5	13.4	7	38.7	38.67	234.9	146.92	157
12/22/99 5:00	12/22/99 5:06	6.2	33.9	872.6	11.1	20	18	029:20	1	6.2	37.9		6.2			0								161
12/22/99 6:58	12/22/99 7:06	8.2	79.2	885.8	13.4	20	18	224:01	2	8.2	51.2		14.3			0				0.0				161
12/22/99 8:56	12/22/99 9:04	7.3	47.1	877.9	18.4	20	18	419:01	3	7.3	45.6		21.7			0				0.0				161
12/22/99 10:54	12/22/99 10:59	5.0	27.8	882.2	24.9	20	18	614:02	4	5.0	30.1		26.7			1	5.0	30.1		5.0				161
12/22/99 12:51	12/22/99 12:55	3.7	23.6	879.9	31.6	20	18	807:54	5	3.7	21.2		30.3			2	3.7	21.2		8.7				161
12/22/99 14:47	12/22/99 14:52	5.3	29.7	871.8	37.0	20	18	1000:28	6	5.3	32.3		36.7			3	5.3	32.3		14.0				161
12/22/99 16:43	12/22/99 16:51	7.5	53.5	868.5	39.3	20	18	1153:22	7	7.5	46.7		43.2			4	7.5	46.7		21.5				161
12/22/99 18:41	12/22/99 18:49	8.0	68.4	882.0	37.9	20	18	1347:53	8	8.0	51.2		51.2			5	8.0	50.1		29.5				161
12/22/99 20:41	12/22/99 20:47	5.5	29.7	870.6	33.0	20	18	1545:00	9	5.5	33.4		56.7			6	5.5	33.4	6	35.0	35	213.7	146.92	161
12/23/99 4:44	12/23/99 4:48	4.0	24.1	878.2	11.2	21	18	23:35.24	10	4.0	23.4	10	60.7	60.67	371.8	0		23.4		0.0				161
12/23/99 6:42	12/23/99 6:50	7.5	52.6	868.0	11.9	21	19	129:55	1	7.5	46.7		7.5			0								161
12/23/99 8:40	12/23/99 8:48	8.0	67.5	882.0	15.7	21	19	324:45	2	8.0	50.1		15.5			0				0.0				161
12/23/99 10:38	12/23/99 10:44	6.2	34.1	877.2	21.6	21	19	519:46	3	6.2	37.9		21.7			1	6.2	37.9		6.2				161
12/23/99 12:36	12/23/99 12:40	3.8	24.3	873.7	28.4	21	19	714:26	4	3.8	22.2		25.5			2	3.8	22.2		10.0				161
12/23/99 14:32	12/23/99 14:37	4.3	25.4	877.7	34.7	21	19	907:30	5	4.3	25.6		29.8			3	4.3	25.6		14.3				161
12/23/99 16:28	12/23/99 16:34	6.7	38.8	876.1	38.7	21	19	1059:55	6	6.7	41.2		36.5			4	6.7	41.2		21.0				161
12/23/99 18:25	12/23/99 18:33	8.0	81.2	872.7	39.1	21	19	1253:37	7	8.0	50.1		44.5			5	8.0	50.1		29.0				161
12/23/99 20:24	12/23/99 20:31	7.2	43.1	879.7	35.7	21	19	1449:26	8	7.2	44.5		51.7			6	7.2	44.5		36.2				161
12/23/99 22:26	12/23/99 22:28	1.7	20.8	879.7	29.4	21	19	1648:29	9	1.7	7.8	9	53.3	53.34	326.2	7	1.7	7.8	7	37.8	37.84	229.3	146.92	161
12/24/99 6:26	12/24/99 6:32	6.3	35.5	868.0	11.1	22	20	035:48	1	6.3	38.9		6.3			0								161
12/24/99 8:24	12/24/99 8:32	8.0	82.8	877.9	13.6	22	20	230:39	2	8.0	50.1		14.3			0				0.0				161
12/24/99 10:22	12/24/99 10:29	7.0	45.3	862.1	18.6	22	20	425:39	3	7.0	43.4		21.3			0				0.0				161
12/24/99 12:20	12/24/99 12:25	4.8	27.2	877.4	25.2	22	20	620:30	4	4.8	28.9		26.2			1	4.8	28.9		4.8				161
12/24/99 14:17	12/24/99 14:21	3.7	23.7	877.9	31.9	22	20	814:22	5	3.7	21.2		29.8			2	3.7	21.2		8.5				161
12/24/99 16:13	12/24/99 16:18	5.7	30.4	880.1	37.2	22	20	1006:47	6	5.7	34.5		36.5			3	5.7	34.5		14.2				161
12/24/99 18:09	12/24/99 18:16	7.5	55.8	862.6	39.4	22	20	1159:50	7	7.5	46.7		43.0			4	7.5	46.7		21.7				161
12/24/99 20:07	12/24/99 20:15	7.8	65.0	867.2	37.8	22	20	1354:31	8	7.8	49.0		50.8			5	7.8	49.0		29.5				161
12/24/99 22:07	12/24/99 22:12	5.3	28.5	879.9	32.7	22	20	1551:38	9	5.3	32.3		56.2			6	5.3	32.3	6	34.8	34.83	212.6	146.92	161
12/25/99 6:10	12/25/99 6:15	4.3	25.1	878.7	11.1	23	20	2341:52	10	4.3	25.6	10	60.5	60.49	370.6	0				0.0				161
12/25/99 8:08	12/25/99 8:16	7.7	55.3	876.6	12.0	23	21	136:23	1	7.7	47.9		7.7			0								161
12/25/99 10:06	12/25/99 10:14	7.8	64.5	885.1	16.0	23	21	331:23	2	7.8	49.0		15.5			0				0.0				161
12/25/99 12:04	12/25/99 12:10	6.2	33.1	883.7	21.9	23	21	528:14	3	6.2	37.9		21.7			1	6.2	37.9		6.2				161
12/25/99 14:02	12/25/99 14:06	3.8	24.1	881.6	28.7	23	21	720:45	4	3.8	22.2		25.5			2	3.8	22.2		10.0				161
12/25/99 15:58	12/25/99 16:02	4.5	25.8	877.7	35.0	23	21	913:48	5	4.5	26.7		30.0			3	4.5	26.7		14.5				161
12/25/99 17:54	12/25/99 18:00	6.7	40.2	863.4	38.8	23	21	1106:23	6	6.7	41.2		36.7			4	6.7	41.2		21.2				161
12/25/99 19:50	12/25/99 19:58	8.0	84.7	875.4	39.0	23	21	1300:05	7	8.0	50.1		44.7			5	8.0	50.1		29.2				161
12/25/99 21:50	12/25/99 21:57	7.0	41.1	877.1	35.5	23	21	1456:04	8	7.0	43.4		51.7			6	7.0	43.4		36.2				161
12/25/99 23:53	12/25/99 23:53	0.3	20.0	882.0	29.1	23	21	1655:46	8	0.0	0.0	8	51.7	51.67	318.4	6	0.0	0.0	6	36.2	36.17	221.5	146.92	161
12/26/99 7:52	12/26/99 7:58	6.5	37.1	864.7	11.2	24	22	042:17	1	6.5	40.1		6.5			0								161
12/26/99 9:50	12/26/99 9:58	8.0	86.7	871.3	13.8	24	22	237:07	2	8.0	50.1		14.5			0				0.0				161
12/26/99 11:48	12/26/99 11:55	7.0	43.6	873.2	18.9	24	22	432:07	3	7.0	43.4		21.5			0				0.0				161
12/26/99 13:46	12/26/99 13:51	4.7	26.8	873.1	25.5	24	22	626:58	4	4.7	27.8		26.2			1	4.7	27.8		4.7				161
12/26/99 15:43	12/26/99 15:47	3.7	23.8	879.9	32.2	24	22	820:40	5	3.7	21.2		29.8			2	3.7	21.2		8.3				161
12/26/99 17:38	12/26/99 17:44	5.8	31.2	883.7	37.4	24	22	1013:05	6	5.8	35.6		36.7			3	5.8	35.6		14.2				161
12/26/99 19:35	12/26/99 19:42	7.7	58.3	882.1	39.4	24	22	1206:08	7	7.7	47.9		43.3			4	7.7	47.9		21.8				161
12/26/99 21:33	12/26/99 21:40	7.8	61.9	881.4	37.6	24	22	1400:59	8	7.8	49.0		51.2			5	7.8	49.0		29.7				161
12/26/99 23:33	12/26/99 23:38	5.0	27.4	872.9	32.4	24	22	1558:25	9	5.0	30.1		56.2			6	5.0	30.1	6	34.7	34.67	211.5	146.92	161
12/27/99 7:36	12/27/99 7:41	4.7	26.1	882.0	11.1	25	22	2348:20	10	4.7	27.8	10	60.8	60.84	372.9	0				0.0				161
12/27/99 9:34	12/27/99 9:42	7.8	58.2	886.8	12.1	25	23	142:51	1	7.8	49.0		7.8			0								161
12/27/99 11:32	12/27/99 11:40	7.7	61.7	863.5	16.2	25	23	337:51	2	7.7	47.9		15.5			0				0.0				161
12/27/99 13:30	12/27/99 13:36	5.8	32.2	876.3	22.2	25	23	532:52	3	5.8	35.6		21.3			1	5.8	35.6		5.8				161
12/27/99 15:28	12/27/99 15:31	3.8	23.9	878.9	29.0	25	23	727:13	4	3.8	22.2		25.2			2	3.8	22.2		9.7				161
12/27/99 17:24	12/27/99 17:28	4.7	26.2	880.3	35.2	25	23	920:07	5	4.7	27.8		29.8			3	4.7							

Rise	Set	Pass Duration [min.]	Max.El at lندر [deg.]	Max.Range [km]	Max.Sun.El [deg.]	Day# [ET]	Sol #	LMST	Pass # that Sol	D/L Pass duration [min.]	D/L Volume [Mbit]/pass w/ 0.50 min.CMD interval/pass	Max # passes that Sol	Cume D/L comm time that sol [min.]	Total D/L comm time/sol [min.]	D/L Volume/sol [Mbit]	Pass # sun el > 20°	Pass dur. sun el > 20° [min.]	D/L Volume [Mbit]/pass w/ 0.50 min.CMD interval/pass [sun el > 20°]	Max # passes sun el > 20°	Cume D/L time sun el > 20° [min.]	D/L time/sol sun el > 20° [min.]	D/L Volume/sol, sun el > 20 deg. [Mbit]	D/L Volume/sol, 4 passes, 6 min/pass [Mbit]	Mars98 Orbiter Daily Science D/L volume [Mbits]
12/30/99 10:44	12/30/99 10:51	7.0	40.7	885.9	11.2	28	26	0:55:13	1	7.0	43.4		7.0			0								161
12/30/99 12:42	12/30/99 12:50	8.0	85.7	871.1	14.1	28	26	2:50:03	2	8.0	50.1		15.0			0					0.0			161
12/30/99 14:40	12/30/99 14:47	6.8	40.5	872.8	19.4	28	26	4:45:03	3	6.8	42.3		21.8			0					0.0			161
12/30/99 16:38	12/30/99 16:42	4.5	25.9	881.0	26.0	28	26	6:39:54	4	4.5	26.7		26.3			1	4.5	26.7		4.5				161
12/30/99 18:34	12/30/99 18:38	3.8	24.1	877.8	32.7	28	26	8:33:27	5	3.8	22.2		30.2			2	3.8	22.2		8.3				161
12/30/99 20:30	12/30/99 20:36	6.0	32.9	876.4	37.7	28	26	10:25:51	6	6.0	36.7		36.2			3	6.0	36.7		14.3				161
12/30/99 22:26	12/30/99 22:34	7.8	63.7	872.7	39.3	28	26	12:19:05	7	7.8	49.0		44.0			4	7.8	49.0		22.2				161
12/31/99 0:24	12/31/99 0:32	7.8	56.0	886.1	37.2	29	26	14:14:05	8	7.8	51.8		51.8			5	7.8	49.0		30.0				161
12/31/99 2:25	12/31/99 2:30	4.5	25.3	879.7	31.8	29	26	16:11:51	9	4.5	26.7	9	56.3	56.32	346.1	6	4.5	26.7	6	34.5	34.49	210.3	146.92	161
12/31/99 10:28	12/31/99 10:33	5.3	28.2	880.2	11.0	29	27	0:01:06	1	5.3	32.3		5.3			0								161
12/31/99 12:25	12/31/99 12:33	8.0	64.3	884.1	12.3	29	27	1:55:47	2	8.0	50.1		13.3			0				0.0				161
12/31/99 14:24	12/31/99 14:31	7.7	56.4	875.1	16.6	29	27	3:50:47	3	7.7	47.9		21.0			0				0.0				161
12/31/99 16:22	12/31/99 16:27	5.5	30.6	869.6	22.8	29	27	5:45:48	4	5.5	33.4		26.5			1	5.5	33.4		5.5				161
12/31/99 18:19	12/31/99 18:23	3.7	23.7	878.4	29.6	29	27	7:40:09	5	3.7	21.2		30.2			2	3.7	21.2		9.2				161
12/31/99 20:15	12/31/99 20:20	4.8	27.1	875.7	35.6	29	27	9:32:53	6	4.8	28.9		36.0			3	4.8	28.9		14.0				161
12/31/99 22:11	12/31/99 22:18	7.2	44.8	877.7	39.0	29	27	11:25:27	7	7.2	44.5		42.2			4	7.2	44.5		21.2				161
1/1/00 0:08	1/1/00 0:16	8.0	83.9	869.5	38.7	30	27	13:19:39	8	8.0	50.1		50.2			5	8.0	50.1		29.2				163
1/1/00 2:08	1/1/00 2:14	6.5	35.8	873.1	34.7	30	27	15:15:57	9	6.5	40.1		56.7			6	6.5	40.1	6	35.7	35.67	218.2	146.92	163
1/1/00 10:13	1/1/00 10:14	1.5	20.6	882.0	11.5	30	27	23:07:59	10	1.5	6.7	10	58.2	58.17	355.1	0				0.0				163
1/1/00 12:09	1/1/00 12:16	7.0	42.6	867.0	11.3	30	28	1:01:41	1	7.0	43.4		7.0			0								163
1/1/00 14:07	1/1/00 14:16	8.2	82.0	887.3	14.2	30	28	2:56:32	2	8.2	51.2		15.2			0				0.0				163
1/1/00 16:06	1/1/00 16:12	6.8	39.1	884.9	19.6	30	28	4:51:32	3	6.8	42.3		22.0			0				0.0				163
1/1/00 18:04	1/1/00 18:08	4.3	25.5	876.6	26.3	30	28	6:46:22	4	4.3	25.6		26.3			1	4.3	25.6		4.3				163
1/1/00 20:00	1/1/00 20:04	3.8	24.3	876.1	32.9	30	28	8:39:55	5	3.8	22.2		30.2			2	3.8	22.2		8.2				163
1/1/00 21:56	1/1/00 22:02	6.2	33.9	884.2	37.8	30	28	10:32:10	6	6.2	37.9		36.3			3	6.2	37.9		14.3				163
1/1/00 23:52	1/2/00 0:00	7.8	66.7	868.9	39.3	30	28	12:25:33	7	7.8	49.0		44.2			4	7.8	49.0		22.2				163
1/2/00 1:50	1/2/00 1:58	7.7	53.3	877.0	37.0	31	28	14:20:43	8	7.7	47.9		51.8			5	7.7	47.9		29.8				163
1/2/00 3:52	1/2/00 3:56	4.0	24.3	878.1	31.4	31	28	16:18:38	9	4.0	23.4	9	56.8	55.83	342.8	6	4.0	23.4	6	33.8	33.83	205.9	146.92	163
1/2/00 11:53	1/2/00 11:59	5.5	29.4	878.7	10.9	31	29	0:07:35	1	5.5	33.4		5.5			0								163
1/2/00 13:51	1/2/00 13:59	7.8	67.6	870.8	12.4	31	29	2:02:25	2	7.8	49.0		13.3			0				0.0				163
1/2/00 15:49	1/2/00 15:57	7.7	54.1	880.7	16.8	31	29	3:57:16	3	7.7	47.9		21.0			0				0.0				163
1/2/00 17:47	1/2/00 17:53	5.5	29.9	878.0	23.0	31	29	5:52:16	4	5.5	33.4		26.5			1	5.5	33.4		5.5				163
1/2/00 19:45	1/2/00 19:48	3.7	23.7	881.6	29.8	31	29	7:46:28	5	3.7	21.2		30.2			2	3.7	21.2		9.2				163
1/2/00 21:41	1/2/00 21:46	5.0	27.6	876.5	35.8	31	29	9:39:12	6	5.0	30.1		36.2			3	5.0	30.1		14.2				163
1/2/00 23:36	1/2/00 23:44	7.2	46.6	867.1	39.0	31	29	11:31:56	7	7.2	44.5		42.3			4	7.2	44.5		21.3				163
1/3/00 1:34	1/3/00 1:42	8.0	80.3	869.9	38.5	32	29	13:26:08	8	8.0	50.3		50.3			5	8.0	50.3		29.3				163
1/3/00 3:33	1/3/00 3:40	6.3	34.3	877.2	34.4	32	29	15:22:36	9	6.3	38.9		56.7			6	6.3	38.9	6	35.7	35.67	218.2	146.92	163
1/3/00 11:38	1/3/00 11:40	2.3	21.3	879.5	11.4	32	29	23:14:08	10	2.3	12.2	10	59.0	59	360.6	0				0.0				163
1/3/00 13:35	1/3/00 13:42	7.2	44.7	869.6	11.3	32	30	1:08:10	1	7.2	44.5		7.2			0								163
1/3/00 15:33	1/3/00 15:41	8.0	78.3	885.5	14.4	32	30	3:03:10	2	8.0	50.1		15.2			0				0.0				163
1/3/00 17:31	1/3/00 17:38	6.5	37.8	874.0	19.9	32	30	4:58:10	3	6.5	40.1		21.7			0				0.0				163
1/3/00 19:29	1/3/00 19:33	4.2	25.2	872.4	26.6	32	30	6:52:51	4	4.2	24.5		25.8			1	4.2	24.5		4.2				163
1/3/00 21:26	1/3/00 21:30	4.0	24.5	877.8	33.1	32	30	8:46:14	5	4.0	23.4		29.8			2	4.0	23.4		8.2				163
1/3/00 23:21	1/3/00 23:27	6.2	34.9	870.2	37.9	32	30	10:38:39	6	6.2	37.9		36.0			3	6.2	37.9		14.3				163
1/4/00 1:18	1/4/00 1:26	7.8	69.8	866.5	39.2	33	30	12:32:02	7	7.8	49.0		43.8			4	7.8	49.0		22.2				163
1/4/00 3:16	1/4/00 3:24	7.5	50.7	870.2	36.8	33	30	14:27:21	8	7.5	46.7		51.3			5	7.5	46.7		29.7				163
1/4/00 5:18	1/4/00 5:21	3.7	23.4	878.7	31.1	33	30	16:25:27	9	3.7	21.2	9	56.0	55.01	337.3	6	3.7	21.2	6	33.3	33.34	202.6	146.92	163
1/4/00 13:19	1/4/00 13:25	5.8	30.7	878.5	10.9	33	31	0:14:04	1	5.8	35.6		5.8			0								163
1/4/00 15:17	1/4/00 15:25	8.0	70.9	886.8	12.5	33	31	2:08:54	2	8.0	50.1		13.8			0				0.0				163
1/4/00 17:15	1/4/00 17:23	7.3	51.8	861.1	17.0	33	31	4:03:54	3	7.3	45.6		21.2			0				0.0				163
1/4/00 19:13	1/4/00 19:19	5.3	29.2	874.8	23.3	33	31	5:58:45	4	5.3	32.3		26.5			1	5.3	32.3		5.3				163
1/4/00 21:11	1/4/00 21:14	3.7	23.6	877.8	30.1	33	31	7:52:57	5	3.7	21.2		30.2			2	3.7	21.2		9.0				163
1/4/00 23:06	1/4/00 23:11	5.2	28.2	881.3	35.9	33	31	9:45:31	6	5.2	31.2		36.3			3	5.2	31.2		14.2				163
1/5/00 1:02	1/5/00 1:09	7.3	48.5	883.2	39.0	34	31	11:38:15	7	7.3	45.6		42.7			4	7.3	45.6		21.5				163
1/5/00 3:00	1/5/00 3:08	8.0	76.5	878.7	38.4	34	31	13:32:36	8	8.0	50.1		50.7			5	8.0	50.1		29.5				163
1/5/00 4:59	1/5/00 5:06	6.2	32.8	882.5	34.1	34	31	15:29:14	9	6.2	37.9		56.8			6	6.2	37.9	6	35.7	35.67	218.2	146.92	163
1/5/00 13:04	1/5/00 13:07	3.0	22.1	882.2	11.3	34	31	23:20:27	10	3.0	16.7	10	59.8	59.83	366.2	0				0.0				163
1/5/00 15:01	1/5/00 15:08	7.3	46.9	872.6	11.3	34	32	1:14:38	1	7.3	45.6		7.3			0								163
1/5/00 16:59	1/5/00 17:07	8.0	75.0	884.9	14.5	34	32	3:09:39	2	8.0	50.1		15.3			0				0.0				163
1/5/00 18:57	1/5/00 19:04	6.3	36.6	864.2	20.1	34	32	5:04:39	3	6.3	38.9		21.7</											

Rise	Set	Pass Duration [min.]	Max.El at linder [deg.]	Max.Range [km]	Max(Sun.El) [deg.]	Day # [ET]	Sol #	LMST	Pass # that Sol	D/L Pass duration [min.]	D/L Volume [Mbit]/pass w/ 0.50 min.CMD interval/pass	Max # passes that Sol	Cume D/L comm time that sol [min.]	Total D/L comm time/sol [min.]	D/L Volume/sol [Mbit]	Pass # sun el > 20°	Pass dur. sun el > 20° [min.]	D/L Volume [Mbit]/pass w/ 0.50 min.CMD interval/pass [sun el > 20°]	Max # passes sun el > 20°	Cume D/L time sun el > 20° [min.]	D/L time/sol sun el > 20° [min.]	D/L Volume/sol, sun el > 20 deg. [Mbit]	D/L Volume/sol, 4 passes, 6 min/pass [Mbit]	Mars98 Orbiter Daily Science D/L volume [Mbits]
18/00 0:17	18/00 0:21	4.2	25.0	880.2	33.5	37	34	8:59:02	5	42	24.5		30.0			3	42	24.5		14.5				163
18/00 2:13	18/00 2:19	6.5	37.1	877.4	38.0	37	34	10:51:26	6	6.5	40.1		36.5			4	6.5	40.1		21.0				163
18/00 4:09	18/00 4:17	8.0	76.5	877.5	39.0	37	34	12:44:59	7	8.0	50.1		44.5			5	8.0	50.1		29.0				163
18/00 6:08	18/00 6:15	7.3	46.0	884.7	36.2	37	34	14:40:28	8	7.3	45.6		51.8			6	7.3	45.6		36.3				163
18/00 8:10	18/00 8:13	2.7	21.8	880.1	30.3	37	34	16:39:13	9	2.7	14.5	9	54.5	54.5	333.9	7	2.7	14.5	7	39.0	39	237.1	146.92	163
18/00 16:11	18/00 16:17	6.2	33.4	877.5	10.7	37	35	0:27:01	1	6.2	37.9		6.2			0								163
18/00 18:09	18/00 18:17	8.0	78.1	869.4	12.7	37	35	2:21:51	2	8.0	50.1		14.2			0				0.0				163
18/00 20:07	18/00 20:14	7.3	47.7	879.4	17.3	37	35	4:16:52	3	7.3	45.6		21.5			0				0.0				163
18/00 22:05	18/00 22:10	5.2	28.0	881.4	23.7	37	35	6:11:42	4	5.2	31.2		26.7			1	5.2	31.2		5.2				163
19/00 0:02	19/00 0:06	3.7	23.6	879.2	30.5	38	35	8:05:44	5	3.7	21.2		30.3			2	3.7	21.2		8.8				163
19/00 1:58	19/00 2:03	5.3	29.5	872.5	36.2	38	35	9:58:19	6	5.3	32.3		36.7			3	5.3	32.3		14.2				163
19/00 3:54	19/00 4:01	7.5	52.7	875.9	38.9	38	35	11:51:12	7	7.5	46.7		43.2			4	7.5	46.7		21.7				163
19/00 5:51	19/00 5:59	8.0	69.6	876.5	38.0	38	35	13:45:43	8	8.0	50.1		51.2			5	8.0	50.1		29.7				163
19/00 7:52	19/00 7:57	5.7	30.1	876.4	33.4	38	35	15:42:40	9	5.7	34.5		56.8			6	5.7	34.5	6	35.3	35.34	216.0	146.92	163
19/00 15:55	19/00 15:59	3.8	23.8	877.2	11.0	38	35	23:33:14	10	3.8	22.2	10	60.7	60.67	371.8	0				0.0				163
19/00 17:53	19/00 18:00	7.7	51.8	879.9	11.3	38	36	1:27:36	1	7.7	47.9		7.7			0								163
19/00 19:51	19/00 19:59	8.0	68.5	887.1	14.8	38	36	3:22:36	2	8.0	50.1		15.7			0				0.0				163
19/00 21:49	19/00 21:55	6.2	34.4	871.3	20.5	38	36	5:17:36	3	6.2	37.9		21.8			1	6.2	37.9		6.2				163
19/00 23:47	19/00 23:51	4.0	24.4	881.4	27.2	38	36	7:12:07	4	4.0	23.4		25.8			2	4.0	23.4		10.2				163
1/1000 1:43	1/1000 1:47	4.3	25.3	880.9	33.7	39	36	9:05:21	5	4.3	25.6		30.2			3	4.3	25.6		14.5				163
1/1000 3:38	1/1000 3:45	6.7	38.4	875.5	38.0	39	36	10:57:45	6	6.7	41.2		36.8			4	6.7	41.2		21.2				163
1/1000 5:35	1/1000 5:43	8.0	80.0	871.6	38.8	39	36	12:51:28	7	8.0	50.1		44.8			5	8.0	50.1		29.2				163
1/1000 7:34	1/1000 7:41	7.2	43.8	881.4	35.9	39	36	14:47:07	8	7.2	44.5		52.0			6	7.2	44.5		36.3				163
1/1000 9:36	1/1000 9:38	2.0	21.0	881.4	29.9	39	36	16:46:10	9	2.0	10.0	9	54.0	54.01	330.6	7	2.0	10.0	7	38.3	38.34	232.7	146.92	163
1/1000 17:37	1/1000 17:43	6.5	34.9	881.5	10.6	39	37	0:33:30	1	6.5	40.1		6.5			0								163
1/1000 19:35	1/1000 19:43	8.2	81.7	886.4	12.7	39	37	2:28:20	2	8.2	51.2		14.7			0				0.0				163
1/1000 21:33	1/1000 21:40	7.2	45.9	875.9	17.5	39	37	4:23:20	3	7.2	44.5		21.8			0				0.0				163
1/1000 23:31	1/1000 23:36	5.0	27.4	880.2	23.9	39	37	6:18:11	4	5.0	30.1		26.8			1	5.0	30.1		5.0				163
1/1100 1:28	1/1100 1:32	3.7	23.7	879.4	30.7	40	37	8:12:13	5	3.7	21.2		30.5			2	3.7	21.2		8.7				166
1/1100 3:23	1/1100 3:29	5.5	30.2	878.0	36.3	40	37	10:04:37	6	5.5	36.0		36.0			3	5.5	33.4		14.2				166
1/1100 5:19	1/1100 5:27	7.7	50.0	885.0	38.9	40	37	11:57:31	7	7.7	47.9		43.7			4	7.7	47.9		21.8				166
1/1100 7:17	1/1100 7:25	8.0	66.2	884.6	37.7	40	37	13:52:12	8	8.0	50.1		51.7			5	8.0	50.1		29.8				166
1/1100 9:18	1/1100 9:23	5.5	28.9	885.1	33.0	40	37	15:49:19	9	5.5	33.4		57.2			6	5.5	33.4	6	35.3	35.34	216.0	146.92	166
1/1100 17:21	1/1100 17:25	4.2	24.7	876.5	10.8	40	37	23:39:43	10	4.2	24.5	10	61.4	61.35	376.3	0				0.0				166
1/1100 19:19	1/1100 19:26	7.5	54.4	861.4	11.3	40	38	1:34:14	1	7.5	46.7		7.5			0								166
1/1100 21:17	1/1100 21:24	7.8	65.5	877.7	14.9	40	38	3:29:05	2	7.8	49.0		15.3			0				0.0				166
1/1100 23:15	1/1100 23:21	6.2	33.4	883.5	20.7	40	38	5:24:05	3	6.2	37.9		21.5			1	6.2	37.9		6.2				166
1/1200 1:12	1/1200 1:16	3.8	24.2	879.4	27.4	41	38	7:18:36	4	3.8	22.2		25.3			2	3.8	22.2		10.0				166
1/1200 3:09	1/1200 3:13	4.5	25.7	881.1	33.8	41	38	9:11:39	5	4.5	26.7		29.8			3	4.5	26.7		14.5				166
1/1200 5:04	1/1200 5:11	6.7	39.7	868.3	38.0	41	38	11:04:14	6	6.7	41.2		36.5			4	6.7	41.2		21.2				166
1/1200 7:01	1/1200 7:09	8.0	83.7	868.4	38.7	41	38	12:57:56	7	8.0	50.1		44.5			5	8.0	50.1		29.2				166
1/1200 9:00	1/1200 9:07	7.0	41.8	879.5	35.6	41	38	14:53:45	8	7.0	43.4		51.5			6	7.0	43.4		36.2				166
1/1200 11:03	1/1200 11:04	1.0	20.3	882.8	29.4	41	38	16:53:08	9	1.0	3.3	9	52.5	52.5	320.6	7	1.0	3.3	7	37.2	37.17	224.9	146.92	166
1/1200 19:02	1/1200 19:09	6.7	36.5	879.3	10.5	41	39	0:39:58	1	6.7	41.2		6.7			0								166
1/1200 21:00	1/1200 21:09	8.2	85.0	880.3	12.8	41	39	2:34:49	2	8.2	51.2		14.8			0				0.0				166
1/1200 22:59	1/1200 23:06	7.2	44.1	881.1	17.7	41	39	4:29:49	3	7.2	44.5		22.0			0				0.0				166
1/1300 0:57	1/1300 1:01	4.8	26.9	881.3	24.1	42	39	6:24:40	4	4.8	28.9		26.8			1	4.8	28.9		4.8				166
1/1300 2:54	1/1300 2:57	3.7	23.8	879.4	30.9	42	39	8:18:32	5	3.7	21.2		30.5			2	3.7	21.2		8.5				166
1/1300 4:49	1/1300 4:55	5.5	30.9	863.8	36.3	42	39	10:11:06	6	5.5	33.4		36.0			3	5.5	33.4		14.0				166
1/1300 6:45	1/1300 6:53	7.7	57.5	878.4	38.8	42	39	12:04:00	7	7.7	43.7		47.9			4	7.7	47.9		21.7				166
1/1300 8:43	1/1300 8:51	7.8	62.9	870.7	37.5	42	39	13:58:50	8	7.8	49.0		51.5			5	7.8	49.0		29.5				166
1/1300 10:44	1/1300 10:49	5.2	27.7	876.7	32.6	42	39	15:56:07	9	5.2	31.2		56.7			6	5.2	31.2	6	34.7	34.67	211.5	146.92	166
1/1300 18:47	1/1300 18:51	4.5	25.7	878.8	10.6	42	39	23:46:12	10	4.5	26.7	10	61.2	61.18	375.2	0				0.0				166
1/1300 20:44	1/1300 20:52	7.7	57.2	870.9	11.3	42	40	1:40:43	1	7.7	47.9		7.7			0								166
1/1300 22:43	1/1300 22:50	7.7	62.6	865.7	15.0	42	40	3:35:43	2	7.7	47.9		15.3			0				0.0				166
1/1400 0:41	1/1400 0:47	6.0	32.5	878.6	20.9	43	40	5:30:34	3	6.0	36.7		21.3			1	6.0	36.7		6.0				166
1/1400 2:38	1/1400 2:42	3.8	24.0	877.2	27.6	43	40	7:25:05	4	3.8	22.2		25.2			2	3.8	22.2		9.8				166
1/1400 4:34	1/1400 4:39	4.7	26.1	881.0	34.0	43	40	9:17:58	5	4.7	27.8		29.8			3	4.7	27.8		14.5				166
1/1400 6:30	1/1400 6:37	6.8	41.1	874.4	38.0	43	40	11:10:33	6	6.8	42.3		36.7			4	6.8	42.3		21.3				166
1/1400 8:27	1/1400 8:35	8.0	87.2	871.8	38.5	43	40	13:04:25	7	8.0	50.1		44.7			5	8.0	50.1		29.3				166
1/1400 10:26</																								

Rise	Set	Pass Duration [min.]	Max.El at linder [deg.]	Max.Range [km]	Max.Sun.El [deg.]	Day# [ET]	Sol #	LMST	Pass # that Sol	D/L Pass duration [min.]	D/L Volume [Mbit]/pass w/ 0.50 min.CMD interval/pass	Max # passes that Sol	Cume D/L comm time that sol [min.]	Total D/L comm time/sol [min.]	D/L Volume/sol [Mbit]	Pass # sun el > 20°	Pass dur. sun el > 20° [min.]	D/L Volume [Mbit]/pass w/ 0.50 min.CMD interval/pass [sun el > 20°]	Max # passes sun el > 20°	Cume D/L time sun el > 20° [min.]	D/L time/sol sun el > 20° [min.]	D/L Volume/sol, sun el > 20 deg. [Mbit]	D/L Volume/sol, 4 passes, 6 min/pass [Mbit]	Mars98 Orbiter Daily Science D/L volume [Mbits]
1/1600 23:52	1/1700 0:00	8.0	87.0	869.0	12.9	45	43	247:56	2	8.0	50.1		14.8			0				0.0				166
1/1700 1:50	1/1700 1:57	6.8	41.0	873.3	17.9	46	43	442:56	3	6.8	42.3		21.7			0				0.0				166
1/1700 3:48	1/1700 3:53	4.5	26.0	880.5	24.5	46	43	6:37:47	4	4.5	26.7		26.2			1	4.5	26.7		4.5				166
1/1700 5:45	1/1700 5:49	3.8	24.0	877.6	31.2	46	43	8:31:19	5	3.8	22.2		30.0			2	3.8	22.2		8.3				166
1/1700 7:41	1/1700 7:47	6.0	32.6	876.6	36.5	46	43	10:23:44	6	6.0	36.7		36.0			3	6.0	36.7		14.3				166
1/1700 9:37	1/1700 9:45	7.8	62.8	880.5	38.5	46	43	12:16:57	7	7.8	43.8		43.8			4	7.8	49.0		22.2				166
1/1700 11:35	1/1700 11:43	7.7	56.9	874.7	36.9	46	43	14:11:58	8	7.7	47.9		51.5			5	7.7	47.9		29.8				166
1/1700 13:36	1/1700 13:41	4.7	25.6	882.7	31.8	46	43	16:09:34	9	4.7	56.2		56.2			6	4.7	27.8	6	34.5	34.5	210.4	146.92	166
1/1700 21:38	1/1700 21:43	5.2	27.9	877.1	10.3	46	43	23:58:59	10	5.2	31.2	10	61.3	61.33	376.2	0				0.0				166
1/1700 23:36	1/1700 23:44	7.8	63.2	869.7	11.2	46	44	1:53:40	1	7.8	49.0		7.8			0								166
1/1800 1:34	1/1800 1:42	7.7	57.3	876.5	15.2	47	44	3:48:40	2	7.7	47.9		15.5			0				0.0				166
1/1800 3:32	1/1800 3:38	5.7	30.8	883.6	21.2	47	44	5:43:41	3	5.7	34.5		21.2			1	5.7	34.5		5.7				166
1/1800 5:30	1/1800 5:34	3.7	23.8	878.9	28.0	47	44	7:38:02	4	3.7	21.2		24.8			2	3.7	21.2		9.3				166
1/1800 7:26	1/1800 7:31	4.8	27.0	879.7	34.2	47	44	9:30:46	5	4.8	28.9		29.7			3	4.8	28.9		14.2				166
1/1800 9:21	1/1800 9:29	7.2	44.3	878.3	37.9	47	44	11:23:20	6	7.2	44.5		36.8			4	7.2	44.5		21.3				166
1/1800 11:19	1/1800 11:27	8.2	84.8	882.5	38.1	47	44	13:17:22	7	8.2	51.2		51.2			5	8.2	51.2		29.5				166
1/1800 13:18	1/1800 13:25	6.7	36.4	882.3	34.5	47	44	15:13:40	8	6.7	41.2		51.7			6	6.7	41.2	6	36.2	36.18	221.6	146.92	166
1/1800 21:23	1/1800 21:24	1.2	20.3	881.5	10.9	47	44	23:05:52	9	1.2	4.5	9	52.9	52.85	322.9	0				0.0				166
1/1800 23:20	1/1800 23:27	7.0	42.0	875.3	10.3	47	45	0:59:34	1	7.0	43.4		7.0			0								166
1/1900 1:18	1/1900 1:26	8.0	83.3	868.9	12.9	48	45	2:54:25	2	8.0	50.1		15.0			0				0.0				166
1/1900 3:16	1/1900 3:23	6.7	39.6	870.9	18.1	48	45	4:49:25	3	6.7	41.2		21.7			0				0.0				166
1/1900 5:14	1/1900 5:19	4.3	25.6	876.1	24.7	48	45	6:44:15	4	4.3	25.6		26.0			1	4.3	25.6		4.3				166
1/1900 7:11	1/1900 7:15	3.8	24.2	878.3	31.3	48	45	8:37:48	5	3.8	22.2		29.8			2	3.8	22.2		8.2				166
1/1900 9:06	1/1900 9:12	6.2	33.5	884.2	36.5	48	45	10:30:03	6	6.2	37.9		36.0			3	6.2	37.9		14.3				166
1/1900 11:03	1/1900 11:11	7.8	65.7	874.7	38.4	48	45	12:23:26	7	7.8	49.0		43.8			4	7.8	49.0		22.2				166
1/1900 13:01	1/1900 13:09	7.7	54.2	881.0	36.6	48	45	14:18:36	8	7.7	47.9		51.5			5	7.7	47.9		29.8				166
1/1900 15:02	1/1900 15:06	4.2	24.7	880.2	31.3	48	45	16:16:22	9	4.2	24.5	9	56.7	56.67	341.7	6	4.2	24.5	6	34.0	34	207.0	146.92	166
1/1900 23:04	1/1900 23:10	5.5	29.0	881.0	10.1	48	46	0:05:28	1	5.5	33.4		5.5			0								166
12000 1:02	12000 1:10	8.0	66.5	881.0	11.2	49	46	2:00:09	2	8.0	50.1		13.5			0				0.0				166
12000 3:00	12000 3:08	7.7	54.8	883.2	15.3	49	46	3:55:09	3	7.7	47.9		21.2			0				0.0				166
12000 4:58	12000 5:04	5.5	30.1	877.5	21.3	49	46	5:50:09	4	5.5	33.4		26.7			1	5.5	33.4		5.5				166
12000 6:56	12000 6:59	3.7	23.7	880.2	28.1	49	46	7:44:21	5	3.7	21.2		30.3			2	3.7	21.2		9.2				166
12000 8:51	12000 8:56	5.0	27.5	878.5	34.3	49	46	9:37:05	6	5.0	30.1		36.3			3	5.0	30.1		14.2				166
12000 10:47	12000 10:54	7.2	46.0	873.2	37.9	49	46	11:29:49	7	7.2	44.5		42.5			4	7.2	44.5		21.3				166
12000 12:45	12000 12:53	8.0	81.4	871.8	37.8	49	46	13:24:01	8	8.0	50.1		50.5			5	8.0	50.1		29.3				166
12000 14:44	12000 14:51	6.5	34.8	885.8	34.1	49	46	15:20:19	9	6.5	40.1		57.0			6	6.5	40.1	6	35.8	35.84	219.3	146.92	166
12000 22:49	12000 22:51	2.2	21.1	881.2	10.7	49	46	23:12:01	10	2.2	11.2	10	59.2	59.18	361.8	0				0.0				166
12100 0:46	12100 0:53	7.2	44.0	877.2	10.1	50	47	1:06:03	1	7.2	44.5		7.2			0								166
12100 2:44	12100 2:52	8.0	79.7	874.7	12.9	50	47	3:00:53	2	8.0	50.1		15.2			0				0.0				166
12100 4:42	12100 4:49	6.7	38.3	875.5	18.2	50	47	4:55:53	3	6.7	41.2		21.8			0				0.0				166
12100 6:40	12100 6:44	4.2	25.3	871.9	24.8	50	47	6:50:44	4	4.2	24.5		26.0			1	4.2	24.5		4.2				166
12100 8:37	12100 8:41	4.0	24.4	880.3	31.5	50	47	8:44:07	5	4.0	23.4		30.0			2	4.0	23.4		8.2				166
12100 10:32	12100 10:38	6.2	34.5	870.1	36.5	50	47	10:36:32	6	6.2	37.9		36.2			3	6.2	37.9		14.3				166
12100 12:29	12100 12:36	7.8	68.8	868.8	38.2	50	47	12:29:55	7	7.8	49.0		44.0			4	7.8	49.0		22.2				166
12100 14:27	12100 14:35	7.7	51.6	883.9	36.2	50	47	14:25:05	8	7.7	47.9		51.7			5	7.7	47.9		29.8				166
12100 16:28	12100 16:32	3.8	23.7	879.9	30.8	50	47	16:23:10	9	3.8	22.2	9	55.5	55.51	340.7	6	3.8	22.2	6	33.7	33.67	204.8	146.92	166
12200 0:30	12200 0:36	5.7	30.3	873.9	9.9	51	48	0:11:57	1	5.7	34.5		5.7			0								166
12200 2:28	12200 2:36	8.0	69.8	879.5	11.1	51	48	2:06:37	2	8.0	50.1		13.7			0				0.0				166
12200 4:26	12200 4:33	7.5	52.5	878.7	15.4	51	48	4:01:38	3	7.5	46.7		21.2			0				0.0				166
12200 6:24	12200 6:29	5.3	29.4	872.1	21.5	51	48	5:56:38	4	5.3	32.3		26.5			1	5.3	32.3		5.3				166
12200 8:21	12200 8:25	3.7	23.6	878.6	28.3	51	48	7:50:50	5	3.7	21.2		30.2			2	3.7	21.2		9.0				166
12200 10:17	12200 10:22	5.2	28.0	881.9	34.3	51	48	9:43:24	6	5.2	31.2		36.3			3	5.2	31.2		14.2				166
12200 12:13	12200 12:20	7.3	47.9	880.9	37.8	51	48	11:36:08	7	7.3	45.6		42.7			4	7.3	45.6		21.5				166
12200 14:10	12200 14:18	8.0	77.8	869.7	37.6	51	48	13:30:29	8	8.0	50.1		50.7			5	8.0	50.1		29.5				166
12200 16:10	12200 16:16	6.2	33.3	875.6	33.7	51	48	15:27:07	9	6.2	37.9		56.8			6	6.2	37.9	6	35.7	35.67	218.2	146.92	166
12300 0:14	12300 0:17	2.8	21.8	882.7	10.4	52	48	23:18:20	10	2.8	15.6	10	59.7	59.67	365.1	0				0.0				166
12300 2:12	12300 2:19	7.3	46.2	880.5	10.0	52	49	1:12:31	1	7.3	45.6		7.3			0								166
12300 4:10	12300 4:18	8.0	76.2	880.5	12.9	52	49	3:07:22	2	8.0	50.1		15.3			0				0.0				166
12300 6:08	12300 6:14	6.5	37.0	879.8	18.3	52	49	5:02:22	3	6.5	40.1		21.8			0				0.0				166
12300 8:06	12300 8:10	4.2	25.0	881.5	25.0	52	49	6:57:03	4	4.2	24.5		26.0			1	4.2	24.5		4.2				166
12300 10:02	12300 10:06	4.0	24.6	878.7	31.6	52	49	8:50:26	5</															

Rise	Set	Pass Duration [min.]	Max.El at lندر [deg.]	Max.Range [km]	Max.Sun.El [deg.]	Day # [ET]	Sol #	LMST	Pass # that Sol	D/L Pass duration [min.]	D/L Volume [Mbit]/pass w/ 0.50 min. CMD interval/pass	Max # passes that Sol	Cume D/L comm time that sol [min.]	Total D/L comm time/sol [min.]	D/L Volume/sol [Mbit]	Pass # sun el > 20°	Pass dur. sun el > 20° [min.]	D/L Volume [Mbit]/pass w/ 0.50 min. CMD interval/pass [sun el > 20°]	Max # passes sun el > 20°	Cume D/L time sun el > 20° [min.]	D/L time/sol sun el > 20° [min.]	D/L Volume/sol, sun el > 20 deg. [Mbit]	D/L Volume/sol, 4 passes, 6 min/pass [Mbit]	Mars98 Orbiter Daily Science D/L volume [Mbits]	
1/2500 1324	1/2500 1330	6.3	36.7	865.0	36.4	54	51	1049:19	6	6.3	38.9		36.2			3	6.3	38.9		14.5				168	
1/2500 1520	1/2500 1528	7.8	75.2	859.1	37.8	54	51	1242:52	7	7.8	49.0		44.0			4	7.8	49.0		22.3				168	
1/2500 1719	1/2500 1726	7.3	46.7	872.2	35.5	54	51	1438:21	8	7.3	45.6		51.3			5	7.3	45.6		29.7				168	
1/2500 1921	1/2500 1924	2.8	22.0	879.3	29.8	54	51	1636:56	9	2.8	15.6	9	54.2	54.15	331.6	6	2.8	15.6	6	32.5	32.49		196.9	146.92	168
1/2600 322	1/2600 328	6.2	32.9	878.2	9.5	55	52	0245:4	1	6.2	37.9		6.2			0				0.0				168	
1/2600 520	1/2600 528	8.0	76.9	875.4	11.1	55	52	2194:4	2	8.0	50.1		14.2			0				0.0				168	
1/2600 718	1/2600 725	7.3	48.4	881.7	15.5	55	52	4144:5	3	7.3	45.6		21.5			0				0.0				168	
1/2600 916	1/2600 921	5.2	28.1	880.8	21.8	55	52	6093:5	4	5.2	31.2		26.7			1	5.2	31.2		5.2				168	
1/2600 1113	1/2600 1117	3.7	23.6	878.4	28.6	55	52	8033:7	5	3.7	21.2		30.3			2	3.7	21.2		8.8				168	
1/2600 1309	1/2600 1314	5.3	29.2	873.1	34.4	55	52	956:12	6	5.3	32.3		36.7			3	5.3	32.3		14.2				168	
1/2600 1505	1/2600 1512	7.3	52.0	862.7	37.6	55	52	1149:05	7	7.3	45.6		43.0			4	7.3	45.6		21.5				168	
1/2600 1702	1/2600 1710	7.8	70.6	862.2	37.0	55	52	1343:36	8	7.8	49.0		50.8			5	7.8	49.0		29.3				168	
1/2600 1902	1/2600 1908	5.8	30.6	882.7	32.8	55	52	1540:24	9	5.8	35.6		56.7			6	5.8	35.6	6	35.2	35.16	214.8	146.92	168	
1/2700 306	1/2700 310	3.7	23.5	876.5	9.8	56	52	2331:07	10	3.7	21.2	10	60.3	60.33	369.5	0				0.0				168	
1/2700 503	1/2700 511	7.5	50.9	872.9	9.8	56	53	125:29	1	7.5	46.7		7.5			0								168	
1/2700 702	1/2700 709	7.8	69.5	864.2	13.0	56	53	320:29	2	7.8	49.0		15.3			0				0.0				168	
1/2700 900	1/2700 906	6.2	34.8	869.4	18.5	56	53	515:29	3	6.2	37.9		21.5			0				0.0				168	
1/2700 1057	1/2700 1101	4.0	24.5	879.0	25.2	56	53	710:00	4	4.0	23.4		25.5			1	4.0	23.4		4.0				168	
1/2700 1254	1/2700 1258	4.2	25.2	872.7	31.8	56	53	903:14	5	4.2	24.5		29.7			2	4.2	24.5		8.2				168	
1/2700 1449	1/2700 1456	6.7	38.0	879.5	36.4	56	53	1055:38	6	6.7	41.2		36.3			3	6.7	41.2		14.8				168	
1/2700 1646	1/2700 1654	8.0	78.7	879.6	37.6	56	53	1249:21	7	8.0	50.1		44.3			4	8.0	50.1		22.8				168	
1/2700 1845	1/2700 1852	7.2	44.5	868.7	35.1	56	53	1445:00	8	7.2	44.5		51.5			5	7.2	44.5		30.0				168	
1/2700 2047	1/2700 2049	2.3	21.3	882.3	29.3	56	53	1643:44	9	2.3	12.2	9	53.8	53.84	329.5	6	2.3	12.2	6	32.3	32.34	195.9	146.92	168	
1/2800 447	1/2800 454	6.3	34.4	873.3	9.3	57	54	031:23	1	6.3	38.9		6.3			0								168	
1/2800 645	1/2800 653	8.0	80.6	867.0	11.0	57	54	226:13	2	8.0	50.1		14.3			0				0.0				168	
1/2800 844	1/2800 851	7.2	46.5	868.7	15.6	57	54	421:13	3	7.2	44.5		21.5			0				0.0				168	
1/2800 1042	1/2800 1047	5.0	27.6	876.1	21.9	57	54	616:04	4	5.0	30.1		26.5			1	5.0	30.1		5.0				168	
1/2800 1239	1/2800 1242	3.7	23.7	880.8	28.7	57	54	810:06	5	3.7	21.2		30.2			2	3.7	21.2		8.7				168	
1/2800 1434	1/2800 1440	5.5	29.9	878.5	34.4	57	54	1020:30	6	5.5	33.4		36.7			3	5.5	33.4		14.2				168	
1/2800 1630	1/2800 1638	7.7	54.3	881.7	37.4	57	54	1155:24	7	7.7	47.9		43.3			4	7.7	47.9		21.8				168	
1/2800 1828	1/2800 1836	8.0	67.3	879.1	36.7	57	54	1350:05	8	8.0	50.1		51.3			5	8.0	50.1		29.8				168	
1/2800 2028	1/2800 2034	5.5	29.3	877.1	32.3	57	54	1547:12	9	5.5	33.4		56.8			6	5.5	33.4	6	35.3	35.34	216.0	146.92	168	
1/2900 432	1/2900 436	4.0	24.4	874.5	9.6	58	54	2337:36	10	4.0	23.4	10	60.8	60.84	372.9	0				0.0				168	
1/2900 629	1/2900 637	7.7	53.5	876.7	9.7	58	55	131:57	1	7.7	47.9		7.7			0								168	
1/2900 827	1/2900 835	7.8	66.4	869.8	13.0	58	55	326:58	2	7.8	49.0		15.5			0				0.0				168	
1/2900 1026	1/2900 1032	6.2	33.8	883.5	18.6	58	55	521:58	3	6.2	37.9		21.7			0				0.0				168	
1/2900 1223	1/2900 1227	3.8	24.2	877.1	25.3	58	55	716:29	4	3.8	22.2		25.5			1	3.8	22.2		3.8				168	
1/2900 1419	1/2900 1424	4.3	25.6	877.0	31.8	58	55	909:33	5	4.3	25.6		29.8			2	4.3	25.6		8.2				168	
1/2900 1615	1/2900 1622	6.7	39.3	875.0	36.3	58	55	1102:07	6	6.7	41.2		36.5			3	6.7	41.2		14.8				168	
1/2900 1812	1/2900 1820	8.0	82.4	873.8	37.4	58	55	1255:49	7	8.0	50.1		44.5			4	8.0	50.1		22.8				168	
1/2900 2011	1/2900 2018	7.0	42.4	866.6	34.7	58	55	1451:38	8	7.0	43.4		51.5			5	7.0	43.4		29.8				168	
1/2900 2213	1/2900 2215	1.3	20.5	879.4	28.8	58	55	1650:52	9	1.3	5.5	9	52.8	52.83	322.8	6	1.3	5.5	6	31.2	31.16	188.1	146.92	168	
1/3000 613	1/3000 620	6.5	36.0	874.1	9.1	59	56	037:51	1	6.5	40.1		6.5			0								168	
1/3000 811	1/3000 819	8.0	84.2	872.5	11.0	59	56	232:42	2	8.0	50.1		14.5			0				0.0				168	
1/3000 1009	1/3000 1017	7.2	44.7	876.4	15.6	59	56	427:42	3	7.2	44.5		21.7			0				0.0				168	
1/3000 1207	1/3000 1212	4.8	27.1	877.3	22.0	59	56	622:33	4	4.8	28.9		26.5			1	4.8	28.9		4.8				168	
1/3000 1404	1/3000 1408	3.7	23.7	878.9	28.8	59	56	816:25	5	3.7	21.2		30.2			2	3.7	21.2		8.5				168	
1/3000 1600	1/3000 1606	5.5	30.7	867.5	34.4	59	56	1008:59	6	5.5	33.4		36.7			3	5.5	33.4		14.0				168	
1/3000 1756	1/3000 1804	7.7	56.7	874.7	37.2	59	56	1201:53	7	7.7	47.9		43.3			4	7.7	47.9		21.7				168	
1/3000 1954	1/3000 2002	7.8	64.0	874.3	36.3	59	56	1356:43	8	7.8	49.0		51.2			5	7.8	49.0		29.5				168	
1/3000 2154	1/3000 2200	5.3	28.1	881.5	31.8	59	56	1553:50	9	5.3	32.3		56.5			6	5.3	32.3	6	34.8	34.83	212.6	146.92	168	
1/3100 557	1/3100 602	4.5	25.4	880.5	9.3	60	56	2343:55	10	4.5	26.7	10	61.0	61	374.0	0				0.0				95	
1/3100 755	1/3100 803	7.8	56.2	882.2	9.6	60	57	138:26	1	7.8	49.0		7.8			0								95	
1/3100 953	1/3100 1001	7.8	63.5	875.7	13.0	60	57	333:26	2	7.8	49.0		15.7			0				0.0				95	
1/3100 1151	1/3100 1157	6.0	32.8	875.8	18.7	60	57	528:27	3	6.0	36.7		21.7			0				0.0				95	
1/3100 1349	1/3100 1353	3.8	24.1	877.3	25.5	60	57	722:58	4	3.8	22.2		25.5			1	3.8	22.2		3.8				95	
1/3100 1545	1/3100 1550	4.5	25.9	881.4	31.9	60	57	915:51	5	4.5	26.7		30.0			2	4.5	26.7		8.3				95	
1/3100 1741	1/3100 1748	6.8	40.6	873.3	36.2	60	57	1108:26	6	6.8	42.3		36.8			3	6.8	42.3		15.2				95	
1/3100 1938	1/3100 1946	8.0	86.1	868.0	37.1	60	57	1302:18	7	8.0	50.1		44.8			4	8.0	50.1		23.2				95	
1/3100 2137	1/3100 2144	6.8	40.5	866.0	34.2	60	57	1458:17	8	6.8	42.3	8	51.7	51.65	318.2	5	6.8	42.3	5	30.0	29.99	183.6	146.92	95	
2100 739	2100 746	6.7	37.7	875.4	8.9	61	58	044:20	1	6.7	41.2		6.7		</										

Rise	Set	Pass Duration [min.]	Max.El at linder [deg.]	Max.Range [km]	Max(Sun.El) [de.g]	Day# [ET]	Sol #	LMST	Pass # that Sol	D/L Pass duration [min.]	D/L Volume [Mbit]/pass w/ 0.50 min.CMD interval/pass	Max # passes that Sol	Cume D/L comm time that sol [min.]	Total D/L comm time/sol [min.]	D/L Volume/sol [Mbit]	Pass # sun el > 20°	Pass dur. sun el > 20° [min.]	D/L Volume [Mbit]/pass w/ 0.50 min.CMD interval/pass [sun el > 20°]	Max # passes sun el > 20°	Cume D/L time sun el > 20° [min.]	D/L time/sol sun el > 20° [min.]	D/L Volume/sol, sun el > 20 deg. [Mbit]	D/L Volume/sol, 4 passes, 6 min/pass [Mbit]	Mars98 Orbiter Daily Science D/L volume [Mbits]
2300 1301	2300 1308	6.8	41.5	874.4	15.7	63	60	4:40:49	3	6.8	42.3		21.7			0				0.0				95
2300 1459	2300 1504	4.7	26.2	880.0	22.2	63	60	6:35:30	4	4.7	27.8		26.3			1	4.7	27.8		4.7				95
2300 1656	2300 1700	3.8	24.0	878.0	28.9	63	60	8:29:12	5	3.8	22.2		30.2			2	3.8	22.2		8.5				95
2300 1851	2300 1857	5.8	32.3	876.9	34.4	63	60	10:21:37	6	5.8	36.6		36.0			3	5.8	36.6		14.3				95
2300 2048	2300 2055	7.7	61.9	863.5	36.8	63	60	12:14:50	7	7.7	47.9		43.7			4	7.7	47.9		22.0				95
2300 2246	2300 2254	7.7	57.9	865.3	35.6	63	60	14:09:51	8	7.7	47.9		51.3			5	7.7	47.9		29.7				95
2400 0047	2400 0051	4.5	26.0	870.2	30.7	64	60	16:07:27	9	4.5	26.7		55.8			6	4.5	26.7	6	34.2	34.17	208.2	146.92	95
2400 0849	2400 0854	5.0	27.5	874.2	8.7	64	60	23:56:52	10	5.0	60.8	10	60.8	60.83	372.8	0				0.0				95
2400 1047	2400 1055	7.8	62.2	877.7	9.3	64	61	1:51:33	1	7.8	49.0		7.8			0								95
2400 1245	2400 1253	7.7	58.1	880.2	13.0	64	61	3:46:33	2	7.7	47.9		15.5			0				0.0				95
2400 1443	2400 1449	5.8	31.1	883.2	18.9	64	61	5:41:24	3	5.8	35.6		21.3			0				0.0				95
2400 1641	2400 1644	3.7	23.8	879.3	25.7	64	61	7:35:55	4	3.7	21.2		25.0			1	3.7	21.2		3.7				95
2400 1837	2400 1841	4.7	26.8	873.4	32.0	64	61	9:28:39	5	4.7	27.8		29.7			2	4.7	27.8		8.3				95
2400 2032	2400 2039	7.0	43.7	874.4	36.0	64	61	11:21:13	6	7.0	43.4		36.7			3	7.0	43.4		15.3				95
2400 2229	2400 2237	8.0	86.2	874.3	36.5	64	61	13:15:15	7	8.0	50.1		44.7			4	8.0	50.1		23.3				95
2500 0029	2500 0035	6.5	36.9	869.0	33.3	65	61	15:11:33	8	6.5	40.1		51.2			5	6.5	40.1	5	29.8	29.84	182.6	146.92	95
2500 0834	2500 0835	0.7	20.1	882.2	9.4	65	61	23:03:54	9	0.7	1.1	9	51.8	51.84	316.1	0				0.0				95
2500 1031	2500 1038	7.0	41.3	879.5	8.4	65	62	0:57:17	1	7.0	43.4		7.0			0								95
2500 1229	2500 1237	8.0	84.5	872.6	10.8	65	62	2:52:18	2	8.0	50.1		15.0			0				0.0				95
2500 1427	2500 1434	6.7	40.1	864.2	15.8	65	62	4:47:18	3	6.7	41.2		21.7			0				0.0				95
2500 1625	2500 1629	4.5	25.8	879.1	22.3	65	62	6:41:59	4	4.5	26.7		26.2			1	4.5	26.7		4.5				95
2500 1822	2500 1826	3.8	24.1	880.6	29.0	65	62	8:35:41	5	3.8	22.2		30.0			2	3.8	22.2		8.3				95
2500 2017	2500 2023	6.2	33.2	884.2	34.4	65	62	10:27:56	6	6.2	37.9		36.2			3	6.2	37.9		14.5				95
2500 2214	2500 2221	7.7	64.8	859.3	36.6	65	62	12:21:19	7	7.7	47.9		43.8			4	7.7	47.9		22.2				95
2600 0012	2600 0019	7.7	55.1	880.5	35.2	66	62	14:16:19	8	7.7	47.9		51.5			5	7.7	47.9		29.8				95
2600 0213	2600 0217	4.3	25.0	882.6	30.2	66	62	16:14:05	9	4.3	25.6	9	55.8	55.84	342.9	6	4.3	25.6	6	34.2	34.17	208.2	146.92	95
2600 1015	2600 1020	5.3	28.6	875.7	8.4	66	63	0:03:21	1	5.3	32.3		5.3			0								95
2600 1213	2600 1221	7.8	65.3	867.0	9.2	66	63	1:58:02	2	7.8	49.0		13.2			0				0.0				95
2600 1411	2600 1418	7.5	55.6	865.5	13.0	66	63	3:53:02	3	7.5	46.7		20.7			0				0.0				95
2600 1609	2600 1615	5.5	30.3	877.0	19.0	66	63	5:48:02	4	5.5	33.4		26.2			0				0.0				95
2600 1806	2600 1810	3.7	23.7	878.7	25.7	66	63	7:42:14	5	3.7	21.2		29.8			1	3.7	21.2		3.7				95
2600 2002	2600 2007	4.8	27.3	877.7	32.0	66	63	9:34:58	6	4.8	28.9		34.7			2	4.8	28.9		8.5				95
2600 2158	2600 2205	7.2	45.4	880.4	35.9	66	63	11:27:42	7	7.2	44.5		41.8			3	7.2	44.5		15.7				95
2600 2355	2700 0003	8.2	82.3	881.1	36.2	66	63	13:21:44	8	8.2	51.2		50.0			4	8.2	51.2		23.8				95
2700 1000	2700 2001	6.5	35.3	881.1	32.8	67	63	15:18:12	9	6.5	40.1		55.5			5	6.5	40.1	5	30.3	30.34	185.9	146.92	95
2700 1000	2700 1001	1.7	20.8	877.2	9.1	67	63	23:10:03	10	1.7	7.8	10	58.2	58.17	355.1	0				0.0				95
2700 1157	2700 1204	7.0	43.3	865.1	8.2	67	64	1:03:56	1	7.0	43.4		7.0			0								95
2700 1355	2700 1403	8.0	80.9	870.1	10.7	67	64	2:58:46	2	8.0	50.1		15.0			0				0.0				95
2700 1553	2700 1600	6.7	38.7	875.3	15.8	67	64	4:53:46	3	6.7	41.2		21.7			0				0.0				95
2700 1751	2700 1755	4.3	25.4	879.0	22.4	67	64	6:48:27	4	4.3	26.0		25.6			1	4.3	25.6		4.3				95
2700 1947	2700 1951	3.8	24.3	874.1	29.1	67	64	8:42:00	5	3.8	22.2		29.8			2	3.8	22.2		8.2				95
2700 2143	2700 2149	6.2	34.2	875.0	34.3	67	64	10:34:25	6	6.2	37.9		36.0			3	6.2	37.9		14.3				95
2700 2339	2700 2347	8.0	67.8	884.2	36.4	67	64	12:27:38	7	8.0	50.1		44.0			4	8.0	50.1		22.3				95
2800 1038	2800 1045	7.5	52.4	872.0	34.7	68	64	14:22:58	8	7.5	46.7		51.5			5	7.5	46.7		29.8				95
2800 1339	2800 1343	4.0	24.0	881.4	29.6	68	64	16:20:53	9	4.0	23.4	9	55.5	55.5	340.6	6	4.0	23.4	6	33.8	33.83	205.9	146.92	95
2800 1141	2800 1146	5.7	29.8	885.5	8.1	68	65	0:09:50	1	5.7	34.5		5.7			0								95
2800 1339	2800 1347	8.0	68.7	878.4	9.0	68	65	2:04:30	2	8.0	50.1		13.7			0				0.0				95
2800 1537	2800 1544	7.5	53.3	871.2	13.0	68	65	3:59:31	3	7.5	46.7		21.2			0				0.0				95
2800 1735	2800 1740	5.3	29.6	871.5	19.0	68	65	5:54:31	4	5.3	32.3		26.5			0				0.0				95
2800 1932	2800 1936	3.7	23.6	879.4	25.8	68	65	7:48:43	5	3.7	21.2		30.2			1	3.7	21.2		3.7				95
2800 2128	2800 2133	5.2	27.8	882.5	32.0	68	65	9:41:17	6	5.2	31.2		35.3			2	5.2	31.2		8.8				95
2800 2324	2800 2331	7.3	47.3	878.6	35.7	68	65	11:34:01	7	7.3	45.6		42.7			3	7.3	45.6		16.2				95
2900 1000	2900 1000	8.0	79.0	874.2	35.9	69	65	13:28:22	8	8.0	50.1		50.7			4	8.0	50.1		24.2				95
2900 1200	2900 1200	6.3	33.8	880.3	32.3	69	65	15:24:50	9	6.3	38.9		57.0			5	6.3	38.9	5	30.5	30.5	187.0	146.92	95
2900 1125	2900 1128	2.7	21.6	883.4	8.7	69	65	23:16:13	10	2.7	14.5	10	59.7	59.67	365.1	0				0.0				95
2900 1323	2900 1330	7.2	45.4	867.7	8.0	69	66	1:10:24	1	7.2	44.5		7.2			0								95
2900 1521	2900 1529	8.0	77.4	872.5	10.7	69	66	3:05:15	2	8.0	50.1		15.2			0				0.0				95
2900 1719	2900 1725	6.5	37.4	873.4	15.8	69	66	5:00:15	3	6.5	40.1		21.7			0				0.0				95
2900 1917	2900 1921	4.2	25.1	878.5	22.4	69	66	6:54:56	4	4.2	24.5		25.8			1	4.2	24.5		4.2				95
2900 2113	2900 2117	4.0	24.6	878.9	29.1	69	66	8:48:19	5	4.0	23.4		29.8			2	4.0	23.4		8.2				95
2900 2309	2900 2315	6.3	35.2	878.5	34.2	69	66	10:40:44	6	6.3	38.9		36.2			3	6.3	38.9		14.5				95
21000 105	21000 113	8.0	71.0	882.2	36.1	70	66	12:34:07	7	8.0	50.1		44.2			4	8.0	50.1		22.5				92
21000 304	21000																							

Rise	Set	Pass Duration [min.]	Max.El at lander [deg]	Max.Range [km]	Max.Sun.El [deg]	Day # [ET]	Sol #	LMST	Pass # that Sol	DIL Pass duration [min.]	DIL Volume [Mbit]/pass w/ 0.50 min. CMD interval/pass	Max # passes that Sol	Cume DIL cmm time that sol [min.]	Total DIL cmm time/sol [min.]	DIL Volume/sol [Mbit]	Pass # sun el > 20'	Pass dur. sun el > 20' [min.]	DIL Volume [Mbit]/pass w/ 0.50 min. CMD interval/pass [sun el > 20']	Max # passes sun el > 20'	Cume DIL time sun el > 20' [min.]	DIL time/sol sun el > 20' [min.]	DIL Volume/sol, sun el > 20 deg [Mbit]	DIL Volume/sol, 4 passes, 6 min/pass [Mbit]	Mars98 Orbiter Daily Science DIL volume [Mbits]
21200 231	21200 239	8.0	74.2	881.4	35.8	72	68	124035	7	8.0	50.7	44.3	4	8.0	50.1	22.5								
21200 430	21200 437	7.5	47.5	885.5	33.8	72	68	143605	8	7.5	46.7	51.8	5	7.5	46.7	30.0								
21200 631	21200 634	3.0	22.3	878.8	28.5	72	68	163439	9	3.0	54.8	54.8	9	3.0	54.8	54.8	9	3.0	54.8	54.8	9	3.0	54.8	54.8
21200 1432	21200 1438	6.0	32.5	870.7	7.5	72	69	02247	1	6.0	36.7	6.0	1	6.0	36.7	6.0	1	6.0	36.7	6.0	1	6.0	36.7	6.0
21200 1630	21200 1638	8.0	75.5	894.5	8.7	72	69	21737	2	8.0	50.1	14.0	0	0	0	0	0	0	0	0	0	0	0	0
21200 1829	21200 1836	7.3	49.0	884.2	13.0	72	69	41238	3	7.3	45.6	21.3	0	0	0	0	0	0	0	0	0	0	0	0
21200 2027	21200 2032	5.2	28.3	880.2	19.1	72	69	60728	4	5.2	31.2	26.5	0	0	0	0	0	0	0	0	0	0	0	0
21200 2224	21200 2227	3.7	23.6	877.5	26.0	72	69	80130	5	3.7	21.2	30.2	1	3.7	21.2	30.2	1	3.7	21.2	30.2	1	3.7	21.2	30.2
21300 019	21300 025	5.3	29.0	877.7	31.9	73	69	95405	6	5.3	32.3	36.5	2	5.3	32.3	90.0	2	5.3	32.3	90.0	2	5.3	32.3	90.0
21300 215	21300 223	7.3	51.3	864.2	35.4	73	69	114658	7	7.3	45.6	42.8	3	7.3	45.6	16.3	3	7.3	45.6	16.3	3	7.3	45.6	16.3
21300 413	21300 421	8.0	71.8	880.5	35.1	73	69	134120	8	8.0	50.1	50.8	4	8.0	50.1	24.3	4	8.0	50.1	24.3	4	8.0	50.1	24.3
21300 613	21300 619	5.8	31.0	880.0	31.2	73	69	153817	9	5.8	35.6	56.7	5	5.8	35.6	30.2	5	5.8	35.6	30.2	5	5.8	35.6	30.2
21300 1417	21300 1420	3.5	23.2	876.0	7.9	73	69	232900	10	3.5	20.0	60.2	10	3.5	20.0	60.2	10	3.5	20.0	60.2	10	3.5	20.0	60.2
21300 1614	21300 1622	7.5	50.1	877.5	7.6	73	70	12322	1	7.5	46.7	7.5	0	7.5	46.7	7.5	0	7.5	46.7	7.5	0	7.5	46.7	7.5
21300 1812	21300 1820	7.8	70.6	869.6	10.5	73	70	31822	2	7.8	49.0	15.3	0	7.8	49.0	15.3	0	7.8	49.0	15.3	0	7.8	49.0	15.3
21300 2011	21300 2017	6.2	35.1	869.5	15.9	73	70	51322	3	6.2	37.9	21.5	0	6.2	37.9	21.5	0	6.2	37.9	21.5	0	6.2	37.9	21.5
21300 2208	21300 2212	4.0	24.5	876.4	22.6	73	70	70753	4	4.0	23.4	25.5	1	4.0	23.4	40	1	4.0	23.4	40	1	4.0	23.4	40
21400 005	21400 009	4.2	25.1	873.2	29.2	74	70	90107	5	4.2	24.5	29.7	2	4.2	24.5	82	2	4.2	24.5	82	2	4.2	24.5	82
21400 200	21400 207	6.5	37.5	874.3	34.0	74	70	105331	6	6.5	40.1	36.2	3	6.5	40.1	147	3	6.5	40.1	147	3	6.5	40.1	147
21400 357	21400 405	8.0	77.6	881.7	35.5	74	70	124704	7	8.0	50.1	44.2	4	8.0	50.1	227	4	8.0	50.1	227	4	8.0	50.1	227
21400 556	21400 603	7.3	45.2	881.2	33.4	74	70	144243	8	7.3	45.6	51.5	5	7.3	45.6	30.0	5	7.3	45.6	30.0	5	7.3	45.6	30.0
21400 758	21400 800	2.5	21.5	880.9	27.8	74	70	164127	9	2.5	13.4	54.0	9	54.0	330.6	6	2.5	13.4	6	32.5	32.5	197.0	146.92	92
21400 1558	21400 1604	6.2	33.9	868.6	7.1	74	71	02916	1	6.2	37.9	6.2	0	6.2	37.9	6.2	0	6.2	37.9	6.2	0	6.2	37.9	6.2
21400 1756	21400 1804	8.0	79.3	875.4	8.6	74	71	22406	2	8.0	50.1	14.2	0	8.0	50.1	0	0	8.0	50.1	0	0	8.0	50.1	0
21400 1954	21400 2002	7.2	47.1	867.8	13.0	74	71	41906	3	7.2	44.5	21.3	0	7.2	44.5	0	0	7.2	44.5	0	0	7.2	44.5	0
21400 2152	21400 2157	5.0	27.8	875.4	19.2	74	71	61357	4	5.0	30.1	26.3	0	5.0	30.1	0	0	5.0	30.1	0	0	5.0	30.1	0
21400 2350	21400 2353	3.5	23.6	871.7	26.0	74	71	80759	5	3.5	20.0	29.8	1	3.5	20.0	3.5	1	3.5	20.0	3.5	1	3.5	20.0	3.5
21500 145	21500 151	5.5	29.7	879.0	31.9	75	71	100023	6	5.5	33.4	35.3	2	5.5	33.4	9.0	2	5.5	33.4	9.0	2	5.5	33.4	9.0
21500 341	21500 349	7.5	53.5	878.4	35.1	75	71	115317	7	7.5	46.7	42.8	3	7.5	46.7	16.5	3	7.5	46.7	16.5	3	7.5	46.7	16.5
21500 539	21500 547	7.8	68.3	864.3	34.7	75	71	134758	8	7.8	49.0	50.7	4	7.8	49.0	24.3	4	7.8	49.0	24.3	4	7.8	49.0	24.3
21500 739	21500 745	5.7	29.7	880.7	30.7	75	71	154455	9	5.7	34.5	56.3	5	5.7	34.5	30.0	5	5.7	34.5	30.0	30	183.7	146.92	92
21500 1543	21500 1546	3.8	24.1	872.9	7.5	75	71	23529	10	3.8	22.2	60.2	10	60.2	368.4	0	0	60.2	368.4	0	0	60.2	368.4	0
21500 1740	21500 1748	7.7	52.6	884.8	7.4	75	72	12950	1	7.7	47.9	0	0	7.7	47.9	0	0	7.7	47.9	0	0	7.7	47.9	0
21500 1938	21500 1946	7.8	67.5	871.7	10.5	75	72	32451	2	7.8	49.0	15.5	0	7.8	49.0	0	0	7.8	49.0	0	0	7.8	49.0	0
21500 2136	21500 2143	6.2	34.1	883.5	15.9	75	72	51951	3	6.2	37.9	21.7	0	6.2	37.9	0	0	6.2	37.9	0	0	6.2	37.9	0
21500 2334	21500 2338	3.8	24.3	874.8	22.6	75	72	71422	4	3.8	22.2	25.5	1	3.8	22.2	3.8	1	3.8	22.2	3.8	1	3.8	22.2	3.8
21600 130	21600 135	4.3	25.4	877.5	29.2	76	72	90726	5	4.3	25.6	29.8	2	4.3	25.6	8.2	2	4.3	25.6	8.2	2	4.3	25.6	8.2
21600 326	21600 332	6.7	38.8	885.0	33.9	76	72	105950	6	6.7	41.2	36.5	3	6.7	41.2	14.8	3	6.7	41.2	14.8	3	6.7	41.2	14.8
21600 523	21600 531	8.0	80.9	883.2	35.2	76	72	125333	7	8.0	50.1	44.5	4	8.0	50.1	22.8	4	8.0	50.1	22.8	4	8.0	50.1	22.8
21600 722	21600 729	7.2	43.1	878.4	32.9	76	72	144921	8	7.2	44.5	51.7	5	7.2	44.5	30.0	5	7.2	44.5	30.0	5	7.2	44.5	30.0
21600 924	21600 926	1.8	20.8	881.8	27.2	76	72	164825	9	1.8	8.9	53.5	9	53.5	327.2	6	1.8	8.9	6	31.8	31.8	192.5	146.92	92
21600 1724	21600 1731	6.5	35.5	882.1	6.8	76	73	03544	1	6.5	40.1	6.5	0	6.5	40.1	0	0	6.5	40.1	0	0	6.5	40.1	0
21600 1922	21600 1930	8.0	83.1	867.5	8.5	76	73	23035	2	8.0	50.1	14.5	0	8.0	50.1	0	0	8.0	50.1	0	0	8.0	50.1	0
21600 2120	21600 2127	7.2	45.3	878.2	13.0	76	73	42535	3	7.2	44.5	21.7	0	7.2	44.5	0	0	7.2	44.5	0	0	7.2	44.5	0
21600 2318	21600 2323	4.8	27.2	873.2	19.2	76	73	62026	4	4.8	28.9	26.5	0	4.8	28.9	0	0	4.8	28.9	0	0	4.8	28.9	0
21700 115	21700 119	3.7	23.7	878.4	26.0	77	73	81418	5	3.7	21.2	30.2	1	3.7	21.2	3.7	1	3.7	21.2	3.7	1	3.7	21.2	3.7
21700 311	21700 316	5.5	30.4	872.7	31.8	77	73	100652	6	5.5	33.4	35.7	2	5.5	33.4	9.2	2	5.5	33.4	9.2	2	5.5	33.4	9.2
21700 507	21700 515	7.7	55.8	879.8	34.9	77	73	115946	7	7.7	47.9	43.3	3	7.7	47.9	16.8	3	7.7	47.9	16.8	3	7.7	47.9	16.8
21700 705	21700 713	7.8	65.1	877.4	34.3	77	73	135427	8	7.8	49.0	51.2	4	7.8	49.0	24.7	4	7.8	49.0	24.7	4	7.8	49.0	24.7
21700 905	21700 910	5.2	28.5	868.4	30.1	77	73	155143	9	5.2	31.2	56.3	5	5.2	31.2	29.8	5	5.2	31.2	29.8	29.84	182.6	146.92	92
21700 1708	21700 1713	4.3	25.1	878.7	7.2	77	73	234148	10	4.3	25.6	60.7	10	60.7	371.8	0	0	60.7	371.8	0	0	60.7	371.8	0
21700 1906	21700 1914	7.7	55.3	873.7	7.1	77	74	13619	1	7.7	47.9	7.7	0	7.7	47.9	0	0	7.7	47.9	0	0	7.7	47.9	0
21700 2104	21700 2112	7.8	64.5	874.8	10.4	77	74	33119	2	7.8	49.0	15.5	0	7.8	49.0	0	0	7.8	49.0	0	0	7.8	49.0	0
21700 2302	21700 2308	6.0	33.1	875.7	16.0	77	74	52620	3	6.0	36.7	21.5	0	6.0	36.7	0	0	6.0	36.7	0	0	6.0	36.7	0
21800 100	21800 104	3.8	24.1	877.4	22.7	78	74	72051	4	3.8	22.2	25.3	1	3.8	22.2	3.8	1	3.8	22.2	3.8	1	3.8	22.2	3.8
21800 256	21800 300	4.5	25.8	881.9	29.2	78	74																	

Rise	Set	Pass Duration [min.]	Max.El at linder [deg.]	Max.Range [km]	Max.Sun.El [deg.]	Day# [ET]	Sol #	LMST	Pass # that Sol	D/L Pass duration [min.]	D/L Volume [Mbit]/pass w/ 0.50 min. CMD interval/pass	Max # passes that Sol	Cume D/L comm time that sol [min.]	Total D/L comm time/sol [min.]	D/L Volume/sol [Mbit]	Pass # sun el > 20°	Pass dur. sun el > 20° [min.]	D/L Volume [Mbit]/pass w/ 0.50 min. CMD interval/pass [sun el > 20°]	Max # passes sun el > 20°	Cume D/L time sun el > 20° [min.]	D/L time/sol sun el > 20° [min.]	D/L Volume/sol, sun el > 20 deg. [Mbit]	D/L Volume/sol, 4 passes, 6 min/pass [Mbit]	Mars98 Orbiter Daily Science D/L volume [Mbits]
22100 0:12	22100 0:19	7.0	42.0	877.0	12.9	81	77	4:38:32	3	7.0	43.4		22.0			0				0.0				90
22100 2:10	22100 2:15	4.7	26.3	879.4	19.3	81	77	6:33:23	4	4.7	27.8		26.7			0				0.0				90
22100 4:07	22100 4:11	3.8	23.9	879.9	26.1	81	77	8:27:05	5	3.8	22.2		30.5			1	3.8	22.2		3.8				90
22100 6:02	22100 6:08	5.8	32.0	877.1	31.7	81	77	10:19:30	6	5.8	36.3		36.3			2	5.8	36.6		9.7				90
22100 7:59	22100 8:06	7.7	61.0	868.4	34.4	81	77	12:12:43	7	7.7	47.9		44.0			3	7.7	47.9		17.3				90
22100 9:57	22100 10:04	7.8	58.9	879.5	33.4	81	77	14:07:34	8	7.8	49.0		51.8			4	7.8	49.0		25.2				90
22100 11:57	22100 12:02	4.7	26.3	873.4	28.9	81	77	16:05:10	9	4.7	27.8		56.5			5	4.7	27.8		29.8			146.92	90
22100 20:00	22100 20:05	5.0	27.1	881.3	6.4	81	77	23:54:45	10	5.0	30.1	10	61.5	61.5	377.3	0			5	0.0	29.83	182.5		90
22100 21:58	22100 22:05	7.7	61.2	861.0	6.7	81	78	1:49:26	1	7.7	47.9		7.7			0								90
22100 23:56	22200 0:04	7.8	58.9	884.1	10.2	81	78	3:44:17	2	7.8	49.0		15.5			0				0.0				90
22200 1:54	22200 2:00	5.8	31.4	882.9	16.0	82	78	5:39:17	3	5.8	35.6		21.3			0				0.0				90
22200 3:51	22200 3:55	3.8	23.8	880.8	22.8	82	78	7:33:38	4	3.8	22.2		25.2			1	3.8	22.2		3.8				90
22200 5:47	22200 5:52	4.7	26.6	874.0	29.1	82	78	9:26:32	5	4.7	27.8		29.8			2	4.7	27.8		8.5				90
22200 7:43	22200 7:50	7.0	43.2	872.8	33.4	82	78	11:19:06	6	7.0	43.4		36.8			3	7.0	43.4		15.5				90
22200 9:40	22200 9:48	8.0	87.7	866.3	34.2	82	78	13:13:08	7	8.0	50.1		44.8			4	8.0	50.1		23.5				90
22200 11:40	22200 11:46	6.7	37.5	878.7	31.3	82	78	15:09:17	8	6.7	41.2	8	51.5	51.5	317.2	5	6.7	41.2	5	30.2	30.17	184.8	146.92	90
22200 21:42	22200 21:49	7.0	40.7	876.9	5.9	82	79	0:55:10	1	7.0	43.4		7.0			0								90
22200 23:40	22200 23:48	8.0	85.2	879.8	8.1	82	79	2:50:11	2	8.0	50.1		15.0			0				0.0				90
22300 1:38	22300 1:45	6.7	40.5	863.4	12.9	83	79	4:45:11	3	6.7	41.2		21.7			0				0.0				90
22300 3:36	22300 3:40	4.5	25.9	875.7	19.4	83	79	6:39:52	4	4.5	26.7		26.2			0				0.0				90
22300 5:33	22300 5:36	3.7	24.1	869.2	26.1	83	79	8:33:34	5	3.7	21.2		29.8			1	3.7	21.2		3.7				90
22300 7:28	22300 7:34	5.8	32.9	862.9	31.6	83	79	10:25:59	6	5.8	35.6		36.7			2	5.8	35.6		9.5				90
22300 9:24	22300 9:32	7.8	63.8	882.5	34.1	83	79	12:19:02	7	7.8	49.0		43.5			3	7.8	49.0		17.3				90
22300 11:23	22300 11:30	7.7	56.0	869.1	33.0	83	79	14:14:12	8	7.7	47.9		51.2			4	7.7	47.9		25.0				90
22300 13:24	22300 13:28	4.3	25.3	874.1	28.2	83	79	16:11:58	9	4.3	25.6	9	55.5	55.5	340.6	5	4.3	25.6	5	29.3	29.33	179.2	146.92	90
22300 21:26	22300 21:31	5.2	28.2	870.8	6.0	83	80	0:01:14	1	5.2	31.2		5.2			0								90
22300 23:24	22300 23:31	7.8	64.3	873.9	6.5	83	80	1:55:55	2	7.8	49.0		13.0			0				0.0				90
22400 1:22	22400 1:29	7.5	56.4	863.0	10.2	84	80	3:50:55	3	7.5	46.7		20.5			0				0.0				90
22400 3:20	22400 3:25	5.7	30.6	876.9	16.0	84	80	5:45:46	4	5.7	34.5		26.2			0				0.0				90
22400 5:17	22400 5:21	3.7	23.7	877.2	22.8	84	80	7:40:07	5	3.7	21.2		29.8			1	3.7	21.2		3.7				90
22400 7:13	22400 7:18	4.8	27.1	878.4	29.1	84	80	9:32:51	6	4.8	28.9		34.7			2	4.8	28.9		8.5				90
22400 9:09	22400 9:16	7.0	44.9	861.9	33.2	84	80	11:25:35	7	7.0	43.4		41.7			3	7.0	43.4		15.5				90
22400 11:06	22400 11:14	8.0	83.9	872.7	33.8	84	80	13:19:37	8	8.0	50.1		49.7			4	8.0	50.1		23.5				90
22400 13:06	22400 13:12	6.5	36.8	881.4	30.7	84	80	15:15:55	9	6.5	40.1		56.2			5	6.5	40.1	5	30.0	30	183.7	146.92	90
22400 21:11	22400 21:12	1.5	20.6	880.1	6.8	84	80	23:07:56	10	1.5	6.7	10	57.7	57.67	351.7	0				0.0				90
22400 23:07	22400 23:15	7.2	42.6	877.9	5.6	84	81	1:01:39	1	7.2	44.5		7.2			0								90
22500 1:06	22500 1:14	8.0	82.0	876.8	7.9	85	81	2:56:39	2	8.0	50.1		15.2			0				0.0				90
22500 3:04	22500 3:10	6.7	39.1	876.1	12.9	85	81	4:51:40	3	6.7	41.2		21.8			0				0.0				90
22500 5:02	22500 5:06	4.3	25.5	875.8	19.4	85	81	6:46:20	4	4.3	25.6		26.2			0				0.0				90
22500 6:58	22500 7:02	3.8	24.3	874.1	26.1	85	81	8:39:53	5	3.8	22.2		30.0			1	3.8	22.2		3.8				90
22500 8:54	22500 9:00	6.2	33.9	880.9	31.5	85	81	10:32:18	6	6.2	37.9		36.2			2	6.2	37.9		10.0				90
22500 10:50	22500 10:58	7.8	66.8	879.1	33.8	85	81	12:25:31	7	7.8	49.0		44.0			3	7.8	49.0		17.8				90
22500 12:48	22500 12:56	7.7	53.3	886.8	32.5	85	81	14:20:41	8	7.7	47.9		51.7			4	7.7	47.9		25.5				90
22500 14:50	22500 14:54	4.2	24.3	883.3	27.6	85	81	16:18:36	9	4.2	24.5	9	55.8	55.84	342.9	5	4.2	24.5	5	29.7	29.67	181.4	146.92	90
22500 22:52	22500 22:57	5.5	29.4	879.6	5.6	85	82	0:07:43	1	5.5	33.4		5.5			0								90
22600 0:49	22600 0:57	7.8	67.5	864.4	6.3	86	82	2:02:23	2	7.8	49.0		13.3			0				0.0				90
22600 2:48	22600 2:55	7.5	54.0	870.1	10.1	86	82	3:57:24	3	7.5	46.7		20.8			0				0.0				90
22600 4:46	22600 4:51	5.5	29.9	879.6	16.0	86	82	5:52:14	4	5.5	33.4		26.3			0				0.0				90
22600 6:43	22600 6:47	3.7	23.7	880.1	22.8	86	82	7:46:36	5	3.7	21.2		30.0			1	3.7	21.2		3.7				90
22600 8:39	22600 8:44	5.0	27.6	883.0	29.1	86	82	9:39:10	6	5.0	36.0		36.0			2	5.0	30.1		8.7				90
22600 10:35	22600 10:42	7.2	46.6	876.5	33.0	86	82	11:31:54	7	7.2	44.5		42.2			3	7.2	44.5		15.8				90
22600 12:32	22600 12:40	8.0	80.0	880.3	33.4	86	82	13:26:06	8	8.0	50.2		50.2			4	8.0	50.1		23.8				90
22600 14:32	22600 14:38	6.3	34.3	885.3	30.1	86	82	15:22:34	9	6.3	38.9		56.5			5	6.3	38.9	5	30.2	30.17	184.8	146.92	90
22600 22:36	22600 22:38	2.2	21.3	876.6	6.3	86	82	23:14:15	10	2.2	11.2		58.7	58.67	358.4	0				0.0				90
22700 0:33	22700 0:41	7.3	44.7	880.3	5.3	87	83	1:08:08	1	7.3	45.6		7.3			0								90
22700 2:31	22700 2:39	8.0	78.5	875.1	7.8	87	83	3:03:08	2	8.0	50.1		15.3			0				0.0				90
22700 4:30	22700 4:36	6.5	37.8	867.0	12.9	87	83	4:58:08	3	6.5	40.1		21.8			0				0.0				90
22700 6:27	22700 6:32	4.3	25.2	882.2	19.4	87	83	6:52:49	4	4.3	26.2		26.2			0				0.0				90
22700 8:24	22700 8:28	4.0	24.5	879.0	26.1	87	83	8:46:12	5	4.0	23.4		30.2			1		23.4		4.0				90
22700 10:19	22700 10:26	6.3	34.9	878.3	31.4	87	83	10:38:37	6	6.3	38.9		36.5			2	6.3	38.9		10.3				90
22700 12:16	22700 12:24	8.0	69.9	878.8	33.5	87	83	12:32:00	7	8.0	50.1		44.5			3	8.0	50.1		18.3				90
22700 14:14	22700 14:22	7.5	50.7	879.2	32.0	87	83	1																

Rise	Set	Pass Duration [min]	Max.El at lander [deg]	Max.Range [km]	MaxSun.El [de.g]	Day # [ET]	Sol #	LMST	Pass # that Sol	D/L Pass duration [min.]	D/L Volume [Mbit]/pass w/ 0.50 min. CMD interval/pass	Max # passes that Sol	Cume D/L comm time that sol [min.]	Total D/L comm time/sol [min.]	D/L Volume/sol [Mbit]	Pass # sun el > 20°	Pass dur. sun el > 20° [min.]	D/L Volume [Mbit]/pass w/ 0.50 min. CMD interval/pass [sun el > 20°]	Max # passes sun el > 20°	Cume D/L time sun el > 20° [min.]	D/L time/sol sun el > 20° [min.]	D/L Volume/sol, sun el > 20 deg. [Mbit]	D/L Volume/sol, 4 passes, 6 min/pass [Mbit]	Mars98 Orbiter Daily Science D/L volume [Mbits]
2/29/00 15:40	2/29/00 15:48	7.3	48.3	873.1	31.4	89	86	14:33:58	8	7.3	45.6		51.7			4	7.3	45.6		25.7				90
2/29/00 17:42	2/29/00 17:45	3.2	22.6	878.5	26.3	89	86	16:32:22	9	3.2	17.8	9	54.8	54.83	336.1	5	3.2	17.8	5	28.8	28.83	175.8	146.92	90

Totals

4860.9

29791

800

4861

29791

2926

17851

506

2926

17851

12635.27

Statistics: TOTAL RELAY OPPORTUNITIES

9.3	av passes/sol	56.5	av comm time/sol
7.0	min passes/sol	38.7	min comm time/sol
10.0	max passes/sol	61.5	max comm time/sol

6.1	av pass length
0.3	min pass length
8.2	max pass length

Statistics: RELAY OPPORTUNITIES at Solar Elevations > 20°

5.9	av passes/sol	34.0	av comm time/sol
5.0	min passes/sol	28.8	min comm time/sol
7.0	max passes/sol	40.2	max comm time/sol

5.8	av pass length
175.8	min pass length
244.8	max pass length

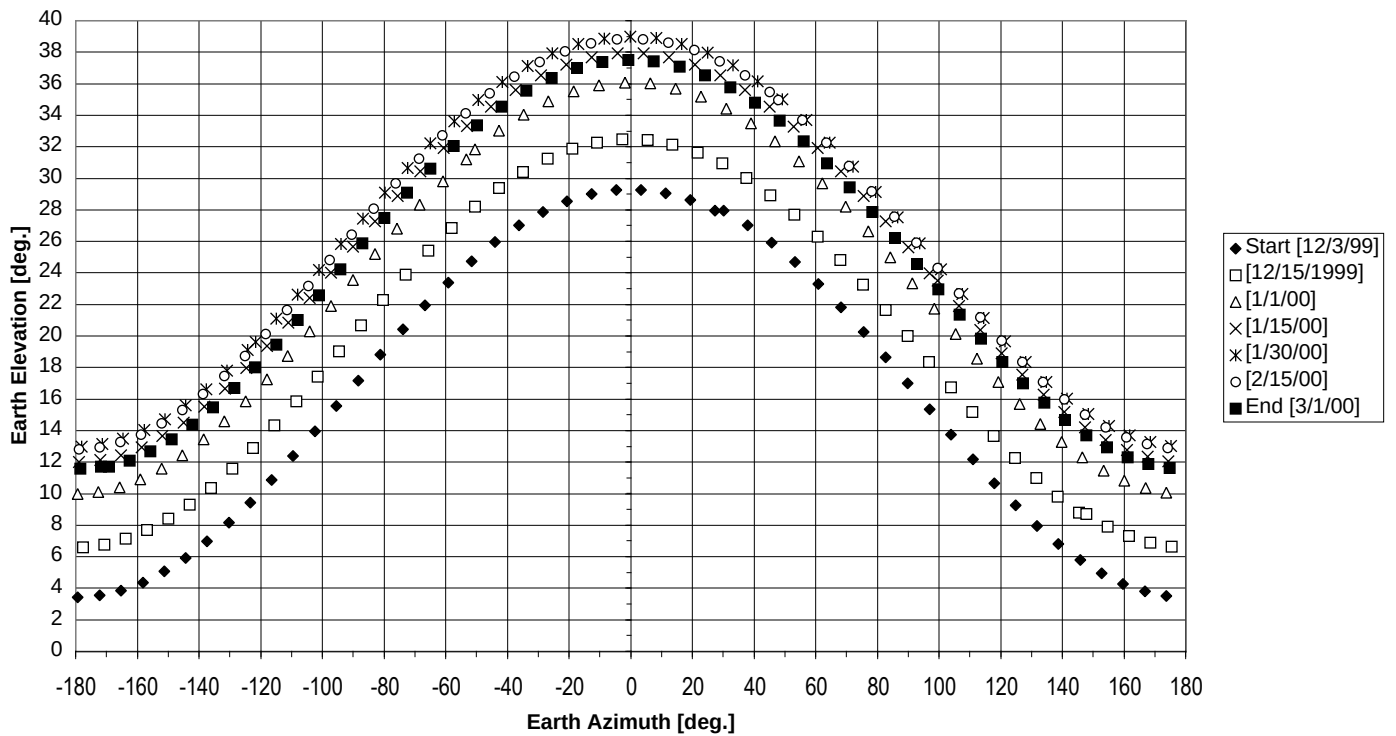
Solar and Earth Geometry for Lander at -76° [planetocentric], and 210°W

Date	Lander Mission Day	Sun Range [AU]	Sun Decl. [deg.]	Min Sun Elev. [deg.]	Max Sun Elev. [deg.]	Earth Range [AU]	Earth Decl. [deg.]	Min Earth Elev. [deg.]	Max Earth Elev. [deg.]	Ls [deg.]
12/3/99	0	1.382	-24.4	10.4	38.4	1.691	-16.3	2.3	30.3	255.8
12/4/99	1	1.382	-24.4	10.4	38.4	1.696	-16.5	2.5	30.5	256.4
12/5/99	2	1.382	-24.5	10.5	38.5	1.702	-16.8	2.8	30.8	257.0
12/6/99	3	1.382	-24.6	10.6	38.6	1.707	-17.1	3.1	31.1	257.7
12/7/99	4	1.382	-24.6	10.6	38.6	1.712	-17.4	3.4	31.4	258.3
12/8/99	5	1.383	-24.7	10.7	38.7	1.718	-17.6	3.6	31.6	258.9
12/9/99	6	1.383	-24.7	10.7	38.7	1.723	-17.9	3.9	31.9	259.6
12/10/99	7	1.383	-24.8	10.8	38.8	1.728	-18.1	4.1	32.1	260.2
12/11/99	8	1.383	-24.8	10.8	38.8	1.734	-18.4	4.4	32.4	260.8
12/12/99	9	1.383	-24.9	10.9	38.9	1.739	-18.6	4.6	32.6	261.5
12/13/99	10	1.384	-24.9	10.9	38.9	1.744	-18.9	4.9	32.9	262.1
12/14/99	11	1.384	-25.0	11.0	39.0	1.750	-19.1	5.1	33.1	262.7
12/15/99	12	1.384	-25.0	11.0	39.0	1.755	-19.4	5.4	33.4	263.4
12/16/99	13	1.384	-25.0	11.0	39.0	1.761	-19.6	5.6	33.6	264.0
12/17/99	14	1.385	-25.1	11.1	39.1	1.766	-19.9	5.9	33.9	264.6
12/18/99	15	1.385	-25.1	11.1	39.1	1.771	-20.1	6.1	34.1	265.3
12/19/99	16	1.385	-25.1	11.1	39.1	1.777	-20.3	6.3	34.3	265.9
12/20/99	17	1.386	-25.1	11.1	39.1	1.782	-20.5	6.5	34.5	266.5
12/21/99	18	1.386	-25.2	11.2	39.2	1.787	-20.8	6.8	34.8	267.2
12/22/99	19	1.386	-25.2	11.2	39.2	1.793	-21.0	7.0	35.0	267.8
12/23/99	20	1.387	-25.2	11.2	39.2	1.798	-21.2	7.2	35.2	268.4
12/24/99	21	1.387	-25.2	11.2	39.2	1.804	-21.4	7.4	35.4	269.0
12/25/99	22	1.388	-25.2	11.2	39.2	1.809	-21.6	7.6	35.6	269.7
12/26/99	23	1.388	-25.2	11.2	39.2	1.814	-21.8	7.8	35.8	270.3
12/27/99	24	1.388	-25.2	11.2	39.2	1.820	-22.0	8.0	36.0	270.9
12/28/99	25	1.389	-25.2	11.2	39.2	1.825	-22.2	8.2	36.2	271.6
12/29/99	26	1.389	-25.2	11.2	39.2	1.831	-22.4	8.4	36.4	272.2
12/30/99	27	1.390	-25.2	11.2	39.2	1.836	-22.6	8.6	36.6	272.8
12/31/99	28	1.390	-25.1	11.1	39.1	1.841	-22.8	8.8	36.8	273.4
1/1/00	29	1.391	-25.1	11.1	39.1	1.847	-22.9	8.9	36.9	274.1
1/2/00	30	1.391	-25.1	11.1	39.1	1.852	-23.1	9.1	37.1	274.7
1/3/00	31	1.392	-25.1	11.1	39.1	1.858	-23.3	9.3	37.3	275.3
1/4/00	32	1.392	-25.0	11.0	39.0	1.863	-23.4	9.4	37.4	275.9
1/5/00	33	1.393	-25.0	11.0	39.0	1.869	-23.6	9.6	37.6	276.6
1/6/00	34	1.394	-25.0	11.0	39.0	1.874	-23.7	9.7	37.7	277.2
1/7/00	35	1.394	-24.9	10.9	38.9	1.879	-23.9	9.9	37.9	277.8
1/8/00	36	1.395	-24.9	10.9	38.9	1.885	-24.0	10.0	38.0	278.4
1/9/00	37	1.395	-24.9	10.9	38.9	1.890	-24.2	10.2	38.2	279.1
1/10/00	38	1.396	-24.8	10.8	38.8	1.896	-24.3	10.3	38.3	279.7
1/11/00	39	1.397	-24.8	10.8	38.8	1.901	-24.4	10.4	38.4	280.3
1/12/00	40	1.397	-24.7	10.7	38.7	1.907	-24.6	10.6	38.6	280.9
1/13/00	41	1.398	-24.6	10.6	38.6	1.912	-24.7	10.7	38.7	281.5
1/14/00	42	1.399	-24.6	10.6	38.6	1.917	-24.8	10.8	38.8	282.2
1/15/00	43	1.399	-24.5	10.5	38.5	1.923	-24.9	10.9	38.9	282.8
1/16/00	44	1.400	-24.5	10.5	38.5	1.928	-25.0	11.0	39.0	283.4
1/17/00	45	1.401	-24.4	10.4	38.4	1.934	-25.1	11.1	39.1	284.0
1/18/00	46	1.401	-24.3	10.3	38.3	1.939	-25.2	11.2	39.2	284.6
1/19/00	47	1.402	-24.2	10.2	38.2	1.945	-25.3	11.3	39.3	285.3
1/20/00	48	1.403	-24.2	10.2	38.2	1.950	-25.4	11.4	39.4	285.9
1/21/00	49	1.404	-24.1	10.1	38.1	1.955	-25.5	11.5	39.5	286.5
1/22/00	50	1.404	-24.0	10.0	38.0	1.961	-25.6	11.6	39.6	287.1
1/23/00	51	1.405	-23.9	9.9	37.9	1.966	-25.6	11.6	39.6	287.7
1/24/00	52	1.406	-23.8	9.8	37.8	1.972	-25.7	11.7	39.7	288.3
1/25/00	53	1.407	-23.7	9.7	37.7	1.977	-25.8	11.8	39.8	288.9
1/26/00	54	1.408	-23.6	9.6	37.6	1.983	-25.8	11.8	39.8	289.5
1/27/00	55	1.408	-23.6	9.6	37.6	1.988	-25.9	11.9	39.9	290.2
1/28/00	56	1.409	-23.5	9.5	37.5	1.993	-25.9	11.9	39.9	290.8
1/29/00	57	1.410	-23.4	9.4	37.4	1.999	-25.9	11.9	39.9	291.4
1/30/00	58	1.411	-23.2	9.2	37.2	2.004	-26.0	12.0	40.0	292.0
1/31/00	59	1.412	-23.1	9.1	37.1	2.010	-26.0	12.0	40.0	292.6
2/1/00	60	1.413	-23.0	9.0	37.0	2.015	-26.0	12.0	40.0	293.2
2/2/00	61	1.414	-22.9	8.9	36.9	2.021	-26.1	12.1	40.1	293.8
2/3/00	62	1.414	-22.8	8.8	36.8	2.026	-26.1	12.1	40.1	294.4

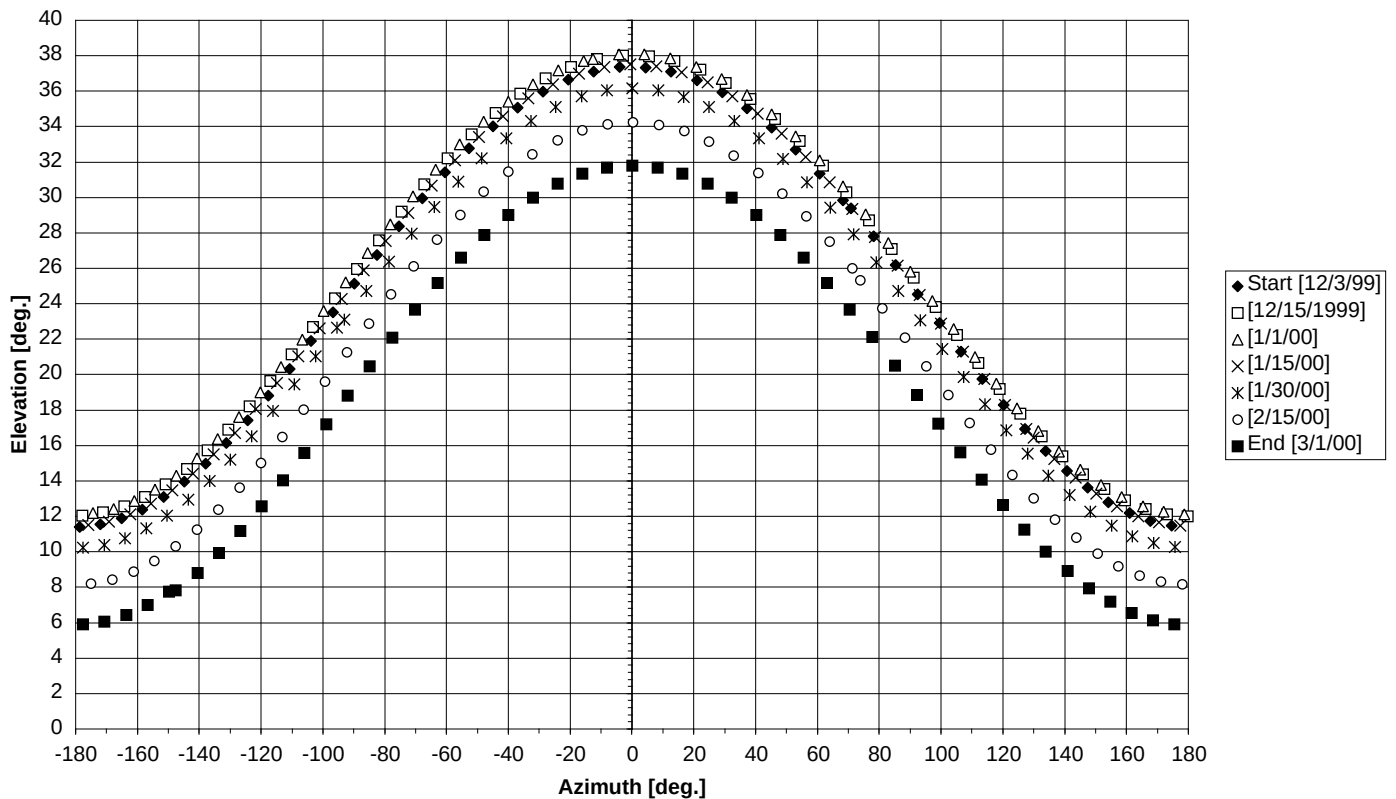
Solar and Earth Geometry for Lander at -76° [planetocentric], and 210°W

Date	Lander Mission Day	Sun Range [AU]	Sun Decl. [deg.]	Min Sun Elev. [deg.]	Max Sun Elev. [deg.]	Earth Range [AU]	Earth Decl. [deg.]	Min Earth Elev. [deg.]	Max Earth Elev. [deg.]	Ls [deg.]
2/4/00	63	1.415	-22.7	8.7	36.7	2.031	-26.1	12.1	40.1	295.0
2/5/00	64	1.416	-22.6	8.6	36.6	2.037	-26.1	12.1	40.1	295.6
2/6/00	65	1.417	-22.4	8.4	36.4	2.042	-26.1	12.1	40.1	296.2
2/7/00	66	1.418	-22.3	8.3	36.3	2.048	-26.1	12.1	40.1	296.8
2/8/00	67	1.419	-22.2	8.2	36.2	2.053	-26.1	12.1	40.1	297.4
2/9/00	68	1.420	-22.1	8.1	36.1	2.058	-26.0	12.0	40.0	298.0
2/10/00	69	1.421	-21.9	7.9	35.9	2.064	-26.0	12.0	40.0	298.6
2/11/00	70	1.422	-21.8	7.8	35.8	2.069	-26.0	12.0	40.0	299.2
2/12/00	71	1.423	-21.7	7.7	35.7	2.074	-26.0	12.0	40.0	299.8
2/13/00	72	1.424	-21.5	7.5	35.5	2.080	-25.9	11.9	39.9	300.4
2/14/00	73	1.425	-21.4	7.4	35.4	2.085	-25.9	11.9	39.9	301.0
2/15/00	74	1.426	-21.3	7.3	35.3	2.091	-25.8	11.8	39.8	301.6
2/16/00	75	1.427	-21.1	7.1	35.1	2.096	-25.8	11.8	39.8	302.2
2/17/00	76	1.428	-21.0	7.0	35.0	2.101	-25.7	11.7	39.7	302.8
2/18/00	77	1.429	-20.8	6.8	34.8	2.107	-25.7	11.7	39.7	303.4
2/19/00	78	1.430	-20.7	6.7	34.7	2.112	-25.6	11.6	39.6	304.0
2/20/00	79	1.431	-20.5	6.5	34.5	2.117	-25.5	11.5	39.5	304.6
2/21/00	80	1.432	-20.4	6.4	34.4	2.123	-25.5	11.5	39.5	305.2
2/22/00	81	1.433	-20.2	6.2	34.2	2.128	-25.4	11.4	39.4	305.8
2/23/00	82	1.434	-20.0	6.0	34.0	2.133	-25.3	11.3	39.3	306.4
2/24/00	83	1.435	-19.9	5.9	33.9	2.138	-25.2	11.2	39.2	307.0
2/25/00	84	1.436	-19.7	5.7	33.7	2.144	-25.1	11.1	39.1	307.5
2/26/00	85	1.438	-19.6	5.6	33.6	2.149	-25.0	11.0	39.0	308.1
2/27/00	86	1.439	-19.4	5.4	33.4	2.154	-24.9	10.9	38.9	308.7
2/28/00	87	1.440	-19.2	5.2	33.2	2.159	-24.8	10.8	38.8	309.3
2/29/00	88	1.441	-19.1	5.1	33.1	2.165	-24.7	10.7	38.7	309.9
3/1/00	89	1.442	-18.9	4.9	32.9	2.170	-24.6	10.6	38.6	310.5
3/2/00	90	1.443	-18.7	4.7	32.7	2.175	-24.5	10.5	38.5	311.0
3/3/00	91	1.444	-18.6	4.6	32.6	2.180	-24.3	10.3	38.3	311.6
3/4/00	92	1.445	-18.4	4.4	32.4	2.185	-24.2	10.2	38.2	312.2
3/5/00	93	1.447	-18.2	4.2	32.2	2.191	-24.1	10.1	38.1	312.8
3/6/00	94	1.448	-18.0	4.0	32.0	2.196	-23.9	9.9	37.9	313.4
3/7/00	95	1.449	-17.8	3.8	31.8	2.201	-23.8	9.8	37.8	313.9
3/8/00	96	1.450	-17.7	3.7	31.7	2.206	-23.6	9.6	37.6	314.5
3/9/00	97	1.451	-17.5	3.5	31.5	2.211	-23.5	9.5	37.5	315.1
3/10/00	98	1.452	-17.3	3.3	31.3	2.216	-23.3	9.3	37.3	315.7
3/11/00	99	1.454	-17.1	3.1	31.1	2.221	-23.2	9.2	37.2	316.2
3/12/00	100	1.455	-16.9	2.9	30.9	2.226	-23.0	9.0	37.0	316.8
3/13/00	101	1.456	-16.7	2.7	30.7	2.231	-22.8	8.8	36.8	317.4
3/14/00	102	1.457	-16.6	2.6	30.6	2.236	-22.7	8.7	36.7	318.0
3/15/00	103	1.458	-16.4	2.4	30.4	2.241	-22.5	8.5	36.5	318.5
3/16/00	104	1.460	-16.2	2.2	30.2	2.246	-22.3	8.3	36.3	319.1
3/17/00	105	1.461	-16.0	2.0	30.0	2.251	-22.1	8.1	36.1	319.7
3/18/00	106	1.462	-15.8	1.8	29.8	2.256	-22.0	8.0	36.0	320.2
3/19/00	107	1.463	-15.6	1.6	29.6	2.261	-21.8	7.8	35.8	320.8
3/20/00	108	1.464	-15.4	1.4	29.4	2.266	-21.6	7.6	35.6	321.4
3/21/00	109	1.466	-15.2	1.2	29.2	2.271	-21.4	7.4	35.4	321.9
3/22/00	110	1.467	-15.0	1.0	29.0	2.276	-21.2	7.2	35.2	322.5
3/23/00	111	1.468	-14.8	0.8	28.8	2.281	-21.0	7.0	35.0	323.1
3/24/00	112	1.469	-14.6	0.6	28.6	2.286	-20.8	6.8	34.8	323.6
3/25/00	113	1.471	-14.4	0.4	28.4	2.291	-20.6	6.6	34.6	324.2
3/26/00	114	1.472	-14.2	0.2	28.2	2.295	-20.4	6.4	34.4	324.7
3/27/00	115	1.473	-14.0	0.0	28.0	2.300	-20.2	6.2	34.2	325.3
3/28/00	116	1.474	-13.8	0.0	27.8	2.305	-19.9	5.9	33.9	325.9
3/29/00	117	1.476	-13.6	0.0	27.6	2.310	-19.7	5.7	33.7	326.4
3/30/00	118	1.477	-13.4	0.0	27.4	2.314	-19.5	5.5	33.5	327.0
3/31/00	119	1.478	-13.2	0.0	27.2	2.319	-19.3	5.3	33.3	327.5
4/1/00	120	1.479	-13.0	0.0	27.0	2.324	-19.1	5.1	33.1	328.1

Earth Az/EI During Landed Science Mission Latitude = 77S



Sun Az/EI During Landed Science Mission Latitude = 77S



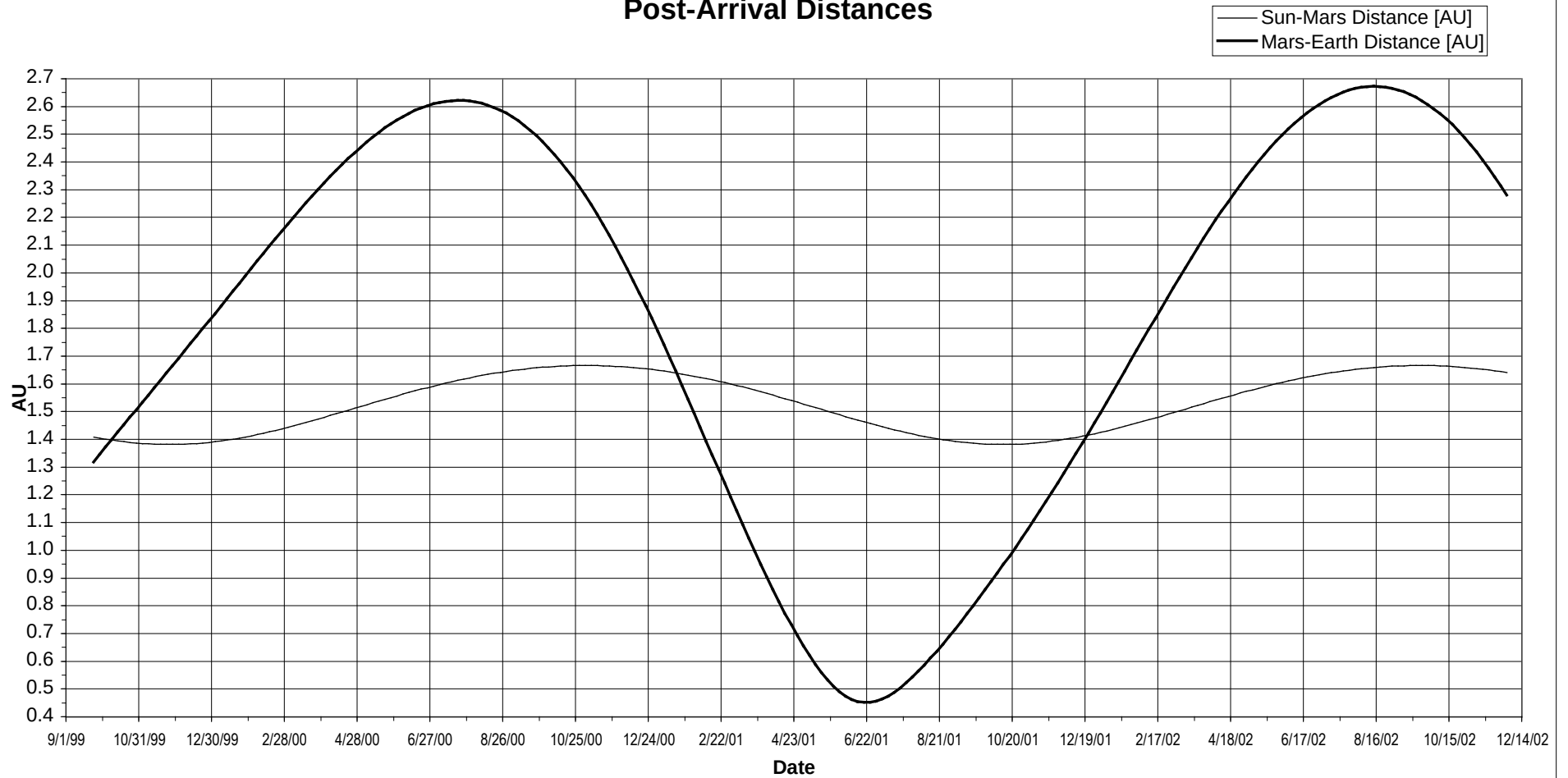
Date	Days from Earliest MOI	Days from Start of Mapping	Sun-Mars Distance [AU]	Mars-Earth Distance [AU]	ESM [deg.]	SEM [deg.]	SME [deg.]	Events
9/24/99	1		1.4085	1.3173	63.6326	73.3347	43.0327	Orbiter MOI
9/29/99	6		1.4045	1.3447	65.4709	71.8521	42.6770	
10/4/99	11		1.4008	1.3718	67.3062	70.4061	42.2877	
10/9/99	16		1.3974	1.3988	69.1398	68.9929	41.8673	
10/14/99	21		1.3943	1.4256	70.9729	67.6092	41.4179	
10/19/99	26		1.3915	1.4523	72.8070	66.2519	40.9411	
10/24/99	31		1.3891	1.4789	74.6431	64.9181	40.4389	
10/29/99	36		1.3869	1.5055	76.4825	63.6049	39.9126	
11/3/99	41		1.3852	1.5320	78.3264	62.3100	39.3636	
11/8/99	46		1.3837	1.5584	80.1758	61.0309	38.7933	
11/13/99	51		1.3826	1.5849	82.0318	59.7654	38.2027	Perihelion Lander Arrival
11/18/99	56		1.3819	1.6114	83.8954	58.5115	37.5930	
11/23/99	61		1.3815	1.6379	85.7674	57.2674	36.9652	
11/28/99	66		1.3815	1.6644	87.6486	56.0312	36.3202	
12/3/99	71		1.3819	1.6910	89.5398	54.8014	35.6588	
12/8/99	76		1.3826	1.7177	91.4416	53.5765	34.9819	
12/13/99	81		1.3837	1.7445	93.3545	52.3552	34.2903	
12/18/99	86		1.3851	1.7713	95.2790	51.1363	33.5847	
12/23/99	91		1.3869	1.7983	97.2155	49.9187	32.8658	
12/28/99	96		1.3890	1.8253	99.1642	48.7015	32.1343	
1/2/00	101		1.3915	1.8523	101.1254	47.4837	31.3909	
1/7/00	106		1.3942	1.8794	103.0992	46.2647	30.6361	
1/12/00	111		1.3973	1.9066	105.0855	45.0438	29.8707	
1/17/00	116		1.4008	1.9338	107.0845	43.8204	29.0951	
1/22/00	121		1.4045	1.9609	109.0960	42.5941	28.3099	
1/27/00	126		1.4084	1.9881	111.1198	41.3644	27.5157	
2/1/00	131		1.4127	2.0152	113.1559	40.1311	26.7130	
2/6/00	136		1.4172	2.0422	115.2039	38.8938	25.9023	
2/11/00	141		1.4220	2.0692	117.2637	37.6524	25.0840	
2/16/00	146		1.4269	2.0959	119.3349	36.4066	24.2585	
2/21/00	151		1.4321	2.1225	121.4174	35.1562	23.4264	End Lander Mission; Start Mapping
2/26/00	156		1.4375	2.1489	123.5107	33.9013	22.5880	
3/2/00	161	1	1.4431	2.1750	125.6148	32.6415	21.7437	
3/7/00	166	6	1.4488	2.2008	127.7293	31.3770	20.8938	
3/12/00	171	11	1.4547	2.2263	129.8539	30.1074	20.0387	
3/17/00	176	16	1.4607	2.2514	131.9885	28.8328	19.1787	
3/22/00	181	21	1.4669	2.2760	134.1328	27.5531	18.3141	
3/27/00	186	26	1.4731	2.3002	136.2868	26.2680	17.4451	
4/1/00	191	31	1.4795	2.3239	138.4503	24.9776	16.5721	
4/6/00	196	36	1.4859	2.3469	140.6233	23.6816	15.6951	
4/11/00	201	41	1.4923	2.3694	142.8056	22.3798	14.8145	
4/16/00	206	46	1.4988	2.3912	144.9974	21.0721	13.9305	
4/21/00	211	51	1.5054	2.4123	147.1986	19.7583	13.0431	
4/26/00	216	56	1.5119	2.4327	149.4093	18.4381	12.1526	
5/1/00	221	61	1.5184	2.4522	151.6296	17.1112	11.2592	
5/6/00	226	66	1.5249	2.4709	153.8596	15.7775	10.3629	
5/11/00	231	71	1.5314	2.4887	156.0994	14.4366	9.4640	
5/16/00	236	76	1.5379	2.5056	158.3493	13.0882	8.5625	
5/21/00	241	81	1.5443	2.5215	160.6091	11.7322	7.6587	
5/26/00	246	86	1.5506	2.5364	162.8788	10.3683	6.7529	
5/31/00	251	91	1.5568	2.5502	165.1582	8.9965	5.8453	Max Earth Dist
6/5/00	256	96	1.5630	2.5629	167.4464	7.6172	4.9365	
6/10/00	261	101	1.5690	2.5744	169.7415	6.2311	4.0274	
6/15/00	266	106	1.5750	2.5848	172.0389	4.8410	3.1201	
6/20/00	271	111	1.5808	2.5939	174.3257	3.4544	2.2199	
6/25/00	276	116	1.5864	2.6018	176.5531	2.1010	1.3460	
6/30/00	281	121	1.5920	2.6084	178.3783	0.9897	0.6320	
7/5/00	286	126	1.5974	2.6137	177.8429	1.3181	0.8389	
7/10/00	291	131	1.6026	2.6175	175.7372	2.6084	1.6544	
7/15/00	296	136	1.6077	2.6200	173.4108	4.0377	2.5516	
7/20/00	301	141	1.6126	2.6211	171.0203	5.5105	3.4692	Max Earth Dist
7/25/00	306	146	1.6173	2.6207	168.5950	7.0094	4.3956	
7/30/00	311	151	1.6218	2.6188	166.1434	8.5294	5.3271	

Date	Days from Earliest MOI	Days from Start of Mapping	Sun-Mars Distance [AU]	Mars-Earth Distance [AU]	ESM [deg.]	SEM [deg.]	SME [deg.]	Events
8/4/00	316	156	1.6261	2.6154	163.6692	10.0687	6.2621	
8/9/00	321	161	1.6303	2.6104	161.1737	11.6267	7.1996	
8/14/00	326	166	1.6342	2.6039	158.6576	13.2033	8.1392	
8/19/00	331	171	1.6379	2.5959	156.1211	14.7986	9.0803	
8/24/00	336	176	1.6414	2.5862	153.5645	16.4130	10.0225	
8/29/00	341	181	1.6447	2.5749	150.9877	18.0468	10.9655	
9/3/00	346	186	1.6478	2.5620	148.3908	19.7002	11.9090	
9/8/00	351	191	1.6506	2.5474	145.7738	21.3737	12.8525	
9/13/00	356	196	1.6532	2.5312	143.1369	23.0675	13.7956	
9/18/00	361	201	1.6556	2.5134	140.4802	24.7819	14.7379	
9/23/00	366	206	1.6577	2.4939	137.8040	26.5172	15.6788	
9/28/00	371	211	1.6596	2.4727	135.1085	28.2736	16.6179	
10/3/00	376	216	1.6613	2.4499	132.3942	30.0513	17.5545	
10/8/00	381	221	1.6627	2.4255	129.6616	31.8505	18.4880	
10/13/00	386	226	1.6638	2.3995	126.9112	33.6711	19.4177	
10/18/00	391	231	1.6647	2.3718	124.1437	35.5134	20.3429	
10/23/00	396	236	1.6654	2.3426	121.3600	37.3773	21.2627	
10/28/00	401	241	1.6658	2.3118	118.5610	39.2628	22.1762	
11/2/00	406	246	1.6660	2.2795	115.7476	41.1699	23.0826	Aphelion
11/7/00	411	251	1.6659	2.2457	112.9210	43.0984	23.9806	
11/12/00	416	256	1.6656	2.2104	110.0824	45.0483	24.8693	
11/17/00	421	261	1.6650	2.1737	107.2331	47.0194	25.7475	
11/22/00	426	266	1.6642	2.1356	104.3747	49.0116	26.6137	
11/27/00	431	271	1.6631	2.0963	101.5086	51.0247	27.4667	
12/2/00	436	276	1.6618	2.0556	98.6364	53.0587	28.3049	
12/7/00	441	281	1.6602	2.0137	95.7598	55.1135	29.1268	
12/12/00	446	286	1.6584	1.9707	92.8806	57.1889	29.9305	
12/17/00	451	291	1.6564	1.9266	90.0006	59.2852	30.7142	
12/22/00	456	296	1.6541	1.8815	87.1218	61.4023	31.4759	
12/27/00	461	301	1.6516	1.8355	84.2460	63.5405	32.2135	
1/1/01	466	306	1.6488	1.7886	81.3751	65.7003	32.9246	
1/6/01	471	311	1.6458	1.7410	78.5113	67.8820	33.6067	
1/11/01	476	316	1.6426	1.6926	75.6565	70.0866	34.2570	
1/16/01	481	321	1.6392	1.6437	72.8125	72.3149	34.8726	
1/21/01	486	326	1.6356	1.5942	69.9815	74.5683	35.4502	
1/26/01	491	331	1.6317	1.5443	67.1653	76.8484	35.9863	
1/31/01	496	336	1.6277	1.4941	64.3658	79.1571	36.4771	
2/5/01	501	341	1.6234	1.4437	61.5849	81.4969	36.9182	
2/10/01	506	346	1.6189	1.3931	58.8242	83.8707	37.3051	
2/15/01	511	351	1.6143	1.3425	56.0855	86.2820	37.6324	
2/20/01	516	356	1.6095	1.2919	53.3705	88.7350	37.8945	
2/25/01	521	361	1.6045	1.2415	50.6805	91.2346	38.0849	
3/2/01	526	366	1.5993	1.1914	48.0171	93.7865	38.1964	
3/7/01	531	371	1.5940	1.1417	45.3816	96.3974	38.2211	
3/12/01	536	376	1.5885	1.0924	42.7751	99.0751	38.1498	
3/17/01	541	381	1.5828	1.0438	40.1987	101.8287	37.9726	
3/22/01	546	386	1.5771	0.9959	37.6535	104.6687	37.6778	
3/27/01	551	391	1.5712	0.9488	35.1403	107.6069	37.2529	
4/1/01	556	396	1.5652	0.9027	32.6598	110.6570	36.6832	
4/6/01	561	401	1.5591	0.8577	30.2126	113.8346	35.9528	
4/11/01	566	406	1.5529	0.8140	27.7994	117.1570	35.0436	
4/16/01	571	411	1.5466	0.7716	25.4205	120.6437	33.9358	
4/21/01	576	416	1.5402	0.7309	23.0761	124.3157	32.6081	
4/26/01	581	421	1.5338	0.6920	20.7666	128.1958	31.0376	
5/1/01	586	426	1.5273	0.6550	18.4921	132.3072	29.2008	
5/6/01	591	431	1.5208	0.6203	16.2526	136.6728	27.0746	
5/11/01	596	436	1.5143	0.5881	14.0484	141.3130	24.6386	
5/16/01	601	441	1.5077	0.5586	11.8796	146.2428	21.8775	
5/21/01	606	446	1.5012	0.5321	9.7470	151.4678	18.7852	
5/26/01	611	451	1.4947	0.5089	7.6521	156.9777	15.3702	
5/31/01	616	456	1.4882	0.4893	5.5998	162.7358	11.6644	
6/5/01	621	461	1.4818	0.4736	3.6065	168.6480	7.7455	
6/10/01	626	466	1.4754	0.4618	1.7651	174.3519	3.8830	

Date	Days from Earliest MOI	Days from Start of Mapping	Sun-Mars Distance [AU]	Mars-Earth Distance [AU]	ESM [deg.]	SEM [deg.]	SME [deg.]	Events
6/15/01	631	471	1.4692	0.4541	1.1472	176.2861	2.5667	Min Earth Dist
6/20/01	636	476	1.4630	0.4505	2.6948	171.2176	6.0876	
6/25/01	641	481	1.4569	0.4509	4.5420	165.1750	10.2830	
6/30/01	646	486	1.4510	0.4551	6.4124	159.1408	14.4468	
7/5/01	651	491	1.4452	0.4628	8.2737	153.2982	18.4281	
7/10/01	656	496	1.4395	0.4737	10.1186	147.7305	22.1508	
7/15/01	661	501	1.4341	0.4874	11.9454	142.4828	25.5719	
7/20/01	666	506	1.4288	0.5035	13.7541	137.5749	28.6711	
7/25/01	671	511	1.4237	0.5218	15.5457	133.0090	31.4454	
7/30/01	676	516	1.4189	0.5419	17.3215	128.7747	33.9038	
8/4/01	681	521	1.4143	0.5635	19.0830	124.8539	36.0631	
8/9/01	686	526	1.4099	0.5863	20.8319	121.2235	37.9446	
8/14/01	691	531	1.4058	0.6103	22.5702	117.8586	39.5712	
8/19/01	696	536	1.4020	0.6352	24.2995	114.7341	40.9663	
8/24/01	701	541	1.3985	0.6609	26.0221	111.8257	42.1522	
8/29/01	706	546	1.3953	0.6873	27.7397	109.1104	43.1499	
9/3/01	711	551	1.3924	0.7143	29.4545	106.5671	43.9784	
9/8/01	716	556	1.3898	0.7419	31.1686	104.1763	44.6551	
9/13/01	721	561	1.3876	0.7700	32.8839	101.9207	45.1953	
9/18/01	726	566	1.3857	0.7985	34.6026	99.7845	45.6129	
9/23/01	731	571	1.3841	0.8275	36.3266	97.7533	45.9200	Perihelion
9/28/01	736	576	1.3829	0.8569	38.0580	95.8146	46.1274	
10/3/01	741	581	1.3820	0.8867	39.7986	93.9568	46.2446	
10/8/01	746	586	1.3815	0.9170	41.5502	92.1698	46.2800	
10/13/01	751	591	1.3814	0.9477	43.3148	90.4442	46.2410	
10/18/01	756	596	1.3816	0.9788	45.0939	88.7719	46.1343	
10/23/01	761	601	1.3822	1.0103	46.8890	87.1454	45.9656	
10/28/01	766	606	1.3832	1.0423	48.7017	85.5580	45.7403	
11/2/01	771	611	1.3845	1.0747	50.5332	84.0039	45.4629	
11/7/01	776	616	1.3862	1.1075	52.3847	82.4776	45.1376	
11/12/01	781	621	1.3882	1.1408	54.2572	80.9745	44.7682	
11/17/01	786	626	1.3905	1.1745	56.1516	79.4903	44.3581	
11/22/01	791	631	1.3932	1.2087	58.0685	78.0212	43.9103	
11/27/01	796	636	1.3962	1.2432	60.0085	76.5640	43.4275	
12/2/01	801	641	1.3995	1.2782	61.9720	75.1158	42.9122	
12/7/01	806	646	1.4031	1.3136	63.9591	73.6741	42.3668	
12/12/01	811	651	1.4069	1.3493	65.9699	72.2368	41.7933	
12/17/01	816	656	1.4111	1.3854	68.0043	70.8020	41.1937	
12/22/01	821	661	1.4155	1.4219	70.0621	69.3682	40.5697	
12/27/01	826	666	1.4202	1.4586	72.1429	67.9342	39.9230	Orbiter end of Mapping
1/1/02	831	671	1.4251	1.4956	74.2461	66.4989	39.2550	
1/6/02	836	676	1.4302	1.5329	76.3712	65.0616	38.5672	
1/11/02	841	681	1.4355	1.5703	78.5175	63.6216	37.8608	
1/16/02	846	686	1.4410	1.6079	80.6842	62.1786	37.1371	
1/21/02	851	691	1.4467	1.6456	82.8704	60.7323	36.3973	
1/26/02	856	696	1.4526	1.6834	85.0752	59.2825	35.6423	
1/31/02	861	701	1.4585	1.7212	87.2977	57.8292	34.8732	
2/5/02	866	706	1.4646	1.7589	89.5368	56.3724	34.0908	
2/10/02	871	711	1.4709	1.7966	91.7916	54.9123	33.2961	
2/15/02	876	716	1.4771	1.8342	94.0611	53.4491	32.4898	
2/20/02	881	721	1.4835	1.8715	96.3443	51.9830	31.6727	
2/25/02	886	726	1.4900	1.9086	98.6403	50.5141	30.8456	
3/2/02	891	731	1.4964	1.9455	100.9482	49.0428	30.0090	
3/7/02	896	736	1.5030	1.9819	103.2670	47.5694	29.1636	
3/12/02	901	741	1.5095	2.0180	105.5960	46.0940	28.3100	
3/17/02	906	746	1.5160	2.0536	107.9345	44.6169	27.4486	
3/22/02	911	751	1.5225	2.0887	110.2817	43.1382	26.5801	
3/27/02	916	756	1.5290	2.1232	112.6370	41.6582	25.7047	
4/1/02	921	761	1.5355	2.1571	114.9999	40.1770	24.8230	
4/6/02	926	766	1.5419	2.1903	117.3700	38.6947	23.9354	
4/11/02	931	771	1.5482	2.2228	119.7467	37.2112	23.0421	
4/16/02	936	776	1.5545	2.2545	122.1298	35.7266	22.1436	
4/21/02	941	781	1.5607	2.2853	124.5190	34.2410	21.2400	

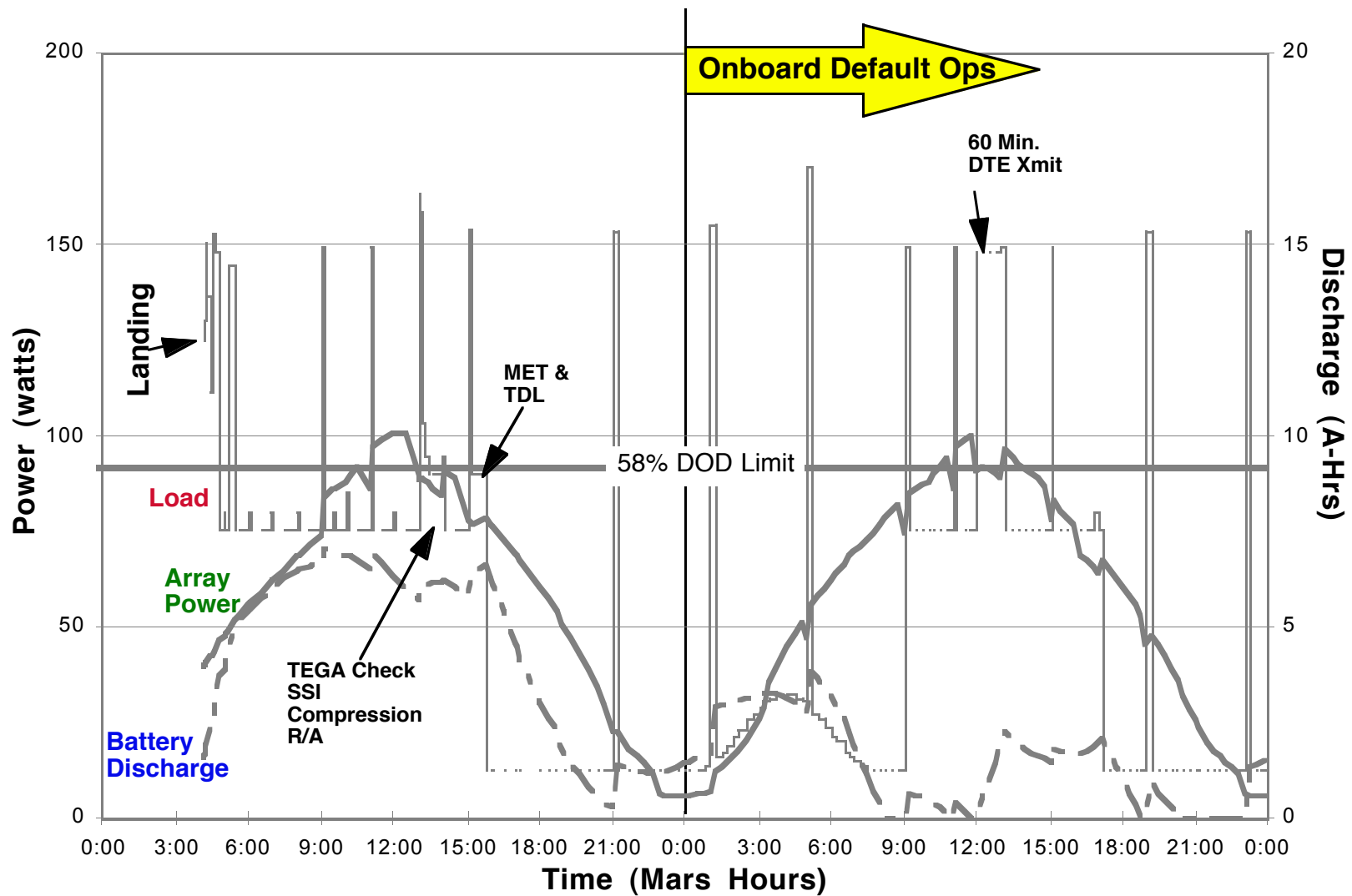
Date	Days from Earliest MOI	Days from Start of Mapping	Sun-Mars Distance [AU]	Mars-Earth Distance [AU]	ESM [deg.]	SEM [deg.]	SME [deg.]	Events
4/26/02	946	786	1.5668	2.3154	126.9143	32.7541	20.3317	
5/1/02	951	791	1.5727	2.3444	129.3153	31.2658	19.4189	
5/6/02	956	796	1.5786	2.3726	131.7222	29.7760	18.5018	
5/11/02	961	801	1.5843	2.3997	134.1350	28.2844	17.5806	
5/16/02	966	806	1.5899	2.4257	136.5536	26.7909	16.6555	
5/21/02	971	811	1.5954	2.4506	138.9783	25.2950	15.7266	
5/26/02	976	816	1.6007	2.4744	141.4093	23.7966	14.7941	
5/31/02	981	821	1.6058	2.4971	143.8466	22.2952	13.8582	
6/5/02	986	826	1.6107	2.5185	146.2906	20.7905	12.9189	
6/10/02	991	831	1.6155	2.5386	148.7416	19.2821	11.9763	
6/15/02	996	836	1.6201	2.5574	151.1997	17.7696	11.0307	
6/20/02	1001	841	1.6245	2.5750	153.6651	16.2528	10.0821	
6/25/02	1006	846	1.6287	2.5911	156.1381	14.7312	9.1307	
6/30/02	1011	851	1.6328	2.6059	158.6187	13.2046	8.1768	
7/5/02	1016	856	1.6366	2.6192	161.1066	11.6729	7.2205	
7/10/02	1021	861	1.6401	2.6311	163.6013	10.1362	6.2625	
7/15/02	1026	866	1.6435	2.6415	166.1015	8.5951	5.3033	
7/20/02	1031	871	1.6467	2.6504	168.6043	7.0512	4.3445	
7/25/02	1036	876	1.6496	2.6578	171.1028	5.5086	3.3887	
7/30/02	1041	881	1.6523	2.6636	173.5787	3.9782	2.4431	
8/4/02	1046	886	1.6548	2.6678	175.9677	2.4998	1.5324	
8/9/02	1051	891	1.6570	2.6704	177.8957	1.3055	0.7988	
8/14/02	1056	896	1.6590	2.6714	177.5634	1.5129	0.9237	Max Earth Distance
8/19/02	1061	901	1.6607	2.6708	175.4183	2.8471	1.7346	
8/24/02	1066	906	1.6622	2.6685	172.9427	4.3892	2.6681	
8/29/02	1071	911	1.6635	2.6646	170.3774	5.9900	3.6326	
9/3/02	1076	916	1.6645	2.6590	167.7698	7.6204	4.6098	
9/8/02	1081	921	1.6653	2.6518	165.1345	9.2715	5.5940	
9/13/02	1086	926	1.6658	2.6428	162.4778	10.9396	6.5826	
9/18/02	1091	931	1.6661	2.6322	159.8026	12.6231	7.5744	
9/23/02	1096	936	1.6661	2.6199	157.1106	14.3211	8.5683	Aphelion
9/28/02	1101	941	1.6659	2.6059	154.4032	16.0330	9.5638	
10/3/02	1106	946	1.6654	2.5902	151.6811	17.7585	10.5603	
10/8/02	1111	951	1.6647	2.5729	148.9454	19.4973	11.5574	
10/13/02	1116	956	1.6637	2.5540	146.1967	21.2489	12.5544	
10/18/02	1121	961	1.6625	2.5334	143.4360	23.0130	13.5510	
10/23/02	1126	966	1.6611	2.5112	140.6641	24.7893	14.5465	
10/28/02	1131	971	1.6594	2.4874	137.8821	26.5773	15.5406	
11/2/02	1136	976	1.6574	2.4620	135.0910	28.3764	16.5326	
11/7/02	1141	981	1.6552	2.4351	132.2920	30.1861	17.5219	
11/12/02	1146	986	1.6528	2.4068	129.4863	32.0058	18.5079	
11/17/02	1151	991	1.6502	2.3770	126.6752	33.8348	19.4900	
11/22/02	1156	996	1.6473	2.3457	123.8603	35.6722	20.4674	
11/27/02	1161	1001	1.6442	2.3131	121.0431	37.5174	21.4395	
12/2/02	1166	1006	1.6408	2.2792	118.2251	39.3694	22.4055	

Post-Arrival Distances

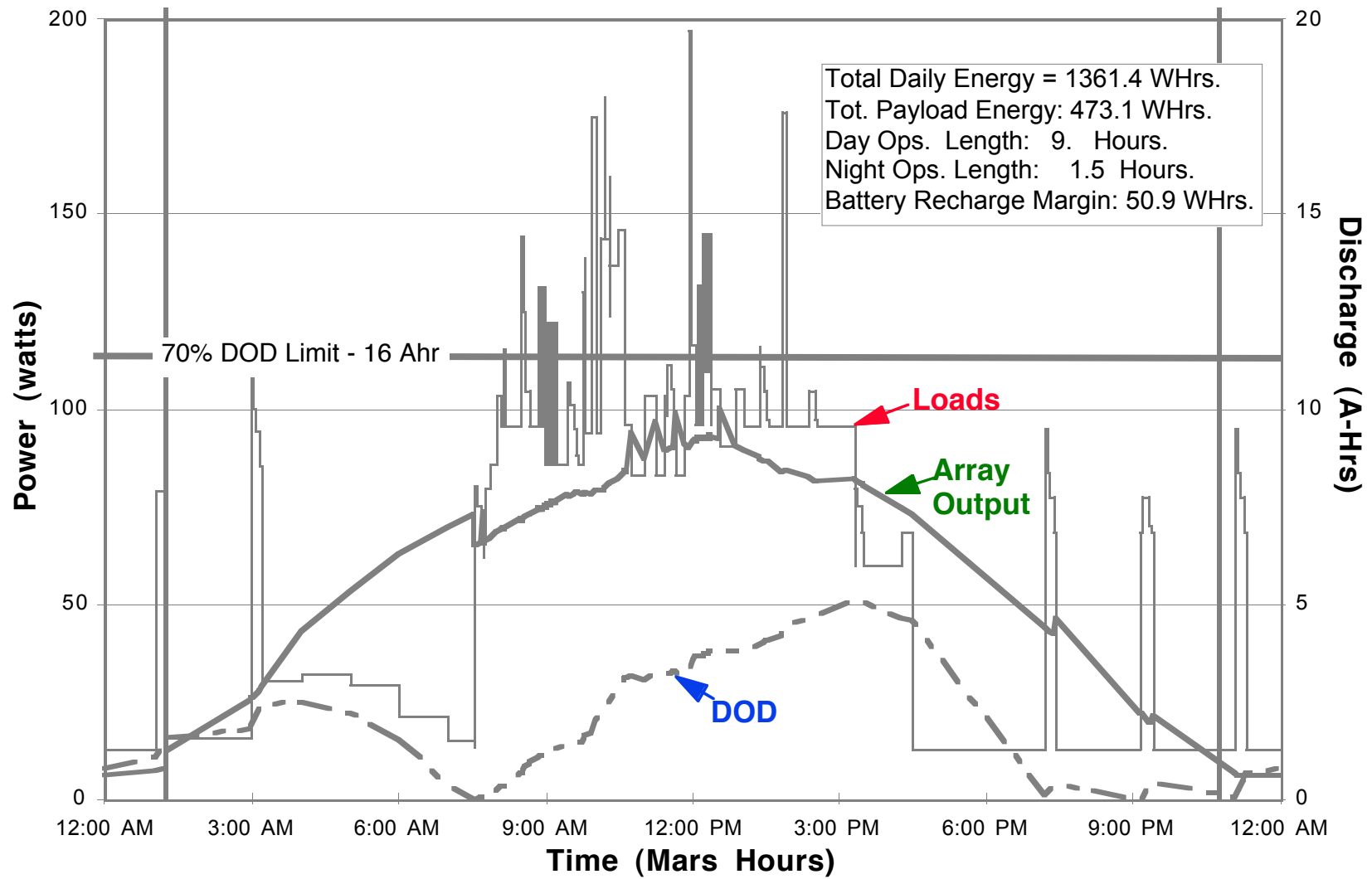


B.5.6 DESIGN REFERENCE MISSION POWER PROFILES

SOL 0,1 POWER PROFILE



TEGA DAY 1 POWER PROFILE



B.5.7 Payload Scenarios

Observation scenarios have been sketched out in order to identify requirements for instrument and ground system capabilities. These scenarios are for nominal, not adverse, conditions. Example science scenarios are:

- **Nominal Sol 1 [TBD]:** The Sol 0,1 scenario shown in section 5.6.2 is a Design Reference Mission, based on conservative assumptions on power capabilities and spacecraft capabilities. Depending on s/c state, other activities may be commanded on Sol 1. The criteria and process for this transition are TBD.
- **Daily Weather [TBD]**
- **Panorama [TBD] - Undeployed
 Multispectral Mineralogy
 Monitor site variability**
- **Trench Layers, Workspace Close-up [TBD]**
- **TEGA Day 2 [TBD]**

Approximately 100 - 200 Mbits is budgeted for daily data volume. The actual daily D/L data volume will depend on the specific payload and s/c bus activities, the number of UHF passes supported, and D/L capability of the relaying orbiter or orbiters.

Daily Energy budgeted to MVACS and LIDAR instruments only = ~225 W-hr (9 hrs x 24 W average) daytime, 156 W-hr (15.6 hrs x 10 W average) nighttime. Payload energy includes 6.5 W for higher processing rate when needed for image compression.

PAYLOAD SCENARIOS

- Observation scenarios developed in order to identify requirements for instrument and ground system capabilities.
- Scenarios are for nominal, not adverse, conditions. [Exception is TEGA Day 1 Design Reference Mission]. Example science scenarios are:
 - **Nominal Sol 1 [TBD]**
 - » Sol 0,1 scenario in section 5.6.2 is a Design Reference Mission, based on conservative assumptions
 - » Depending on s/c state, other activities may be commanded on Sol 1.
 - Criteria and process for this transition are TBD.
 - **Daily Weather [TBD]**
 - **Panorama [TBD]**
 - **Undeployed**
 - **Multispectral Mineralogy**
 - **Monitor site variability**
 - **Trench Layers, Workspace Close-up [TBD]**
 - **TEGA Day 2 [TBD]**
- **Daily Data Volume budgeted** = approximately 100 - 200 Mbits
 - Actual daily data volume will depend on payload and s/c bus activities, number of UHF passes, D/L capability of relaying orbiter or orbiters.
- **Daily Energy budgeted to MVACS and LIDAR instruments only:**
 - **Daytime:** 225 W-hr (9 hrs x 24 W average)
 - **Nighttime:** 156 W-hr (15.6 hrs x 10 W average)
 - Payload energy includes 6.5 W for higher processing rate when needed for image compression

Nominal Sol 1 Payload Scenario [TBD]

To be Supplied

NOMINAL SOL 1 PAYLOAD SCENARIO - TO BE UPDATED

Mon, Dec 16, 1996 1996-351T21:00:00 UTC to Wed, Dec 18, 1996 1996-353T03:00:00 UTC	Tu Dec17 1996-352 00:00:00	Tu Dec17 1996-352 04:00:00	Tu Dec17 1996-352 08:00:00	Tu Dec17 1996-352 12:00:00	Tu Dec17 1996-352 16:00:00	Tu Dec17 1996-352 20:00:00	We Dec18 1996-353 00:00:00
Lander High	Lander_High_Night	Lander_High_Night	Lander_High_Night	Lander_High_Night	Lander_High_Night	Lander_High_Night	Lander_High_Night
MET Sensor	MET_Sensor	MET_Sensor	MET_Sensor	MET_Sensor	MET_Sensor	MET_Sensor	MET_Sensor
LIDAR	LIDAR	LIDAR	LIDAR	LIDAR	LIDAR	LIDAR	LIDAR
MET TDL	MET_WARM_TDL	MET_WARM_TDL	MET_WARM_TDL	MET_WARM_TDL	MET_WARM_TDL	MET_WARM_TDL	MET_WARM_TDL
MET On	MET_On	MET_On	MET_On	MET_On	MET_On	MET_On	MET_On
Lander Low	Lander_Low	Lander_Low	Lander_Low	Lander_Low	Lander_Low	Lander_Low	Lander_Low
SSI/RAC	SSI_RAC_On						
SSI Images	SSI_Images						
DTE	Lander_DTE						
RA On	RA_On						
RAC Images	RAC_Images						
RA Dig	RA_Dig						
TEGA On	TEGA_On	TEGA_Warm					
UHF Relay	Lander_UHF	Lander_UHF	Lander_UHF				
C&DH	Lander_CDH_20	Lander_CDH_20	Lander_CDH_20				
TEGA Cook	TEGA_Cook	TEGA_High_B					
Harness				Harness			
TEGA_Alive				TEGA_Alive			

Daily Weather Scenario [TBD]

Science Objectives: Investigate the diurnal temperature cycle, humidity, wind regime, and regional climate; monitor water exchange between the atmosphere, surface, and subsurface; measure atmospheric opacity and column-integrated water vapor abundance.

Payload Activity:

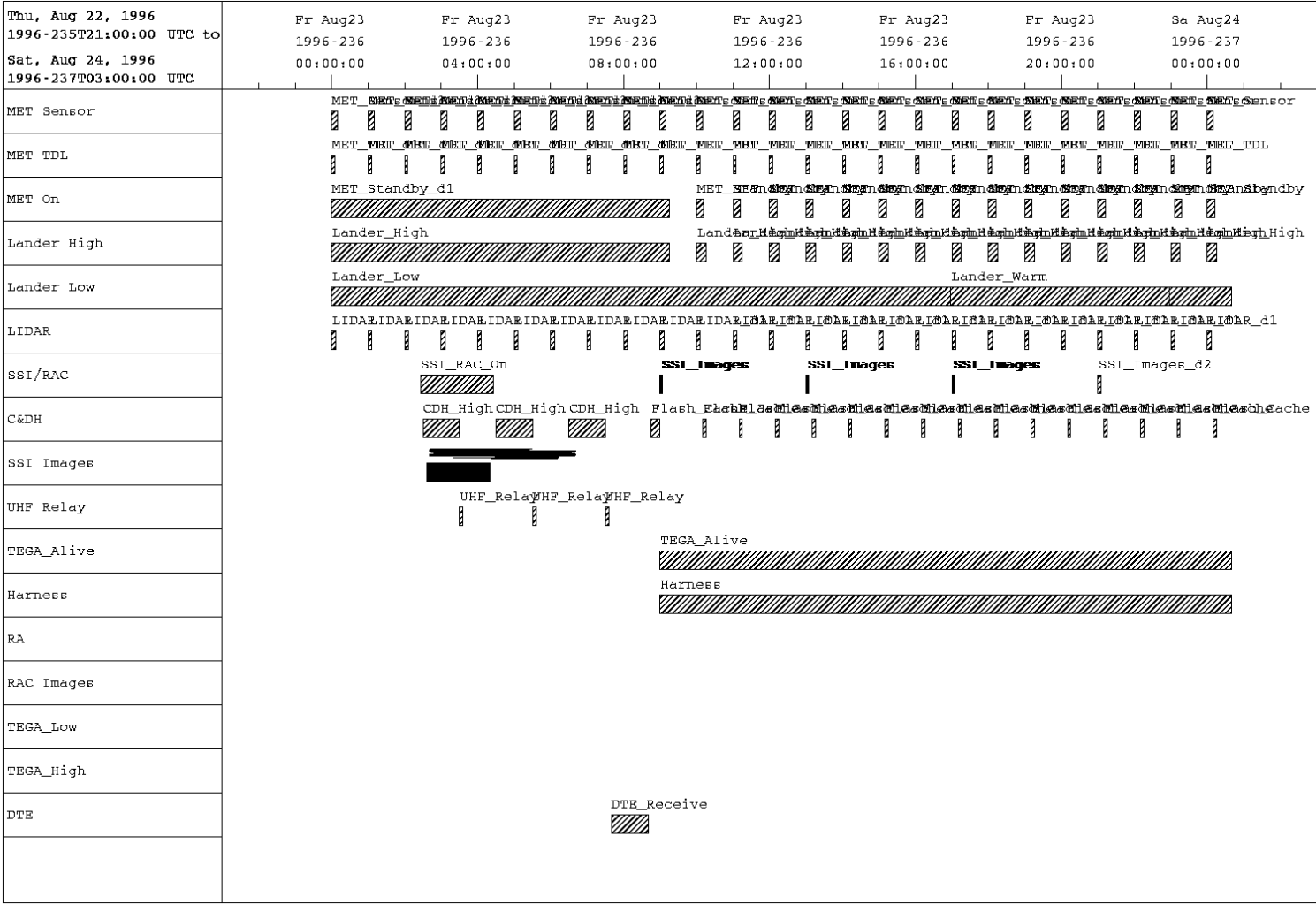
1. MET is on for full diurnal cycle, with sensors duty-cycled on once per hour for 10 minutes
2. Once per 4 hours through full diurnal cycle SSI acquires 4 images of the sun
3. Once per day SSI acquires 2 orthogonal sky swaths, compressed to the equivalent of 10 images (requires 1-2 hours to collect data set)
4. LIDAR is cycled on at the same time as MET

Frequency: Several times per week with MET + SSI, every day with at least MET

Total Energy: 141 W-hr

Daily Data Volume: 42 Mbits = 32 Mbits MET + 10 Mbits SSI (includes high rate processing for SSI)

DAILY WEATHER SCENARIO



Panorama Scenario [TBD]

Science Objectives: Study the geologic setting, topography, mineralogy, and short-time-scale variability of the lander landing site

Payload Activity:

- A. **Undeployed Panorama:** Execute a TBD-position monochromatic panorama of the landing site prior to mast deployment
Frequency: once
- B. **Mineralogic Panorama:** Execute a 36x6 position mosaic through all mineralogic filters (8 filters per optical channel)
Playback over 3 - 7 days
Frequency: 3 times - beginning, middle, end of mission
- C. **Site Variability:** Execute a 36x6 position mosaic through 4 filters per optical channel
Playback over 2 - 4 days
Frequency: once per week

Total Daily Data Volume:

Total Daily Energy:

A:	48 images = 9.4 Mbits (assumes 4x compression)	3 W-hr
B:	3456 images = 679 Mbits / 7 days (assumes 2x compression)	161 W-hr [including daily weather]
C:	1728 images = 340 Mbits / 4 days (assumes 2x compression)	161 W-hr [including daily weather]

PANORAMA SCENARIO

Thu, Aug 22, 1996 1996-235T21:00:00 UTC to Sat, Aug 24, 1996 1996-237T03:00:00 UTC	Fr Aug23 1996-236 00:00:00	Fr Aug23 1996-236 04:00:00	Fr Aug23 1996-236 08:00:00	Fr Aug23 1996-236 12:00:00	Fr Aug23 1996-236 16:00:00	Fr Aug23 1996-236 20:00:00	Sa Aug24 1996-237 00:00:00
Lander High	Lander_High			Lander_High			
Lander Low	Lander_Low			Lander_Warm			
MET Sensor	MET_Sensor						
MET TDL	MET_TDL						
LIDAR	LIDAR						
MET On	MET_Standby_d1			MET_Standby			
SSI/RAC	SSI_RAC_On			SSI_Images		SSI_Images_d2	
SSI Images							
C&DH	CDH_High			Flash_Flash			
UHF Relay	UHF_Relay						
TEGA Alive				TEGA_Alive			
Harness				Harness			
RA							
RAC Images							
TEGA_Low							
TEGA_High							
DTE	DTE_Receive						

Trench Scenario [TBD]

Science Objectives: Identify subsurface layering of soil; presence of ground ice; measure surface and subsurface soil temperatures;
characterize soil mechanical properties (hardness, cohesion, etc.)

Payload Activity:

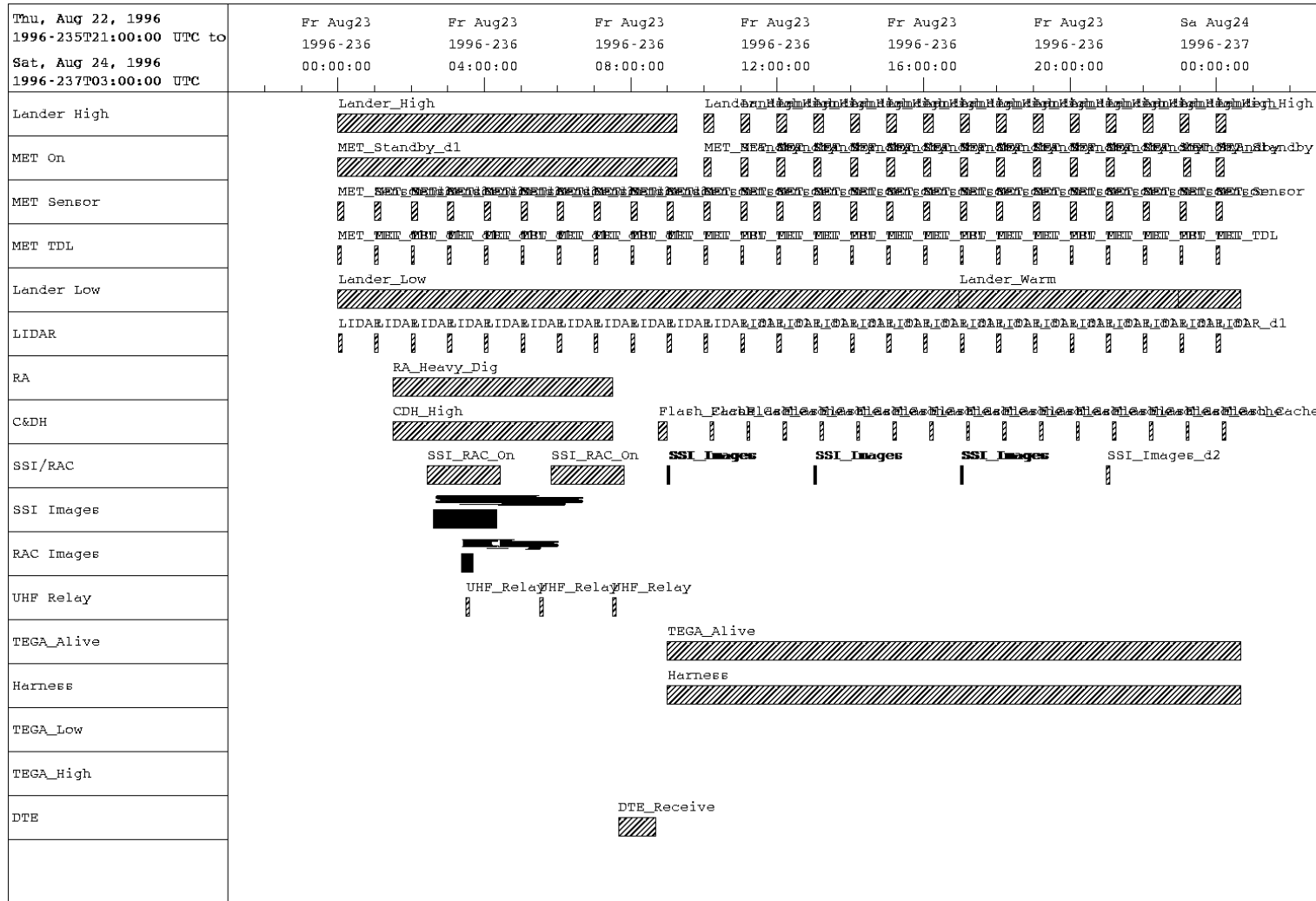
1. (After acquisition and analysis of panorama images of arm workspace) position RA scoop to desired trench start position.
2. Dig approx. 10 cm (6 hours?)
3. Use SSI and RAC to image sides and bottom of trench, 2-color, 5x4 strips, once per hour.
4. Repeat steps 2 to 4, for 5 or more days

Frequency: Four times during primary mission

Total Data Volume: 111 Mbits/day [assuming 2x compression] x 5 days (288 images per day)

Total Energy: 330 Whr/day [includes daily weather] x 5 days

TRENCH SCENARIO



TEGA Day 2 Scenario [TBD]

This completes the TEGA activity started the previous day. After cooling overnight, the sample is cooked to 1300K in a programmed series of steps. In addition, a full daily weather scenario is carried out.

TEGA DAY 2 SCENARIO

Thu, Aug 22, 1996 1996-235T21:00:00 UTC to Sat, Aug 24, 1996 1996-237T03:00:00 UTC	Fr Aug23 1996-236 00:00:00	Fr Aug23 1996-236 04:00:00	Fr Aug23 1996-236 08:00:00	Fr Aug23 1996-236 12:00:00	Fr Aug23 1996-236 16:00:00	Fr Aug23 1996-236 20:00:00	Sa Aug24 1996-237 00:00:00
Lander High	Lander_High		Lander_High				
MET Sensor	MET_Sensor		MET_Sensor				
MET TDL	MET_TDL		MET_TDL				
LIDAR	LIDAR		LIDAR				
MET On	MET_Standby_d1		MET_Standby_d1				
Lander Low	Lander_Low		Lander_Warm				
TEGA_High	TEGA_High		TEGA_High				
SSI/RAC	SSI		SSI_Images		SSI_Images		SSI_Images_d2
C&DH	CDH_High		Flash_Pack		Flash_Pack		Flash_Pack
UHF Relay	UHF_Relay		UHF_Relay				
TEGA Alive			TEGA_Alive				
Harness			Harness				
RA							
SSI Images							
RAC Images							
TEGA_Low							
DTE	DTE_Receive						

B.6 Lander Configuration Drawings

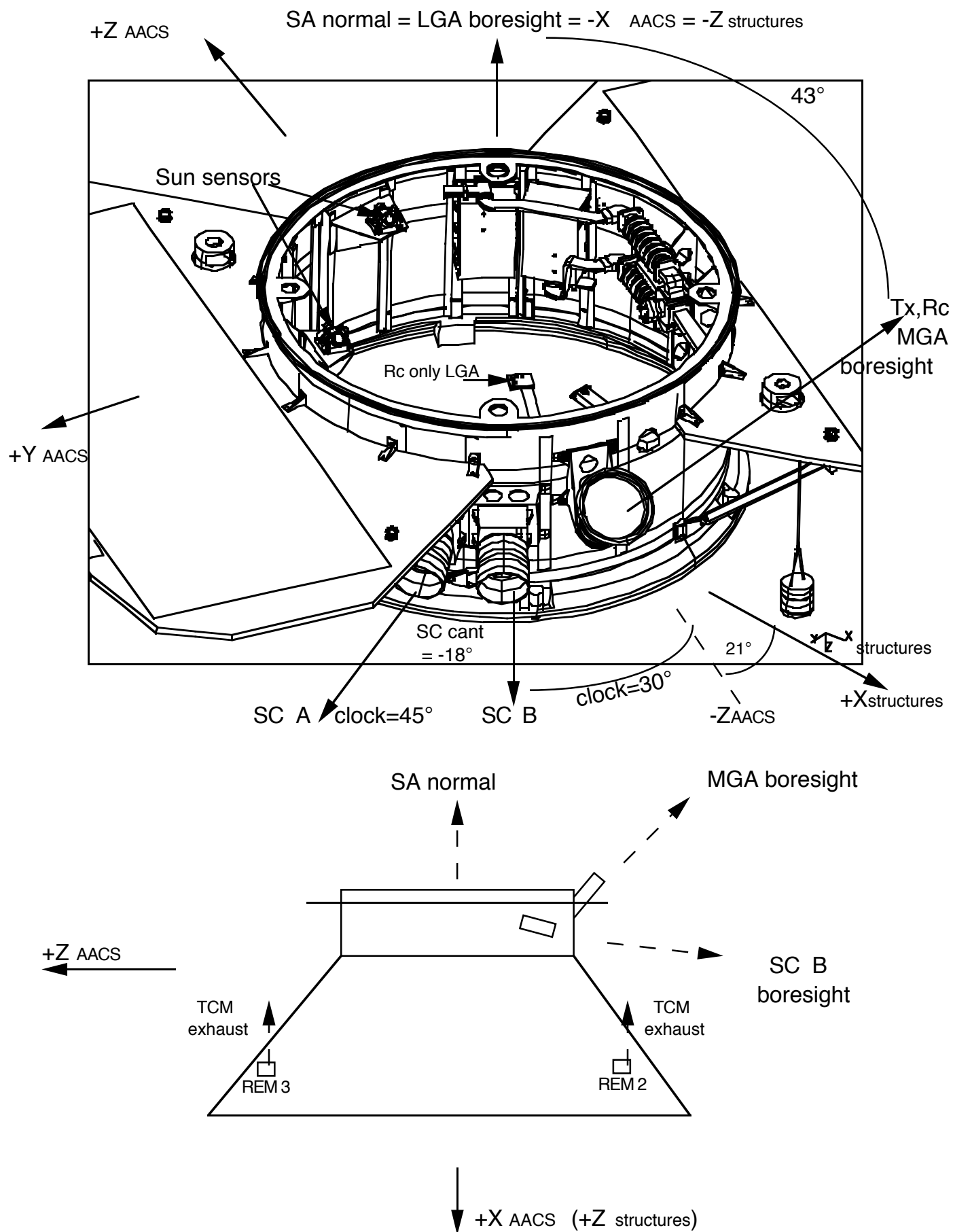
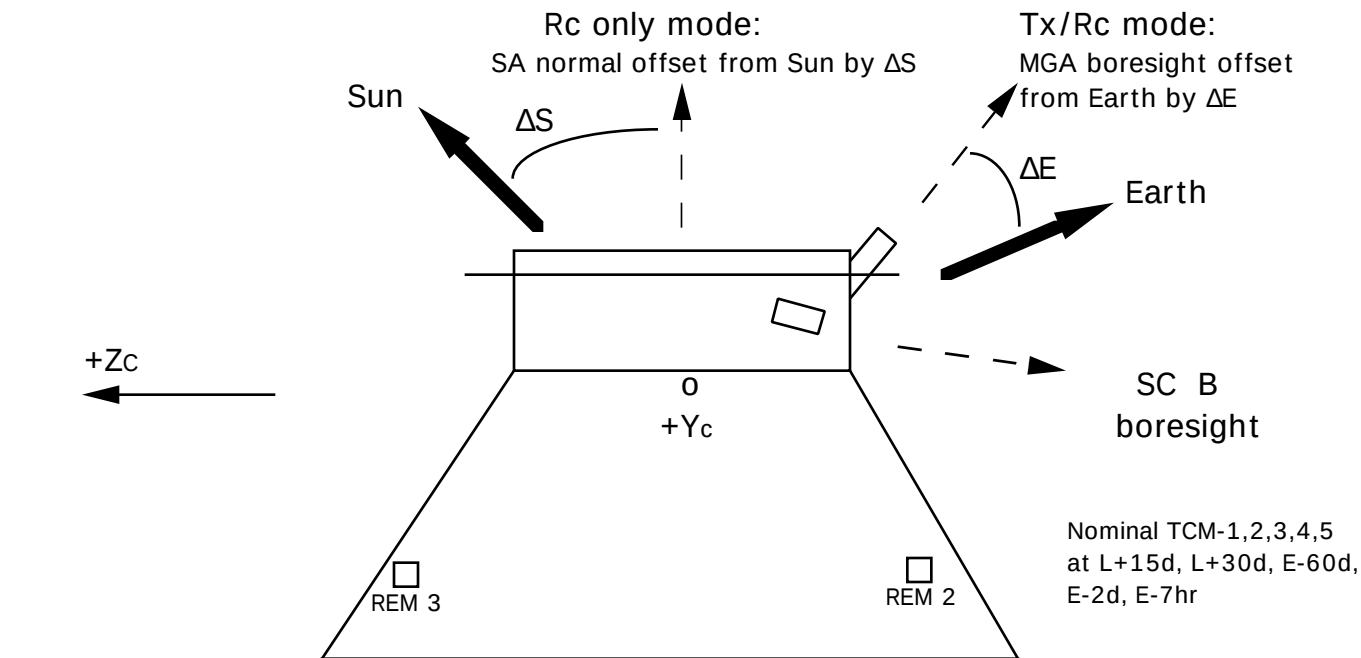


Figure 1.3.6.13.1-1 Lander Cruise Stage Configuration



- S-P-E plane same as X_c - Z_c plane
- Safe mode same as normal mode (ΔS for Rc only, ΔE for Tx/Rc)

TCM
 ΔV

$+X_c$ ($+Z$ structures)

Cruise Orientations

(Table from XC0246)

day	SPE	offset, deg		Edist
L+	deg	ΔE	ΔS	AU
1	120	42	0	0
60	71	15	0	0.1
120	11	-5	0	0.2
180	40	0	0	0.5
330	37	0	0	1.7
		Tx/Rc	Rc only	

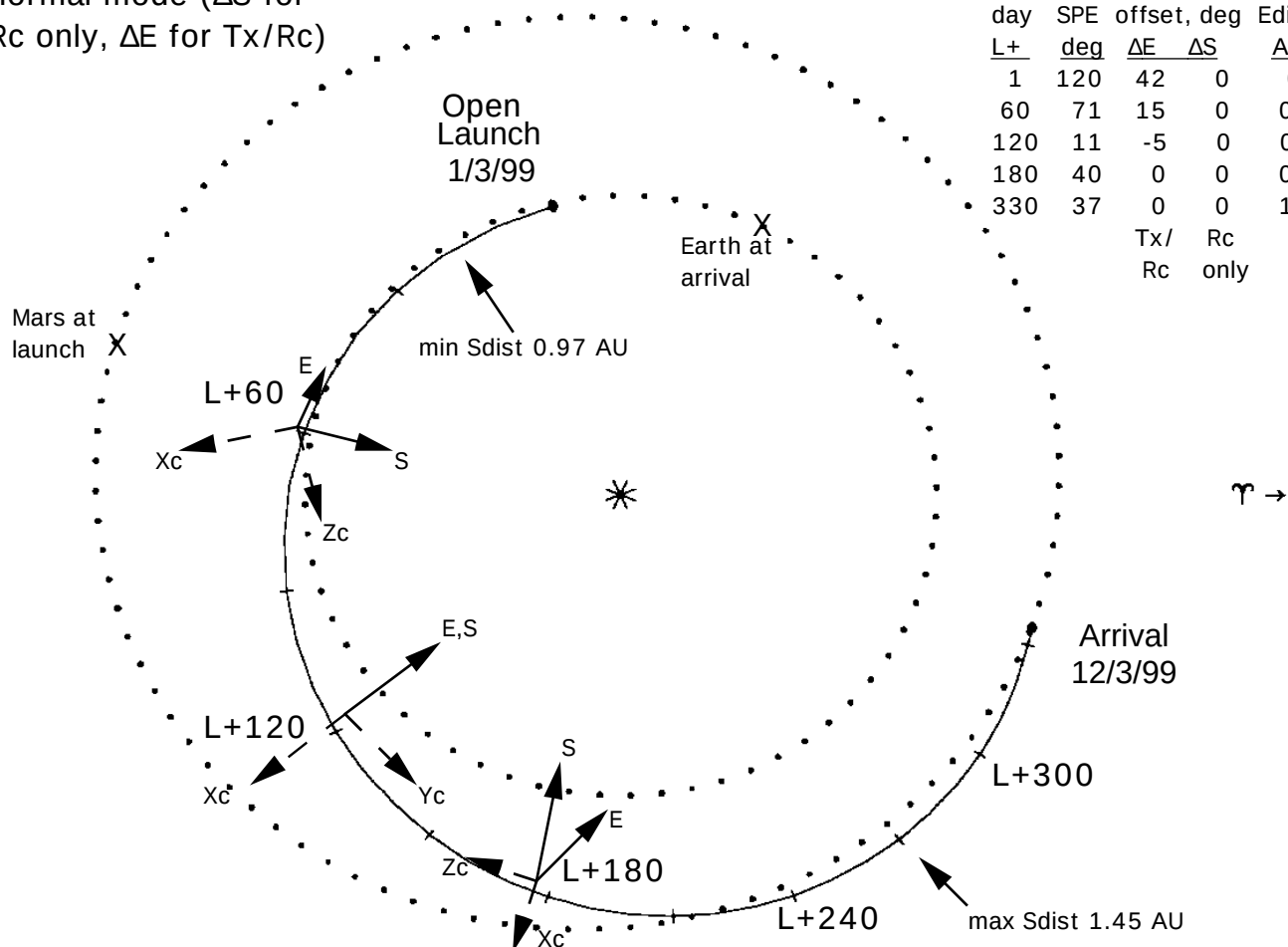
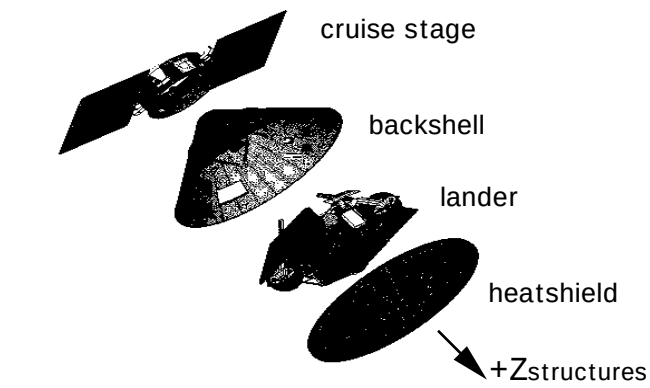
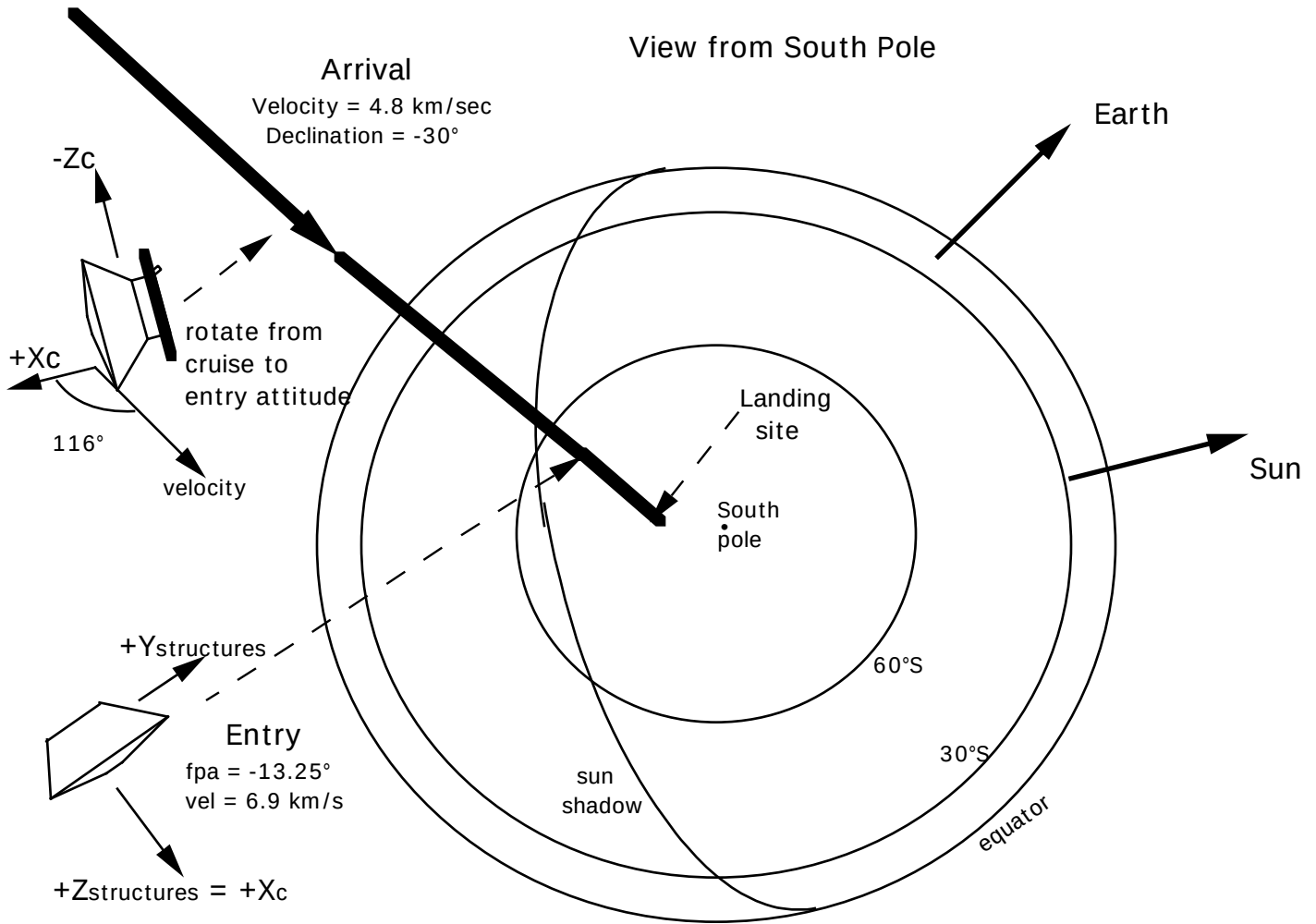


Figure 1.3.6.13.1-2 Lander Cruise Geometry



Typical Arrival Timeline		
Event	Time	Altitude, km
TCM-5	E-7 hr	125,000
Rotate to entry	E-7 m	1450
Cruise stage sep	E-5 m	950
Cruise probe sep	E-4:40	900
Entry	E	125
Parachute deploy	E+2:30	7
Desc engines start	E+4:00	2
Landing	E+4:40	0



launch period		arrival		landing	
day	date	date	latitude	LTST	
open	1/3/99	12/3/99	76°S	4:14	
close prim	1/10/99	12/3/99	75°S	4:10	
close	1/16/99	12/15/99	75°S	3:37	

Figure 1.3.6.13.1-3 Mars Approach to Landing

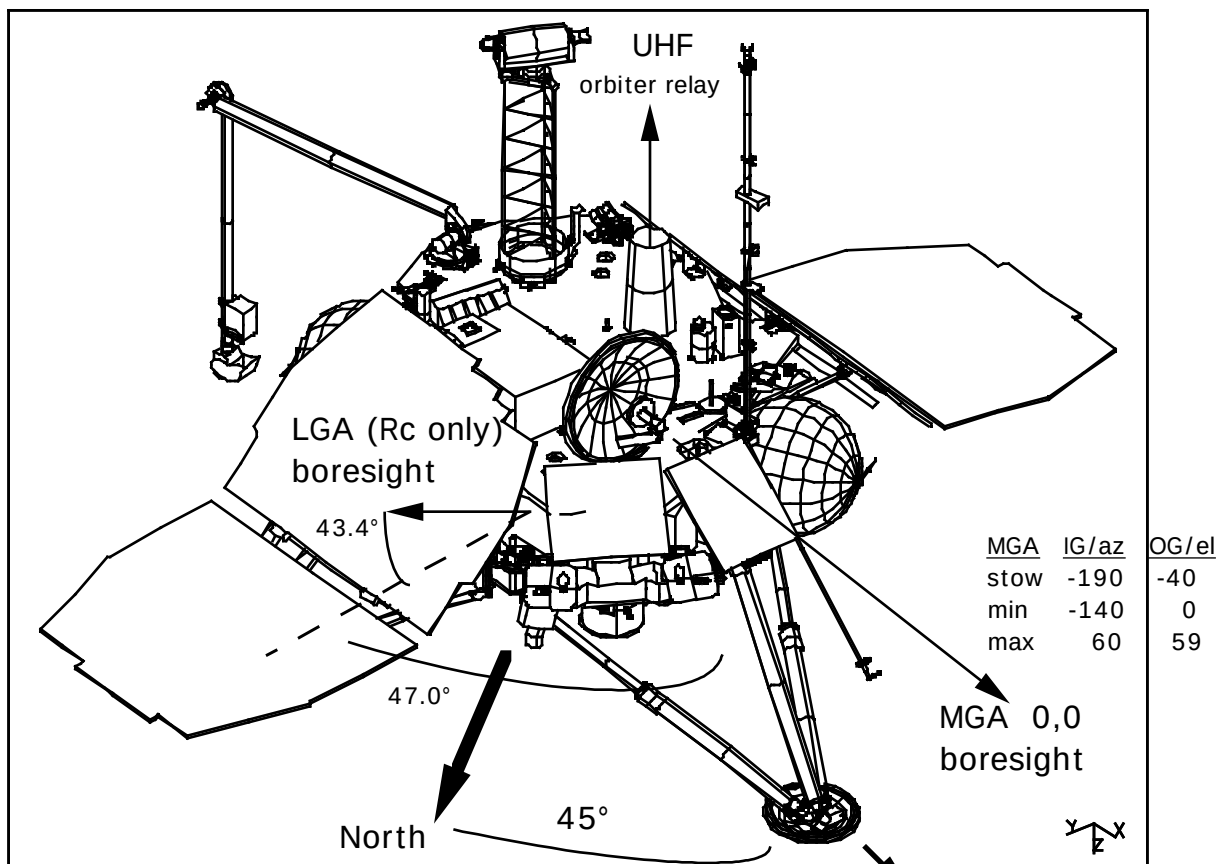


Figure 1.3.6.13.1-4 Landed Configuration

B.7 Lander Navigation Memo

This memo was last updated November 26, 1996, and should be used only as a general discussion of the navigation approach and assumptions used in the navigation analysis. Since the last update, there have been changes in approach deadbands and propulsion system characteristics, addition of DSN and other constraints, and additional navigation analyses have been undertaken. All of these changes will affect both ΔV estimates and approach control capabilities.

To: Distribution
From: Pieter Kallemeyn
Subject: Navigation analysis report for the Mars Surveyor '98 Lander

SUMMARY

This memo details the work to date in characterizing the navigation capability for the Mars Surveyor '98 Lander mission. This report supersedes those results that were first presented in Reference [1].

Statistical information on the required ΔV for interplanetary TCM usage was calculated using the resulting OD error covariances, execution errors for the TCMs and an injection error covariance from McDonnell Douglas (received June 12, 1996). The total interplanetary ΔV required for 95% confidence is 61.2 m/sec. The 1σ B-plane guidance error ellipse for the last midcourse maneuver is 3.16 km by 0.13 km with an uncertainty in the linearized time of flight of 0.12 seconds. This guidance error is equivalent to a 3σ uncertainty in flight path angle at entry of 0.46° .

INTERPLANETARY PHASE NAVIGATION ANALYSIS

Reference Trajectory

The reference trajectory used for this orbit determination and guidance analysis is a Type 2 Earth-Mars transfer corresponding to the first day of the MSP '98 lander primary launch period. The trajectory is shown in Figure 1 and summarized in Table 1.

LANDER TRAJECTORY OPEN OF PRIMARY LAUNCH PERIOD

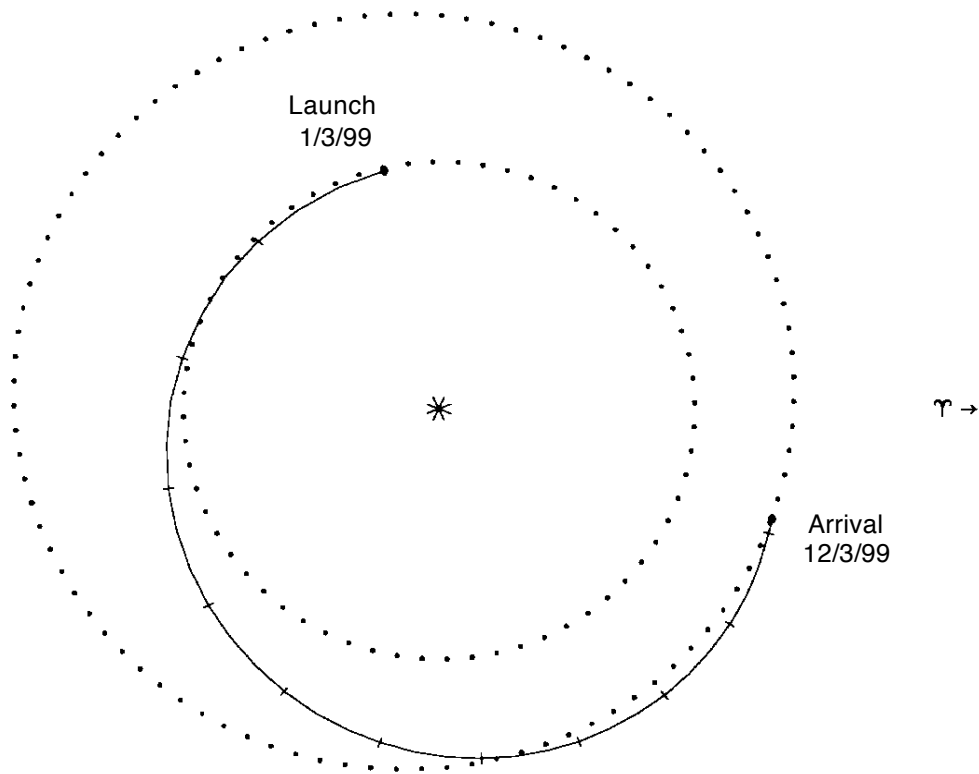


Figure 1: Mars '98 lander trajectory corresponding to a 1/3/1999 launch

Table 1: Lander reference trajectory characteristics

Injection Date	Arrival Date	Length	Arrival V_{∞} (km/sec)
1/3/1999, 21:20	12/3/1999, 20:25	333 days 23 hours	4.84

Trajectory Correction Maneuvers

The five opportunities currently planned for interplanetary trajectory correction maneuvers (TCM's) are described in Table 2.

Table 2: Scheduled trajectory correction maneuvers

TCM #	Relative Date	Calendar Date	Comments
TCM-1	Launch+15 days	1/18/99	Corrects LV injection errors
TCM-2	Launch+30 days	2/17/99	Corrects NAV errors at TCM-1
TCM-3	Arrival-60 days	10/4/99	Targets to orbit insertion point
TCM-4	Arrival-2 days	12/1/99	Corrects errors from TCM-3
TCM-5	Arrival-8 hours	12/3/99	Final targetting maneuver

ORBIT DETERMINATION ASSUMPTIONS

Tracking Data

Table 3 shows the tracking coverage assumed for the orbit determination analysis. For the first 30 days of flight, there will be 1 pass (4 hours duration) per day. After 30 days of flight, the tracking schedule is decreased to 1 pass (4 hours duration) per DSN complex per week, giving a total of 3 passes per week.

Because it is important to reconstruct the TCM's, monitoring them will require more than 3 passes per week. Therefore, 3.5 days before a TCM, tracking coverage is increased to 1 pass (4 hours) per day, and is maintained until 3.5 days after the TCM is completed. For this OD study, it was assumed that tracking coverage could be increased to 3 passes per day during the 24-hour period centered on the maneuver time. It is expected, however, that a single 4-hr pass would be sufficient for this time. It is important that the entire TCM execution be monitored from a single DSN station.

Near-Simultaneous Tracking of the Lander and Orbiter

The final 45 days of flight is the most critical for navigation, therefore tracking coverage is increased from 3 passes per week to 3 passes per day. Starting 30 days before lander arrival, tracking data from the lander will be combined with tracking data from the MSP '98 Orbiter (which would be aerobraking during this time) or the Mars Global Surveyor. This technique, dubbed "near-simultaneous orbiter/lander tracking", reduces the effects of error sources that are common to both spacecraft. These error sources include station locations, Earth orientation, troposphere and ionosphere delay, Earth and Mars ephemeris, and solar plasma. By simultaneously reducing the tracking data from both spacecraft, a better estimate of the lander's trajectory (with respect to Mars) is possible.

For this OD study, tracking data from the lander for the final 45 days was simulated in a "4 hours ON-5 hours OFF" manner consistent with the current transmitter on-off cycle limits. For the final 30 days of flight, tracking data from the MSP '98 Orbiter was simulated such that there would be 4 hours of orbiter data during the 5-hour tracking data gap from the lander, and vice-versa (see figure 2). The actual schedule of tracking passes for the Orbiter and Lander during this time is yet to be finalized, and will depend on transmitter on-off times for each spacecraft as well as which orbiter (MSP '98 or MGS) is used.

Table 3: Tracking Data schedule for lander OD analysis

Period	Tracking Schedule
Launch to Launch + 30 days	One 4-hour pass of Doppler and range per day
Launch +30 to Arrival -45 days	one 4-hour pass per complex per week (3 passes/week) of Doppler and range
Arrival - 45 days to Arrival	Approx. 3 passes per day (4 h ON/5 h OFF) of Doppler and range.
<i>Coverage for TCM-1, -2 and -3:</i>	
TCM -/+ 3.5 days	One 4-hour pass per day of Doppler and range
TCM -/+ 12 hours	Three 4-hour passes of Doppler and range

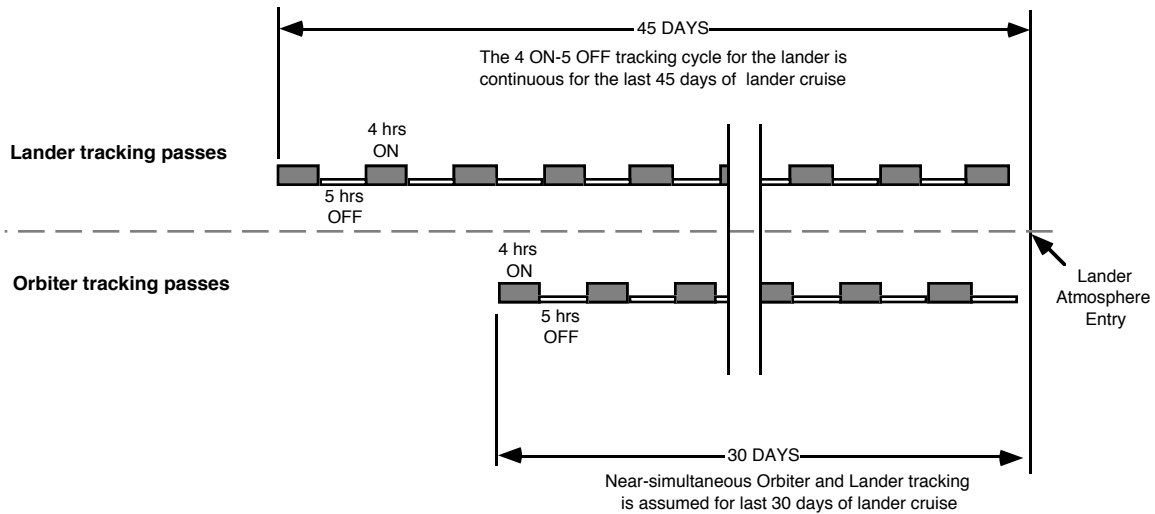


Figure 2: Near-Simultaneous Tracking Schedule used for OD study

Orbit Determination Error Sources

Table 4 gives a summary of the error sources included in the OD study, their nominal value, and level of assumed uncertainty. Many of the error sources (such as media, Earth motion, and non-gravitational accelerations) are assumed to be random in nature, and are therefore modeled as first-order Gauss-Markov processes. This model involves statistically correlated behavior, and is useful for describing these phenomena. Table 4 gives the steady-state uncertainty and the correlation time for the stochastic parameters. Parameters listed in Table 4 without these values, such as solar pressure, station locations, initial position and velocity, were assumed to be non-stochastic (bias) parameters. A complete description of these error source models can be found in References [2] through [6].

Modelling Non-Grav Errors Caused by Attitude Control

The Lander is three-axis stabilized, relying on star camera and ring-laser gyros for attitude determination and a set of eight thrusters for attitude control. During communication periods, the lander is assumed autonomously control its attitude with a deadband of 10.0° . In-between communication periods, this deadband is loosened to 60.0° [7]. The non-gravitational errors due to the unpredictability of thruster activity is the largest contributor to the overall guidance error. Therefore, considerable attention was paid toward the modelling of their effect for the orbit determination problem.

It was decided to use a stochastic acceleration model in the filter to model these nongrav effects. The direction of the accelerations was assumed fixed to the spacecraft coordinate frame, and the spacecraft frame was assumed to be Sun pointed. When tracking data was available from the Lander, the acceleration solutions are updated every 20 minutes. while in-between tracking periods, the acceleration solutions are updated every 80 minutes. The relative size of the three components of the acceleration updates were adjusted to account for the relative placement of the ACS thrusters and the expected thruster firing frequency [7]. Table 5 gives the values of the stochastic acceleration model used for this study.

Table 4: Orbit Determination error assumptions for MSP '98 Lander interplanetary cruise

Error Source	Nominal value	Apriori uncertainty (1 σ)	Corr. Time (days)	Steady-State Unc.	Comments
2-way Doppler noise	-	3 mHz	-	-	
SRA range noise	-	1.4 meters	-	-	
Initial Position (lander and orbiter)	variable	100 km	-	-	
Initial Velocity (lander and orbiter)	variable	1.0 km/s	-	-	
Solar Radiation Model for lander:					
entry vehicle: specular	0.15	0.15	-	-	2.4 m ² , Sun pointed
diffuse	0.09	0.09	-	-	
solar panels: specular	0.1	0.1	-	-	2.4 m ² Sun pointed
diffuse	0.37	0.37	-	-	
S/C component area	100%	1%	-	-	error in sunlit area
self-induced delta-V from autonomous attitude control		variable	zero	variable	(see table ?? below)
TCM magnitude ¹	variable	0.33% (TCM1) 0.66% (TCM2-5)	-	-	from Exhibit 1
TCM pointing	variable	0.33% (TCM1) 0.66% (TCM2-5)	-	-	
Station-induced range bias	0	1 meter	0.0 d	1 meter	independent across all three stations
S/C-induced range bias	-	7 meters (lander) 1 meter (orbiter)	zero	-	assumed constant for all of cruise
Troposphere calibrations	0	5 cm	0.1 d	5 cm	
Night Ionosphere calibrations	0	1 cm	1.0 d	1 cm	
Day Ionosphere calibrations	0	3 cm	0.2 d	3 cm	
Station locations	variable	10 cm	-	-	
Polar Motion calibrations	0	10 cm	2.0 d	10 cm	
UTC calibration	0	30 cm	1.0 d	30 cm	

¹ In addition to this proportional magnitude error, there is a fixed magnitude error (1 σ) of .033 m/s when $\Delta V > 2$ m/s (TCM-1) and 0.0033 m/s when $\Delta V < 2$ m/s (TCMs 2-5) [Exhibit 1, requirement 3.C.2].

Table 5: Stochastic Acceleration Model Parameters for MSP '98 Lander

Time period	Solution updates	Process Noise (PSIGMA) Values (in km/s ²)		
		Sun-line (Radial)	Out-of-Plane (Normal)	In-Plane (Transverse)
During a tracking pass:	every 20 minutes	8.3E-13	7.6E-12	7.6E-12
Inbetween tracking passes	every 80 minutes	2.1E-13	1.9E-12	1.9E-12

Orbit Determination Analysis Results

The Orbit Determination Program (ODP) coupled with the MIRAGE OD filter was used for this analysis [8]. MIRAGE employs a batch-sequential filtering method to a set of simulated Doppler and range data (scheduled according to Table 3). For maneuvers 1 through 4, tracking data up to 5 days before each TCM was reduced and fit to the reference trajectory. For TCM-5, tracking data up to 10 hours before entry was used, with TCM-5 occurring at Entry-8 hours (operational constraints may require this maneuver to be moved closer to entry). The orbit determination error covariance was mapped to the Mars-centered, Mars-Mean-Equator of Date *B*-plane at a time 1 hour before closest approach to Mars (A description of this coordinate frame is provided in Appendix A). The important results are the size, shape and orientation of the error ellipse in the two-dimensional *B*-plane and the linearized time of flight uncertainty. The orbit determination knowledge uncertainties for each of the five TCM's are described in Table 6 and illustrated in Figure 3.

Table 6: Lander orbit determination knowledge uncertainty (1 σ) at the time of TCM design (TCM-5 days).

[The reference frame is the Mars-Centered, Mars Mean Equator of Date *B*-plane while the reference time is 1 hour prior to closest approach to Mars]

	Ellipse Semi-Major Axis (km)	Ellipse Semi-Minor Axis (km)	Ellipse orientation relative to T-axis	Linearized time of flight (seconds)
TCM-1	894	39	25°	57
TCM-2	182	14	20°	14
TCM-3	7.03	2.6	107°	1.1
TCM-4	4.10	0.25	105°	0.31
TCM-5	3.13	0.11	103°	0.12

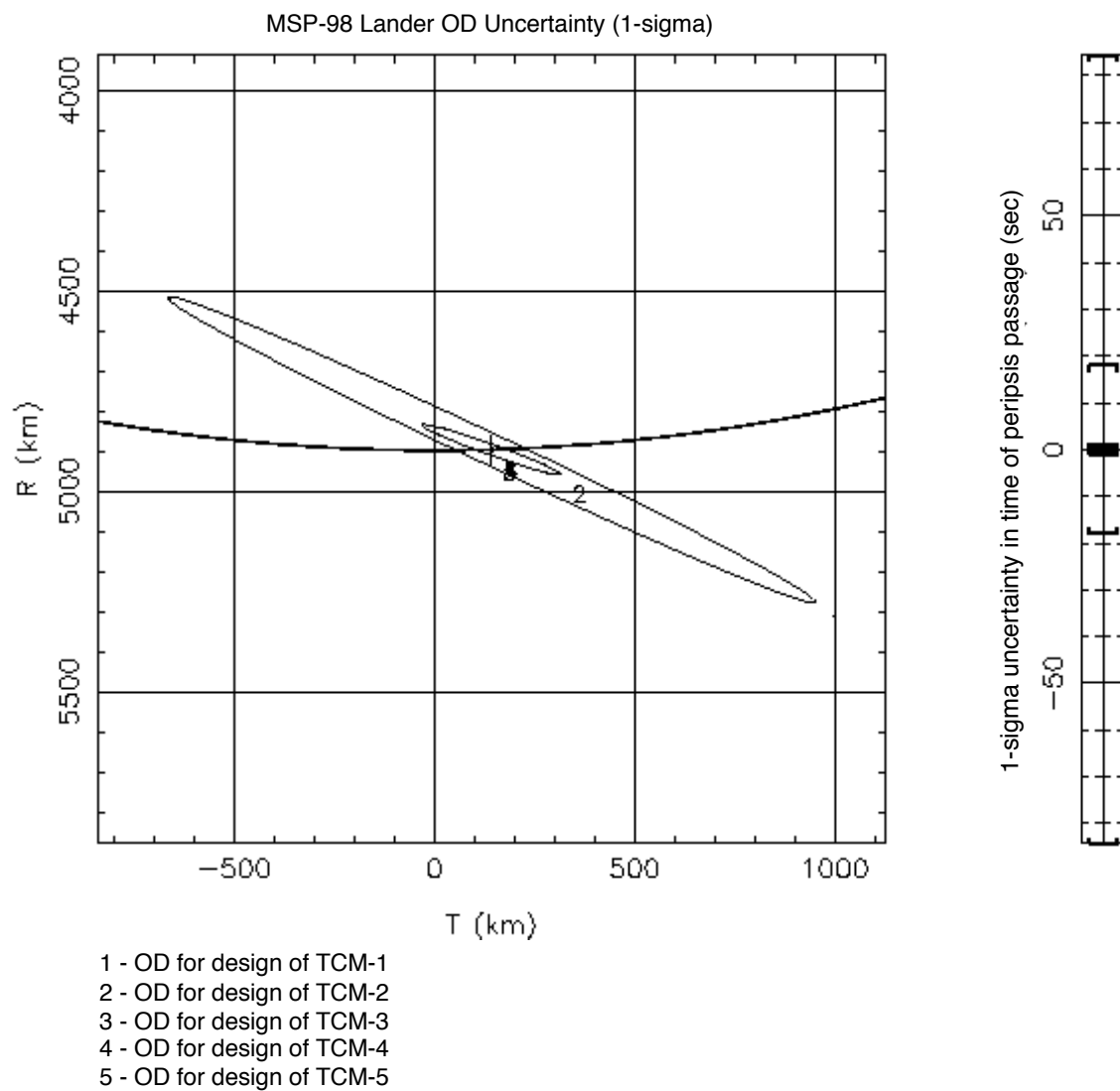


Figure 3a: Orbit determination results for the Lander mapped in the B-plane

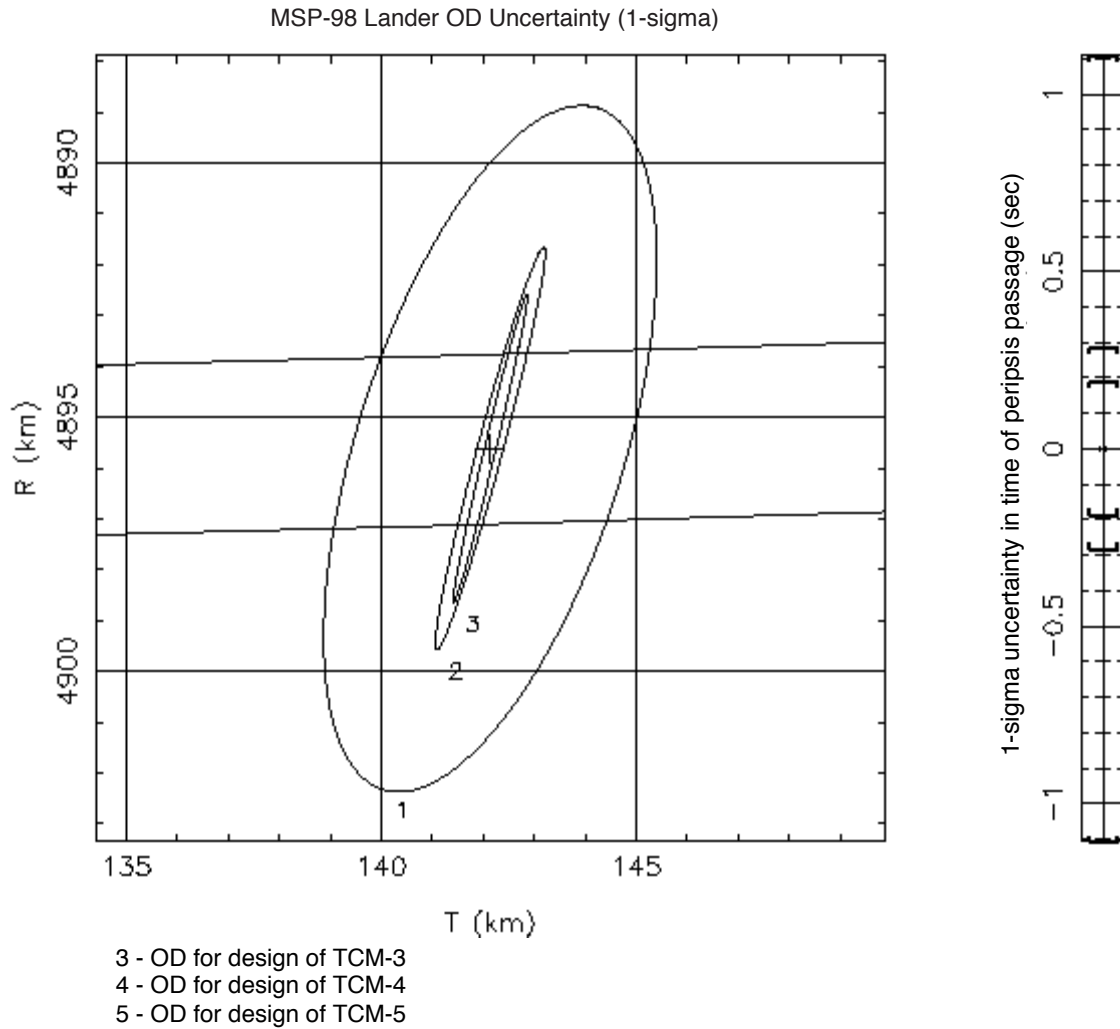


**Figure 3b: Orbit determination results for the Lander mapped in the B-plane
(for TCM3,TCM4 and TCM5)**

Guidance Analysis Results

The OD results from Table 5 were combined with the maneuver execution assumptions described in Table 7 below to determine statistical data on the ΔV magnitude required for all four TCMs. The JPL programs INJCOV, LAMBIC, and PQ were used for this analysis [9].

Table 7: Trajectory correction maneuver assumptions for lander

Deterministic part of TCM-1	Fixed Magnitude Error (1- σ)	Proportional Magnitude Error (1- σ)	Proportional Pointing Error (1- σ)
13.8 m/s	0.033 m/s for TCM-1 0.0033 m/s for TCM 2-5	0.33% for TCM-1 0.66% for TCM 2-5	0.33% for TCM-1 0.66% for TCM 2-5

The launch vehicle injection errors were modeled with a covariance supplied by McDonnell-Douglas for the Delta-II 7425 launch vehicle received June 12, 1996. (see Appendix B). Using K-matrices for the nominal trajectory, this injection covariance was mapped to the

Mars B-plane at closest approach. The resulting 1-sigma uncertainty ellipse is shown in Figure 4 along. NASA planetary protection regulations requires the injection aimpoint to positioned so that the probability of the upper stage impacting Mars is less than 10^{-4} . Therefore the launch vehicle aimpoint was targeted to $B \cdot R = 60,000$ km, $B \cdot T = -20,000$ km, as shown in Figure 4. Critical plane targetting of TCM-1 was not used in this analysis (as it was for the MSP '98 Orbiter analysis), because the lander needs to arrive at Mars at a pre-determined time in order to lander and the desired location.

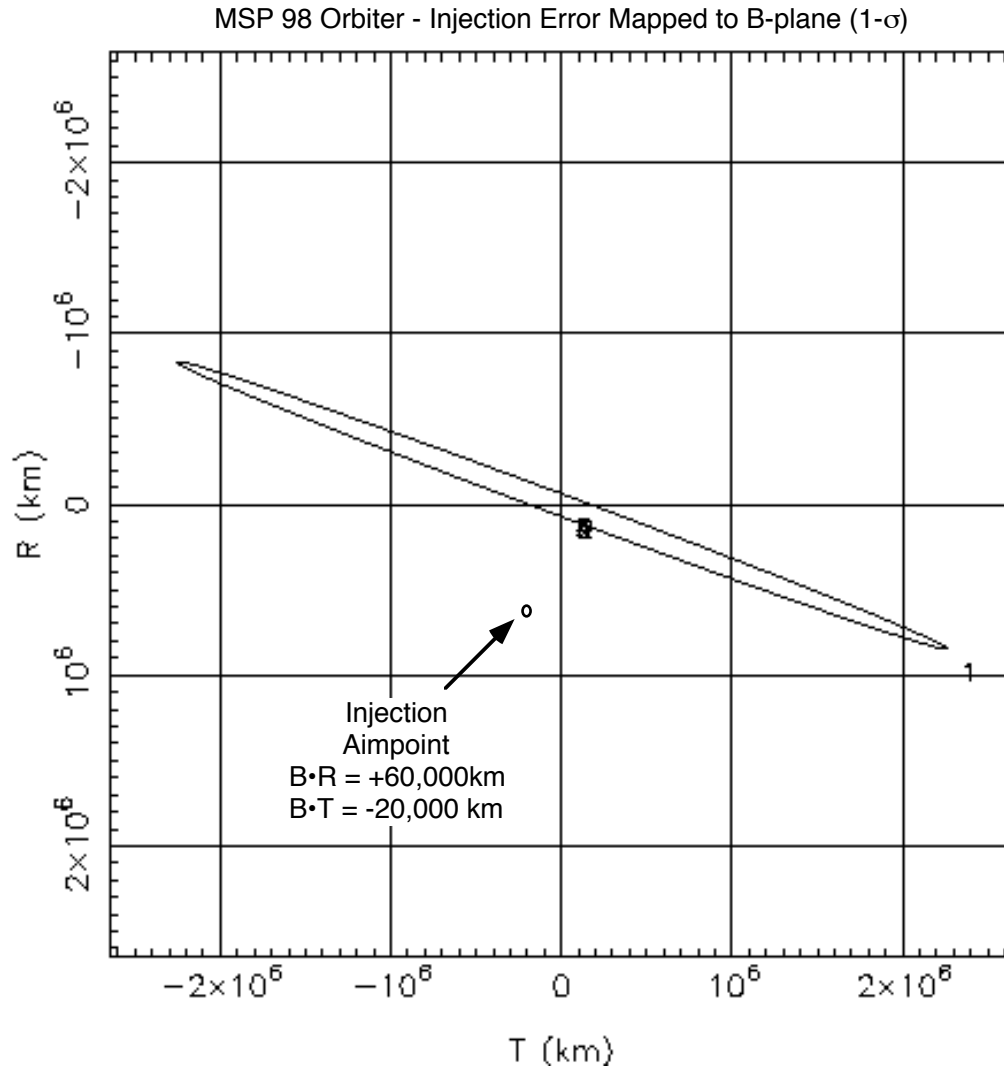


Figure 4: Injection error covariance mapped to the Mars B-plane, and injection aimpoint for $P(\text{impact}) < 1.0 \text{E-}4$

Table 8 gives the ΔV results from LAMBIC. Figure 5 is a histogram illustrating the statistical spread of required ΔV for the lander.

Table 8: Results of maneuver analysis (m/s) for lander

Maneuver	Mean	1 σ	95%-low	95%-high
TCM-1	30.28	16.0	9.86	59.90
TCM-2	0.41	0.34	0.08	1.07
TCM-3	0.17	0.18	0.01	0.53
TCM-4	0.09	0.05	0.03	0.18
TCM-5	0.16	0.10	0.04	0.36
Mission Total	31.10	16.25	10.29	61.20

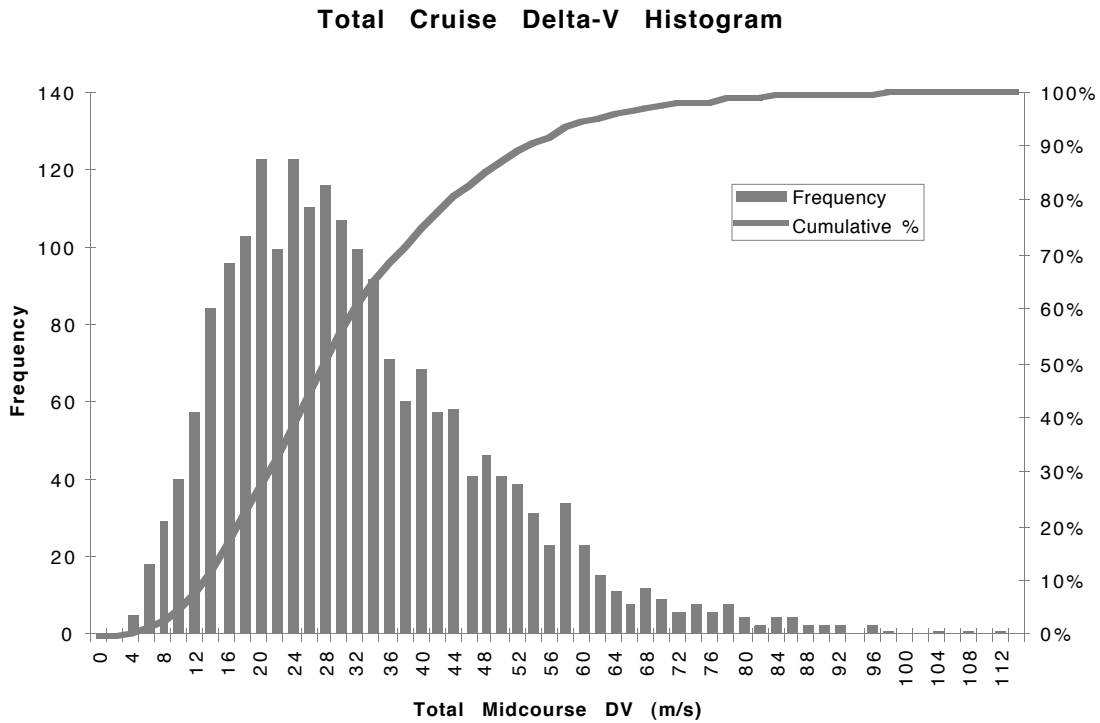


Figure 5: Histogram of maneuver ΔV (m/s) for interplanetary TCM usage

LAMBIC also provides the guidance error covariance, mapped to the Mars-Centered B-plane at closest approach (Table 9 and Figure 6). The guidance error is different than the OD error in that it includes maneuver execution errors. Guidance error from TCM-1 and TCM-2 are considerably larger than the corresponding OD error because these maneuvers are large and the resulting maneuver ΔV error is also large. Also, there is considerably more time between execution of these maneuvers and the arrival at Mars, so these errors propagate longer into a larger B-plane error. TCM-3 thru TCM-5 are much smaller maneuvers and they occur closer to Mars, therefore their resulting guidance errors are not significantly larger than their corresponding OD errors.

Table 8: Maneuver Delivery Uncertainty Ellipses (1- σ) for lander mapped in the Mars-centered, Mars Mean Equator of Date B-plane

	Semi-Major Axis (km)	Semi-Minor Axis (km)	Ellipse Orientation to T-axis	Linearized Time of Flight
TCM-1	12871	538	19°	1060
TCM-2	1209	38	19°	93.7
TCM-3	19.1	10.8	17°	2.55
TCM-4	4.1	0.63	105°	0.33
TCM-5	3.16	0.13	104°	0.12

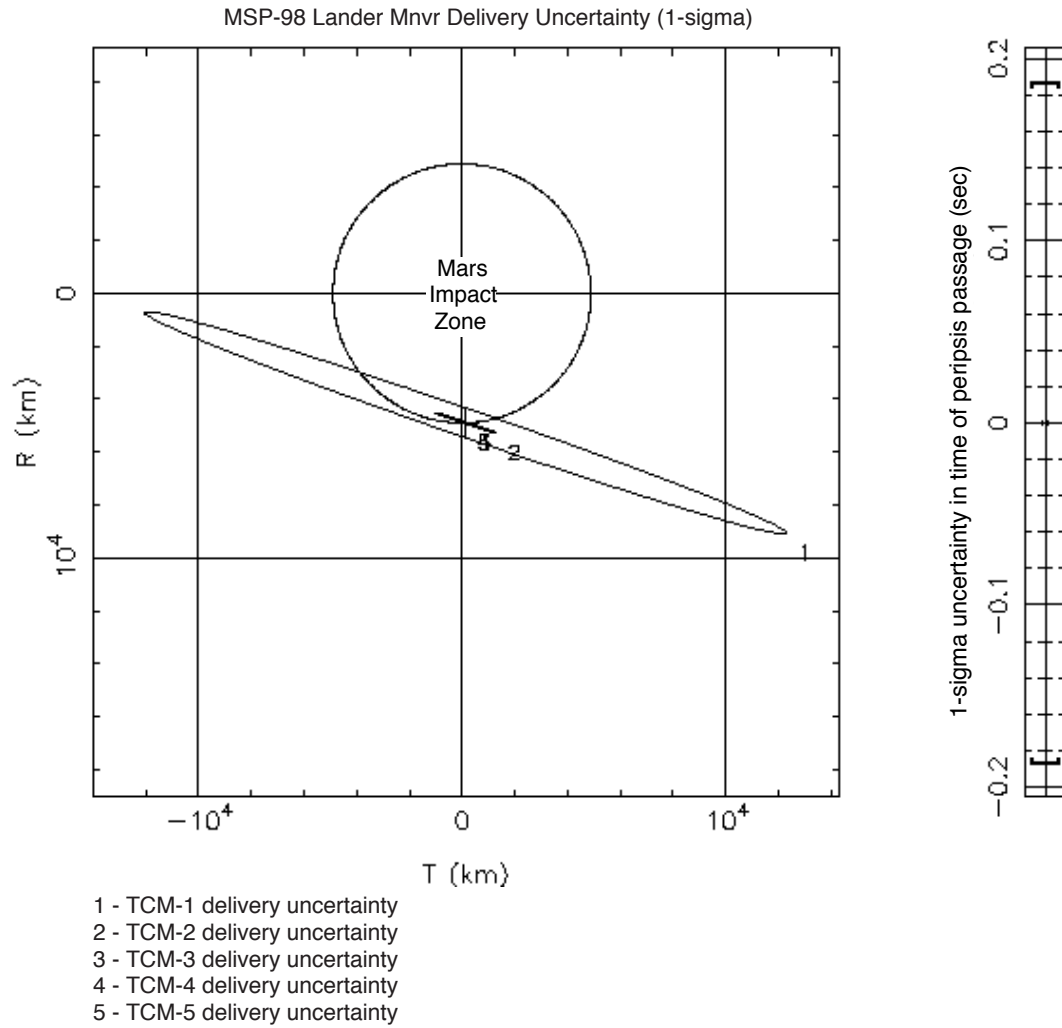


Figure 6a: Guidance error results (1- σ) for the lander, mapped in the Mars-centered, Mars Mean Equator of Date B-plane (TCM-1 and TCM-2)

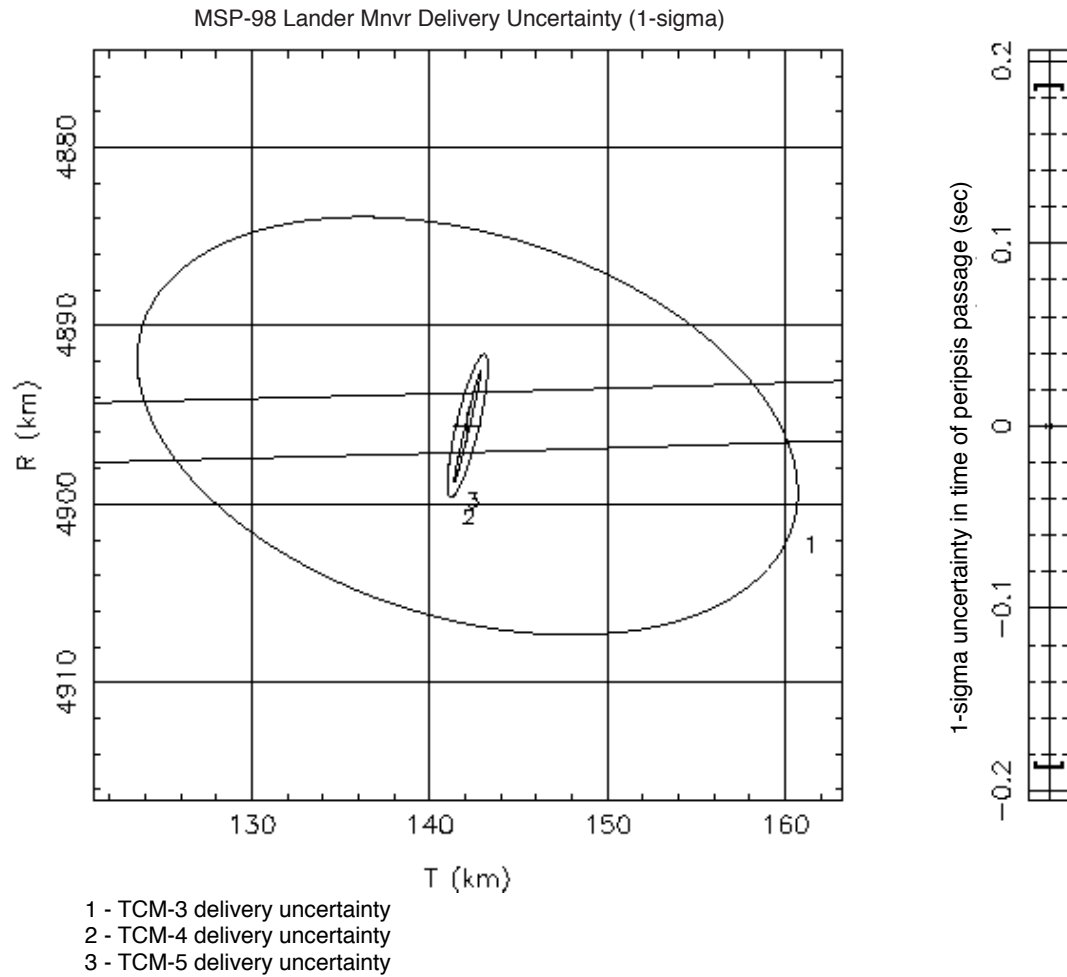


Figure 6b: Guidance error results (1- σ) for the lander, mapped in the Mars-centered, Mars Mean Equator of Date B-plane (TCM-3, TCM-4 and TCM-5)

Comments

1) **Nongrav modelling:** Although detailed, the nongrav model used in this study needs to be improved upon for flight operations. It will be necessary to establish a detailed interface from the Spacecraft Engineering group to the NAV group that provides an accurate history (time and ΔV direction/magnitude) of not only past thruster activity obtained from telemetry, but also the best estimate of predicted thruster activity. This thruster ΔV history will be used by the NAV team as *a priori* information both for flight path prediction as well as nongrav error estimation.

2) **Possible improvements to this baseline:** The largest single contributor to the guidance error budget is the nongrav effects arising from attitude control. If this effect can be minimized in the last few weeks before entry, it will certainly improve the overall uncertainty. If you can't "minimize the errors", then "maximize the data". It might be more practical to improve the data quality to achieve an overall guidance error improvement. For Mars '98, range is the primary data type, and for this OD study it was weighted at 1.4 meters (based on an

extrapolation of the current Mars Pathfinder capabilities). If it's possible to improve the ranging capability on both the spacecraft and station end, an improvement in the guidance errors will follow.

DISTRIBUTION

JPL:

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Appendix A

Definition of the Asymptotic Aiming Plane Coordinate System (B-plane)

The asymptotic aiming plane, or *B-plane*, coordinate system, is shown in Fig. 7. The orientation of this system in space is defined by the arrival asymptote direction, designated $\mathbf{S}$, which is parallel to the velocity vector $\mathbf{V}_\infty$. The unit vectors $\mathbf{T}$ and $\mathbf{R}$ form an orthogonal triad with $\mathbf{S}$; the direction of $\mathbf{T}$ is chosen to lie in the Martian equatorial plane, at a given date. The point of aim corresponding to the desired landing site is defined by the miss vector, $\mathbf{B}$, in Fig. 7, which is oriented in the $\mathbf{T}$ - $\mathbf{R}$ plane, called the *B-plane*, by the angle ϕ , and has magnitude $|\mathbf{B}|$. The miss vector specifies where the point of closest approach would be if the target body had no mass and did not deflect the flight path. Navigational uncertainty is characterized by a two-dimensional dispersion ellipse in the B-plane with semi-major axis SMA , semi-minor axis $SMIA$, and orientation angle θ , and by the uncertainty in the time of arrival at the point of atmospheric entry, the time of arrival.

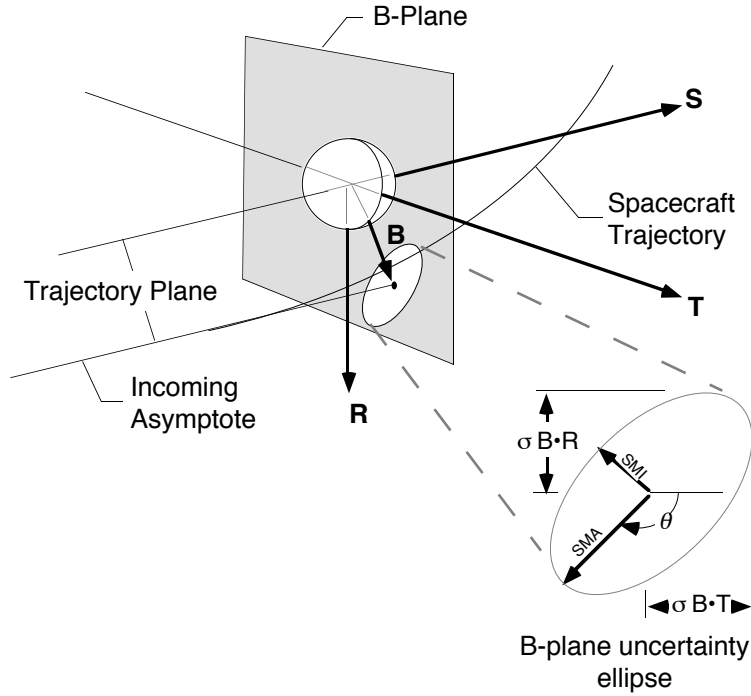


Figure 7: Target-centered aiming plane (B-plane) coordinate system.

Appendix B

Injection error covariance of the Delta II 7425 Launch Vehicle for the Mars Surveyor '98 lander mission

Delta 7425 MARS LANDER Mission - 1/3/99 Launch Date
Preliminary Orbit Injection Covariance Matrix without PCS Effects
Based on Updated Velocity Pointing Error and Coning Velocity loss

MSP LANDER - 1/3/99 --99.7% PCS -- 95 FLT AZ

COVARIANCE MATRIX OF TECO INJECTION CONDITIONS BASED ON -3 SIGMA SENSITIVITIES

		VELOCITY	GAMMA	AZIMUTH	LONG. + W	LATITUDE	RADIUS
		FT/SEC	DEGREES	DEGREES	DEGREES	DEGREES	FEET
VELOCITY	FT/SEC	0.20481144E+03	-0.34414708E+00	0.24644275E+00	0.11585842E-01	0.65757311E-02	-0.14555668E+05
GAMMA	DEGREES	-0.34414708E+00	0.34200888E-01	-0.79730416E-03	-0.27300273E-02	-0.12506890E-02	0.55998423E+01
AZIMUTH	DEGREES	0.24644275E+00	-0.79730416E-03	0.33821900E-01	0.21692060E-02	0.99387262E-03	0.10299844E+02
LONG. + W	DEGREES	0.11585842E-01	-0.27300273E-02	0.21692060E-02	0.72944830E-02	0.33353893E-02	0.37684516E+02
LATITUDE	DEGREES	0.65757311E-02	-0.12506890E-02	0.99387262E-03	0.33353893E-02	0.15323557E-02	0.15713724E+02
RADIUS	FEET	-0.14555668E+05	0.55998423E+01	0.10299844E+02	0.37684516E+02	0.15713724E+02	0.18575764E+08
THETA LP	DEGREES	-0.10951174E+01	0.11077725E+00	-0.23624354E-02	-0.81764250E-02	-0.37420695E-02	-0.38567364E+02
PSI LP	DEGREES	0.79214216E+00	-0.76392393E-03	0.10848763E+00	0.21700173E-02	0.99264329E-03	0.10301716E+02
		THETA LP	PSI LP				
		DEGREES	DEGREES				
VELOCITY	FT/SEC	-0.10951174E+01	0.79214216E+00				
GAMMA	DEGREES	0.11077725E+00	-0.76392393E-03				
AZIMUTH	DEGREES	-0.23624354E-02	0.10848763E+00				
LONG. + W	DEGREES	-0.81764250E-02	0.21700173E-02				
LATITUDE	DEGREES	-0.37420695E-02	0.99264329E-03				
RADIUS	FEET	-0.38567364E+02	0.10301716E+02				
THETA LP	DEGREES	0.35911889E+00	-0.22105251E-02				
PSI LP	DEGREES	-0.22105251E-02	0.35121659E+00				

Delta 7425 MARS LANDER Mission - 1/3/99 Launch Date
Preliminary Orbit Injection Covariance Matrix (NASA SYSTEM) without PCS Effects
Based on Updated Velocity Pointing Error and Coning Velocity loss

MSP LANDER - 1/3/99 --99.7% PCS -- 95 FLT AZ

COVARIANCE MATRIX OF TECO INJECTION CONDITIONS BASED ON -3 SIGMA SENSITIVITIES

		X (NASA) FEET	Y (NASA) FEET	Z (NASA) FEET	VX (NASA) FT/SEC	VY (NASA) FT/SEC	VZ (NASA) FT/SEC
X (NASA)	FEET	0.12955602E+10	-0.44595644E+06	-0.11353480E+08	0.20861946E+05	0.87340089E+01	-0.15132762E+07
Y (NASA)	FEET	-0.44595644E+06	0.81890678E+06	0.72748347E+04	-0.11564407E+02	-0.39518354E+03	0.52334715E+03
Z (NASA)	FEET	-0.11353480E+08	0.72748347E+04	0.18629851E+08	-0.15000721E+05	0.25932517E+00	0.25271242E+05
VX (NASA)	FT/SEC	0.20861946E+05	-0.11564407E+02	-0.15000721E+05	0.21395418E+03	-0.22743382E+03	-0.41093276E+03
VY (NASA)	FT/SEC	0.87340089E+01	-0.39518354E+03	0.25932517E+00	-0.22743382E+03	0.14425404E+05	-0.94326117E+01
VZ (NASA)	FT/SEC	-0.15132762E+07	0.52334715E+03	0.25271242E+05	-0.41093276E+03	-0.94326117E+01	0.16195217E+05
THETA LP	DEGREES	0.34462515E+04	-0.11851555E+01	-0.30232036E+02	-0.18426648E+01	-0.46291040E-01	0.67006008E+02
PSI LP	DEGREES	-0.91454712E+03	0.14727620E+00	0.80899712E+01	0.11069379E+01	-0.71110810E+02	0.11134903E+01
		THETA LP DEGREES	PSI LP DEGREES				
X (NASA)	FEET	0.34462515E+04	-0.91454712E+03				
Y (NASA)	FEET	-0.11851555E+01	0.14727620E+00				
Z (NASA)	FEET	-0.30232036E+02	0.80899712E+01				
VX (NASA)	FT/SEC	-0.18426648E+01	0.11069379E+01				
VY (NASA)	FT/SEC	-0.46291040E-01	-0.71110810E+02				
VZ (NASA)	FT/SEC	0.67006008E+02	0.11134903E+01				
THETA LP	DEGREES	0.35911889E+00	-0.22105251E-02				
PSI LP	DEGREES	-0.22105251E-02	0.35121659E+00				

X, Y, Z (NASA) Coordinate System:

Positive x-axis is parallel to the projection of the instantaneous vehicle velocity vector onto a plane perpendicular to the radius vector. Z-axis positive away from the earth along the radius vector. Y-axis completes the right-handed orthogonal system. The origin is at the nominal vehicle position point and the system is inertial.

Delta 7425 MARS Lander Mission - 1/10/99 Launch Date
Preliminary Orbit Injection Covariance Matrix without PCS Effects
Based on Updated Velocity Pointing Error and Coning Velocity loss

MSP LANDER - 1/10/99 --99.7% PCS -- 95 FLT AZ

COVARIANCE MATRIX OF TECO INJECTION CONDITIONS BASED ON -3 SIGMA SENSITIVITIES

		VELOCITY FT/SEC	GAMMA DEGREES	AZIMUTH DEGREES	LONG. + W DEGREES	LATITUDE DEGREES	RADIUS FEET
VELOCITY	FT/SEC	0.23176285E+03	0.97154177E+00	0.21990679E+00	-0.10004462E+00	-0.41921734E-01	-0.16699383E+05
GAMMA	DEGREES	0.97154177E+00	0.34526204E-01	-0.85645106E-03	-0.25898198E-02	-0.11225974E-02	-0.75129331E+00
AZIMUTH	DEGREES	0.21990679E+00	-0.85645106E-03	0.34389507E-01	0.23375187E-02	0.10133142E-02	0.16541624E+02
LONG. + W	DEGREES	-0.10004462E+00	-0.25898198E-02	0.23375187E-02	0.72511665E-02	0.31370227E-02	0.54786821E+02
LATITUDE	DEGREES	-0.41921734E-01	-0.11225974E-02	0.10133142E-02	0.31370227E-02	0.13637945E-02	0.22080169E+02
RADIUS	FEET	-0.16699383E+05	-0.75129331E+00	0.16541624E+02	0.54786821E+02	0.22080169E+02	0.19838134E+08
THETA LP	DEGREES	0.32062229E+01	0.11126253E+00	-0.26623133E-02	-0.80003360E-02	-0.34642081E-02	-0.56371724E+02
PSI LP	DEGREES	0.78086637E+00	-0.89545751E-03	0.10935985E+00	0.23377992E-02	0.10112691E-02	0.16543005E+02
		THETA LP DEGREES	PSI LP DEGREES				
VELOCITY	FT/SEC	0.32062229E+01	0.78086637E+00				
GAMMA	DEGREES	0.11126253E+00	-0.89545751E-03				
AZIMUTH	DEGREES	-0.26623133E-02	0.10935985E+00				
LONG. + W	DEGREES	-0.80003360E-02	0.23377992E-02				
LATITUDE	DEGREES	-0.34642081E-02	0.10112691E-02				
RADIUS	FEET	-0.56371724E+02	0.16543005E+02				
THETA LP	DEGREES	0.35878437E+00	-0.28244087E-02				
PSI LP	DEGREES	-0.28244087E-02	0.35145700E+00				

Delta 7425 MARS LANDER Mission - 1/10/99 Launch Date
Preliminary Orbit Injection Covariance Matrix (NASA SYSTEM) without PCS Effects
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MSP LANDER - 1/10/99 --99.7% PCS -- 95 FLT AZ

COVARIANCE MATRIX OF TECO INJECTION CONDITIONS BASED ON -3 SIGMA SENSITIVITIES

		X (NASA) FEET	Y (NASA) FEET	Z (NASA) FEET	VX (NASA) FT/SEC	VY (NASA) FT/SEC	VZ (NASA) FT/SEC
X (NASA)	FEET	0.12471384E+10	-0.64759778E+06	-0.18236751E+08	0.22970762E+05	0.10227128E+02	-0.14710695E+07
Y (NASA)	FEET	-0.64759778E+06	0.75999307E+06	0.12823007E+05	-0.16205728E+02	-0.44221693E+03	0.76465697E+03
Z (NASA)	FEET	-0.18236751E+08	0.12823007E+05	0.19874635E+08	-0.16197518E+05	0.31738532E+01	0.33266453E+05
VX (NASA)	FT/SEC	0.22970762E+05	-0.16205728E+02	-0.16197518E+05	0.25951160E+03	-0.23298055E+03	0.84254241E+03
VY (NASA)	FT/SEC	0.10227128E+02	-0.44221693E+03	0.31738532E+01	-0.23298055E+03	0.14454554E+05	0.10996707E+02
VZ (NASA)	FT/SEC	-0.14710695E+07	0.76465697E+03	0.33266453E+05	0.84254241E+03	0.10996707E+02	0.16147102E+05
THETA LP	DEGREES	0.33182855E+04	-0.17213248E+01	-0.48559863E+02	0.44352793E+01	0.54042157E-01	0.67080383E+02
PSI LP	DEGREES	-0.96948169E+03	0.15753084E+00	0.14260922E+02	0.11307599E+01	-0.71195772E+02	0.10936408E+01
		THETA LP DEGREES	PSI LP DEGREES				
X (NASA)	FEET	0.33182855E+04	-0.96948169E+03				
Y (NASA)	FEET	-0.17213248E+01	0.15753084E+00				
Z (NASA)	FEET	-0.48559863E+02	0.14260922E+02				
VX (NASA)	FT/SEC	0.44352793E+01	0.11307599E+01				
VY (NASA)	FT/SEC	0.54042157E-01	-0.71195772E+02				
VZ (NASA)	FT/SEC	0.67080383E+02	0.10936408E+01				
THETA LP	DEGREES	0.35878437E+00	-0.28244087E-02				
PSI LP	DEGREES	-0.28244087E-02	0.35145700E+00				

X, Y, Z (NASA) Coordinate System:

Positive x-axis is parallel to the projection of the instantaneous vehicle velocity vector onto a plane perpendicular to the radius vector. Z-axis positive away from the earth along the radius vector. Y-axis completes the right-handed orthogonal system. The origin is at the nominal vehicle position point and the system is inertial.

Delta 7425 MARS Lander Mission - 1/16/99 Launch Date
Preliminary Orbit Injection Covariance Matrix without PCS Effects
Based on Updated Velocity Pointing Error and Coning Velocity loss

MSP LANDER - 1/16/99 --99.7% PCS -- 95 FLT AZ

COVARIANCE MATRIX OF TECO INJECTION CONDITIONS BASED ON -3 SIGMA SENSITIVITIES

		VELOCITY FT/SEC	GAMMA DEGREES	AZIMUTH DEGREES	LONG. + W DEGREES	LATITUDE DEGREES	RADIUS FEET
VELOCITY	FT/SEC	0.20332140E+03	-0.25490987E+00	0.24309051E+00	-0.41689121E-02	-0.62713315E-03	-0.14617355E+05
GAMMA	DEGREES	-0.25490987E+00	0.34517490E-01	-0.74095539E-03	-0.25349086E-02	-0.11631357E-02	0.30083521E+01
AZIMUTH	DEGREES	0.24309051E+00	-0.74095539E-03	0.34203457E-01	0.20745008E-02	0.95199156E-03	0.12526794E+02
LONG. + W	DEGREES	-0.41689121E-02	-0.25349086E-02	0.20745008E-02	0.69837143E-02	0.31979875E-02	0.45240938E+02
LATITUDE	DEGREES	-0.62713315E-03	-0.11631357E-02	0.95199156E-03	0.31979875E-02	0.14716626E-02	0.19191119E+02
RADIUS	FEET	-0.14617355E+05	0.30083521E+01	0.12526794E+02	0.45240938E+02	0.19191119E+02	0.18629072E+08
THETA LP	DEGREES	-0.79878258E+00	0.11123887E+00	-0.22714018E-02	-0.78343934E-02	-0.35909464E-02	-0.47054166E+02
PSI LP	DEGREES	0.78669454E+00	-0.71301128E-03	0.10909061E+00	0.20752840E-02	0.95067191E-03	0.12528598E+02
		THETA LP DEGREES	PSI LP DEGREES				
VELOCITY	FT/SEC	-0.79878258E+00	0.78669454E+00				
GAMMA	DEGREES	0.11123887E+00	-0.71301128E-03				
AZIMUTH	DEGREES	-0.22714018E-02	0.10909061E+00				
LONG. + W	DEGREES	-0.78343934E-02	0.20752840E-02				
LATITUDE	DEGREES	-0.35909464E-02	0.95067191E-03				
RADIUS	FEET	-0.47054166E+02	0.12528598E+02				
THETA LP	DEGREES	0.35874288E+00	-0.21488519E-02				
PSI LP	DEGREES	-0.21488519E-02	0.35097358E+00				

Delta 7425 MARS LANDER Mission - 1/16/99 Launch Date
Preliminary Orbit Injection Covariance Matrix (NASA SYSTEM) without PCS Effects
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MSP LANDER - 1/16/99 --99.7% PCS -- 95 FLT AZ

COVARIANCE MATRIX OF TECO INJECTION CONDITIONS BASED ON -3 SIGMA SENSITIVITIES

		X (NASA) FEET	Y (NASA) FEET	Z (NASA) FEET	VX (NASA) FT/SEC	VY (NASA) FT/SEC	VZ (NASA) FT/SEC
X (NASA)	FEET	0.12420555E+10	-0.43909006E+06	-0.14737716E+08	0.20615450E+05	0.11842071E+02	-0.14643914E+07
Y (NASA)	FEET	-0.43909006E+06	0.81596426E+06	0.81353026E+04	-0.11394285E+02	-0.40431925E+03	0.51801484E+03
Z (NASA)	FEET	-0.14737716E+08	0.81353026E+04	0.18666579E+08	-0.14995076E+05	0.23469204E+00	0.29213427E+05
VX (NASA)	FT/SEC	0.20615450E+05	-0.11394285E+02	-0.14995076E+05	0.20874105E+03	-0.22780977E+03	-0.29628805E+03
VY (NASA)	FT/SEC	0.11842071E+02	-0.40431925E+03	0.23469204E+00	-0.22780977E+03	0.14426882E+05	-0.76091966E+01
VZ (NASA)	FT/SEC	-0.14643914E+07	0.51801484E+03	0.29213427E+05	-0.29628805E+03	-0.76091966E+01	0.16160632E+05
THETA LP	DEGREES	0.33043588E+04	-0.11670049E+01	-0.39240118E+02	-0.12719579E+01	-0.37309041E-01	0.67152201E+02
PSI LP	DEGREES	-0.87521139E+03	0.12525426E+00	0.10459152E+02	0.11085931E+01	-0.71092723E+02	0.10684595E+01
		THETA LP DEGREES	PSI LP DEGREES				
X (NASA)	FEET	0.33043588E+04	-0.87521139E+03				
Y (NASA)	FEET	-0.11670049E+01	0.12525426E+00				
Z (NASA)	FEET	-0.39240118E+02	0.10459152E+02				
VX (NASA)	FT/SEC	-0.12719579E+01	0.11085931E+01				
VY (NASA)	FT/SEC	-0.37309041E-01	-0.71092723E+02				
VZ (NASA)	FT/SEC	0.67152201E+02	0.10684595E+01				
THETA LP	DEGREES	0.35874288E+00	-0.21488519E-02				
PSI LP	DEGREES	-0.21488519E-02	0.35097358E+00				

X, Y, Z (NASA) Coordinate System:

Positive x-axis is parallel to the projection of the instantaneous vehicle velocity vector onto a plane perpendicular to the radius vector. Z-axis positive away from the earth along the radius vector. Y-axis completes the right-handed orthogonal system. The origin is at the nominal vehicle position point and the system is inertial.

Delta 7425 MARS Lander Mission - 1/27/99 Launch Date
Preliminary Orbit Injection Covariance Matrix without PCS Effects
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MSP LANDER - 1/27/99 --99.7% PCS -- 95 FLT AZ

COVARIANCE MATRIX OF TECO INJECTION CONDITIONS BASED ON -3 SIGMA SENSITIVITIES

		VELOCITY	GAMMA	AZIMUTH	LONG. + W	LATITUDE	RADIUS
		FT/SEC	DEGREES	DEGREES	DEGREES	DEGREES	FEET
VELOCITY	FT/SEC	0.20256164E+03	-0.28859402E+00	0.24192418E+00	0.38360094E-02	0.30274768E-02	-0.13310859E+05
GAMMA	DEGREES	-0.28859402E+00	0.34580531E-01	-0.64320840E-03	-0.24528963E-02	-0.11897673E-02	0.53652432E+01
AZIMUTH	DEGREES	0.24192418E+00	-0.64320840E-03	0.34147910E-01	0.17860617E-02	0.86637585E-03	0.93981719E+01
LONG. + W	DEGREES	0.38360094E-02	-0.24528963E-02	0.17860617E-02	0.66758205E-02	0.32314374E-02	0.37788209E+02
LATITUDE	DEGREES	0.30274768E-02	-0.11897673E-02	0.86637585E-03	0.32314374E-02	0.15720338E-02	0.16886651E+02
RADIUS	FEET	-0.13310859E+05	0.53652432E+01	0.93981719E+01	0.37788209E+02	0.16886651E+02	0.17295317E+08
THETA LP	DEGREES	-0.90849039E+00	0.11132532E+00	-0.19796028E-02	-0.76204979E-02	-0.36924877E-02	-0.39843735E+02
PSI LP	DEGREES	0.77721808E+00	-0.61319637E-03	0.10909417E+00	0.17867286E-02	0.86523677E-03	0.93973405E+01

		THETA LP	PSI LP
		DEGREES	DEGREES
VELOCITY	FT/SEC	-0.90849039E+00	0.77721808E+00
GAMMA	DEGREES	0.11132532E+00	-0.61319637E-03
AZIMUTH	DEGREES	-0.19796028E-02	0.10909417E+00
LONG. + W	DEGREES	-0.76204979E-02	0.17867286E-02
LATITUDE	DEGREES	-0.36924877E-02	0.86523677E-03
RADIUS	FEET	-0.39843735E+02	0.93973405E+01
THETA LP	DEGREES	0.35865306E+00	-0.18491752E-02
PSI LP	DEGREES	-0.18491752E-02	0.35088671E+00

Delta 7425 MARS LANDER Mission - 1/27/99 Launch Date
Preliminary Orbit Injection Covariance Matrix (NASA SYSTEM) without PCS Effects
Based on Updated Velocity Pointing Error and Coning Velocity loss

MSP LANDER - 1/27/99 --99.7% PCS -- 95 FLT AZ

COVARIANCE MATRIX OF TECO INJECTION CONDITIONS BASED ON -3 SIGMA SENSITIVITIES

		X (NASA)	Y (NASA)	Z (NASA)	VX (NASA)	VY (NASA)	VZ (NASA)
		FEET	FEET	FEET	FT/SEC	FT/SEC	FT/SEC
X (NASA)	FEET	0.12295151E+10	-0.33172880E+06	-0.12056630E+08	0.18181664E+05	0.11848384E+02	-0.14513680E+07
Y (NASA)	FEET	-0.33172880E+06	0.87211878E+06	0.58532559E+04	-0.89580692E+01	-0.35713073E+03	0.39123956E+03
Z (NASA)	FEET	-0.12056630E+08	0.58532559E+04	0.17329717E+08	-0.13670184E+05	-0.11993797E+01	0.26024879E+05
VX (NASA)	FT/SEC	0.18181664E+05	-0.89580692E+01	-0.13670184E+05	0.20859130E+03	-0.22555044E+03	-0.32316197E+03
VY (NASA)	FT/SEC	0.11848384E+02	-0.35713073E+03	-0.11993797E+01	-0.22555044E+03	0.14426108E+05	-0.80428342E+01
VZ (NASA)	FT/SEC	-0.14513680E+07	0.39123956E+03	0.26024879E+05	-0.32316197E+03	-0.80428342E+01	0.16145903E+05
THETA LP	DEGREES	0.32708142E+04	-0.88161565E+00	-0.32100727E+02	-0.14278825E+01	-0.39431966E-01	0.67182218E+02
PSI LP	DEGREES	-0.76679566E+03	0.34808165E-01	0.75822856E+01	0.11006229E+01	-0.71096270E+02	0.94399803E+00
		THETA LP	PSI LP				
		DEGREES	DEGREES				
X (NASA)	FEET	0.32708142E+04	-0.76679566E+03				
Y (NASA)	FEET	-0.88161565E+00	0.34808165E-01				
Z (NASA)	FEET	-0.32100727E+02	0.75822856E+01				
VX (NASA)	FT/SEC	-0.14278825E+01	0.11006229E+01				
VY (NASA)	FT/SEC	-0.39431966E-01	-0.71096270E+02				
VZ (NASA)	FT/SEC	0.67182218E+02	0.94399803E+00				
THETA LP	DEGREES	0.35865306E+00	-0.18491752E-02				
PSI LP	DEGREES	-0.18491752E-02	0.35088671E+00				

X, Y, Z (NASA) Coordinate System:

Positive x-axis is parallel to the projection of the instantaneous vehicle velocity vector onto a plane perpendicular to the radius vector. Z-axis positive away from the earth along the radius vector. Y-axis completes the right-handed orthogonal system. The origin is at the nominal vehicle position point and the system is inertial.

Delta 7425 MARS Lander Mission
Preliminary 99.7 % PCS Effects on Injection Velocity

MSP LANDER - 1/3/99 --99.7% PCS -- 95 FLT AZ

=====			
VELOCITY DEFICIT VS. PROBABILITY			
=====			
VELOCITY DEFICIT (FPS)	PROBABILITY LEVEL	VELOCITY DEFICIT (FPS)	PROBABILITY LEVEL
0.00	0.99760	25.27	0.99890
0.13	0.99770	26.36	0.99900
1.18	0.99780	28.75	0.99910
7.56	0.99790	30.74	0.99920
10.19	0.99800	33.20	0.99930
12.71	0.99810	40.21	0.99940
12.72	0.99820	41.82	0.99950
13.72	0.99830	57.57	0.99960
15.25	0.99840	68.55	0.99970
16.07	0.99850	104.94	0.99980
17.19	0.99860	115.44	0.99990
18.56	0.99870	164.98	1.00000
20.03	0.99880		
=====			

THE CORRESPONDING SENSITIVITIES TO THE ABOVE VELOCITY DEFICITS ARE:*

IN POLAR COORDINATES-	
PARAMETER	SENSITIVITY
-----	-----
INERTIAL RADIUS	0.000966 (NMI/FPS)
INERTIAL VELOCITY	0.985352 (FPS/FPS)
INERTIAL FLIGHT PATH ANGLE	0.000416 (DEG/FPS)
AZIMUTH	-0.000102 (DEG/FPS)
LONGITUDE (+W)	-0.000361 (DEG/FPS)
GEOCENTRIC LATITUDE	-0.000154 (DEG/FPS)

* BASED ON A VELOCITY DEFICIT OF 17.19 FPS (0.99860 PROBABILITY LEVEL)

Delta 7425 MARS Lander Mission
Preliminary 99.865 % Probable Maximum and Minimum
Injection Condition Dispersions
Based on Updated Velocity Pointing Error and Coning Velocity Loss

McDonnell Douglas Aerospace-Space Transportation Division

<u>Launch date:</u>	1/3/99	1/10/99	1/16/99	1/25/99	<u>Launch date:</u>	1/3/99	1/10/99	1/16/99	1/25/99
<u>PCS (%):</u>	99.7	99.7	99.7	99.7	<u>PCS (%):</u>	99.7	99.7	99.7	99.7
<u>Parameter</u>					<u>Parameter</u>				
Injection altitude (nmi)	+2.1 -2.3	+2.2 -2.3	+2.1 -2.3	+2.1 -2.2	Inclination (deg)	+0.44 -0.45	+0.43 -0.43	+0.45 -0.45	+0.47 -0.47
Injection Velocity (fps)	+41.8 -46.4	+41.0 -46.9	+41.0 -46.2	+40.9 -46.1	Longitude of the ascending node (deg)	+0.66 -0.68	+0.72 -0.74	+0.66 -0.69	+0.59 -0.62
Elevation angle (deg)	+0.56 -0.55	+0.57 -0.55	+0.57 -0.55	+0.57 -0.55	Argument of perigee (deg)	+1.14 -1.18	+1.18 -1.23	+1.15 -1.20	+1.12 -1.18
Azimuth angle (deg)	+0.55 -0.55	+0.56 -0.56	+0.56 -0.56	+0.55 -0.56	True anomaly (deg)	+1.04 -1.01	+1.06 -1.03	+1.06 -1.03	+1.06 -1.03
Longitude (+w,deg)	+0.25 -0.26	+0.25 -0.25	+0.25 -0.25	+0.24 -0.24	Perigee altitude (nmi)	+2.3 -2.5	+2.3 -2.5	+2.2 -2.4	+2.2 -2.3
Geocentric latitude (deg)	+0.11 -0.12	+0.11 -0.11	+0.11 -0.11	+0.12 -0.12	V infinity magnitude (fps)	+132.8 -160.1	+145.8 -173.6	+141.7 -169.9	+144.0 -173.2
Note: Errors do not include launch time effects					Right ascension of V infinity (deg)	+0.97 -0.88	+1.18 -1.08	+1.01 -0.90	+1.01 -0.91
					Declination of V infinity (fps)	+0.58 -0.52	+0.66 -0.61	+0.59 -0.53	+0.60 -0.53

B.8 34m BWG Usage and Tracking Schedule Modifications

DSN coverage for the majority of the mission is via the 34m subnet and the 70m subnet. Use of the 34m HEF antennae has been maximized, but 34m BWG support is necessary for limited intervals, to accommodate DSN usage conflicts. In addition, some modification of the nominal tracking profile is required in order to accommodate conflicts with other missions using the same DSN assets. The following spreadsheet summarizes the use of BWG antennae and/or modifications to the tracking schedule required during the Lander mission.

Summary of Recommendations - DSN Resource Contention Resolution [Mars98]

PCK DRAFT - 4/29/97, updated 7/18/97

Contention Period	Recommendation (Source)	Dates	M98 Orbiter Action	Impact on M98 Orbiter	M98 Lander Action	Impact on M98 Lander	Comments
# 6 [1/4/99 - 3/7/99]	M98 Lander and Orbiter use BWG on days when MGS has continuous coverage. (RAP)	1/5/99 - 1/12/99	Use GLD & CAN HEF overlap [6 2-hr passes/week?]. Supplement with BWG to total 7 4-hr passes/week. Some coverage from all 3 stations required.	No Impact.	BWG: continuous coverage to 1/10/99 BWG: 7 4-hr passes/week 1/10/99 - 1/12/99	No Impact.	• GLD/CAN overlap pass duration of 2-hrs is an estimate, with pre&post-cal taken out.
		1/13/99 - 1/19/99	HEF: 6 4-hr passes/week	Reduced monitoring	BWG: 7 4-hr passes/week	No Impact.	
		1/20/99 - 1/27/99	Use GLD & CAN HEF overlap [6 2-hr passes/week?]. Supplement with BWG to total 7 4-hr passes/week. Some coverage from all 3 stations required.	No Impact.	BWG: 7 4-hr passes/week	No Impact.	
		1/28/99 - 2/2/99	HEF: 6 4-hr passes/week	Reduced monitoring	BWG: 7 4-hr passes/week	No Impact.	
		2/3/99 - 2/10/99	Use GLD & CAN HEF overlap [6 2-hr passes/week?]. Supplement with BWG to total 7 4-hr passes/week. Some coverage from all 3 stations required.	No Impact.	BWG: 7 4-hr passes/week	No Impact.	
		2/11/99 - 2/17/99	HEF [MAD only]: 7 4-hr passes/week	Reduced Nav accuracy	BWG: 7 4-hr passes/week	No Impact.	• MGS diametric occultations
		2/18/99 - 2/22/99	BWG: 7 4-hr passes/week	No Impact.	Use GLD & CAN HEF overlap [6 2-hr passes/week?].	Reduced monitoring, nav accuracy	
		2/23/99 - 3/5/99	BWG: 7 4-hr passes/week from GLD & CAN	Reduced Nav accuracy	HEF: GLD 4 hr/day, CAN 1 hr/day	Reduced nav accuracy	
# 8 [5/3/99 - 5/9/99]	M98 Lander and Orbiter use BWG (RAP)	5/3/99 - 5/9/99	BWG: 7 4-hr passes/week	No Impact.	Use GLD/CAN HEF overlap [7 3-hr passes/week?]. Supplement with BWG to total 7 4-hr passes/week. Some coverage from all 3 stations required.	No Impact.	• Lander's use of BWG requires deadbands tightened to $\pm 9'$, leading to minimal propellant hit [< 0.1 kg].
# 9 [6/21/99 - 7/25/99]	M98 Lander & Orbiter use BWG every 3rd day (RAP)	6/21/99 - 7/25/99	1 4-hr HEF pass/day* except every 3rd day, go to 1 4-hr BWG pass.	No Impact.	No action required.	No impact.	
# 10 [7/26/99 - 8/15/99]	M98 Lander & Orbiter use BWG (RAP)	8/2/99 - 8/9/99	BWG: 7 4-hr passes/week	No Impact.	Use GLD/CAN HEF overlap [7 3-hr passes/week?]. Supplement with BWG to total 7 4-hr passes/week. Some coverage from all 3 stations required.	No Impact.	• Lander's use of BWG may require deadbands tightened to $\pm$ TBD*, leading to propellant hit.
# 11 [8/16/99 - 10/16/99]	M98 Lander use BWG (RAP)	8/16/99 - 10/16/99	No action required. Orbiter receives needed HEF tracking during approach.	No Impact.	Lander uses HEF throughout. 1 4-hr pass/day* except every 3rd day, the Lander pass is truncated to fit within DSN capability.	Reduction in monitoring. Other impacts TBD [e.g. impact on TCM-3 10/4/99].	• Lander alternative: use BWG during 8/16-9/10/99 only, requiring deadbands tightened to $\pm 2'$ for 25 days, leading to propellant hit of 0.1 kg. + TBD impacts.
# 12 [10/18/99 - 12/5/99]	Give Stardust 6 contiguous hrs/week of HEF time. (Stardust)	10/18/99 - 12/5/99	No action required. Orbiter receives needed HEF tracking during aerobraking.	No Impact.	Lander gets requisite HEF tracking [near-simultaneous w/ Orbiter] except for Stardust tracks. Per 4/24/97 agreement, no Stardust tracks occur 11/26/99 - 12/5/99.	No impact.	
week 38-39, 1999	Accept 2-3 hr/day gap in continuous 70m coverage for Orbiter. (GLL)	9/21/99 - 9/25/99	Accept, per GLL memo 4/1/97, 2-3 hr gap in continuous 70m coverage.	No Impact	No action required.	No impact.	
week 48 - 49, 1999	Maximize use of Canberra 70m antenna for Lander D/L during Sol 0,1. (GLL)	12/1/99 - 12/5/99	Accept, per GLL memo 4/1/97, reduction in DSS-14 [Goldstone] coverage in favor of DSS-43 [Canberra].	No Impact	No action required.	No impact..	

* Baseline Coverage

Legend: GLD = Goldstone, MAD = Madrid, CAN = Canberra

B.9 Approach Tracking Schedule

Shown is a strawman tracking schedule for the Lander from Entry - 45 days to Entry - 30 days, and an integrated [Orbiter + Lander] schedule of tracks for the interval of near-simultaneous tracking starting 30 days from Entry. These tracks have not been edited to be consistent with Earth view periods, but are intended to show the approximate variation of lander track durations and timing as a function of date.

B.9.1: Entry - 45d to Entry - 30d

B.9.2: Near Simultaneous Tracking - Integrated Tracking Schedule

B.9.3: Lander Track Durations

Lander Tracks E-45d to Entry	Days from Entry	Start Track	SSPA on duration [hr]	End Track
4on/5 off starting E-45 1h 24 m between tracks				
-45.03		10/19/99 20:15	4.00	10/20/99 0:15
-44.65		10/20/99 5:15	4.00	10/20/99 9:15
-44.28		10/20/99 14:15	4.00	10/20/99 18:15
-43.90		10/20/99 23:15	4.00	10/21/99 3:15
-43.53		10/21/99 8:15	4.00	10/21/99 12:15
-43.15		10/21/99 17:15	4.00	10/21/99 21:15
-42.78		10/22/99 2:15	4.00	10/22/99 6:15
-42.40		10/22/99 11:15	4.00	10/22/99 15:15
-42.03		10/22/99 20:15	4.00	10/23/99 0:15
-41.65		10/23/99 5:15	4.00	10/23/99 9:15
-41.28		10/23/99 14:15	4.00	10/23/99 18:15
-40.90		10/23/99 23:15	4.00	10/24/99 3:15
-40.53		10/24/99 8:15	4.00	10/24/99 12:15
-40.15		10/24/99 17:15	4.00	10/24/99 21:15
-39.78		10/25/99 2:15	4.00	10/25/99 6:15
-39.40		10/25/99 11:15	4.00	10/25/99 15:15
-39.03		10/25/99 20:15	4.00	10/26/99 0:15
-38.65		10/26/99 5:15	4.00	10/26/99 9:15
-38.28		10/26/99 14:15	4.00	10/26/99 18:15
-37.90		10/26/99 23:15	4.00	10/27/99 3:15
-37.53		10/27/99 8:15	4.00	10/27/99 12:15
-37.15		10/27/99 17:15	4.00	10/27/99 21:15
-36.78		10/28/99 2:15	4.00	10/28/99 6:15
-36.40		10/28/99 11:15	4.00	10/28/99 15:15
-36.03		10/28/99 20:15	4.00	10/29/99 0:15
-35.65		10/29/99 5:15	4.00	10/29/99 9:15
-35.28		10/29/99 14:15	4.00	10/29/99 18:15
-34.90		10/29/99 23:15	4.00	10/30/99 3:15
-34.53		10/30/99 8:15	4.00	10/30/99 12:15
-34.15		10/30/99 17:15	4.00	10/30/99 21:15
-33.78		10/31/99 2:15	4.00	10/31/99 6:15
-33.40		10/31/99 11:15	4.00	10/31/99 15:15
-33.03		10/31/99 20:15	4.00	11/1/99 0:15
-32.65		11/1/99 5:15	4.00	11/1/99 9:15
-32.28		11/1/99 14:15	4.00	11/1/99 18:15
-31.90		11/1/99 23:15	4.00	11/2/99 3:15
-31.53		11/2/99 8:15	4.00	11/2/99 12:15
-31.15		11/2/99 17:15	4.00	11/2/99 21:15

Integrated Tracking Schedule
Near-Simultaneous Tracking
Open Primary [Starting E-30d]

Assumptions:

- Minimum 2 hr / lander track
- Minimum 1h 24 m between tracks
- 4 on/ 5 off or equivalent
- Use 0.5h Orbiter tracks and 4 on/5 off Lander tracks 2d before end of AB
- End near-simul tracking NLT Entry-30h

Days	to s/c.	Start	Track 1	End
Entry	antenna	Track	duration	Track
-30.7	Orb.HEF	11/3/99 4:25	3.83	11/3/99 8:15
-30.5	Lander	11/3/99 9:39	2.05	11/3/99 11:42
-30.3	Orb.HEF	11/3/99 13:06	3.77	11/3/99 16:52
-30.1	Lander	11/3/99 18:16	4.00	11/3/99 22:16
-30.0	Orb.BWG	11/3/99 21:40	3.72	11/4/99 1:24
-29.6	Orb.HEF	11/4/99 6:06	3.68	11/4/99 9:46
-29.4	Lander	11/4/99 11:10	4.00	11/4/99 15:10
-29.3	Orb.BWG	11/4/99 14:26	3.62	11/4/99 18:03
-28.9	Orb.HEF	11/4/99 22:38	3.57	11/5/99 2:12
-28.7	Lander	11/5/99 3:36	4.00	11/5/99 7:36
-28.6	Orb.BWG	11/5/99 6:45	3.53	11/5/99 10:17
-28.3	Orb.HEF	11/5/99 14:44	3.47	11/5/99 18:13
-28.1	Lander	11/5/99 19:37	4.00	11/5/99 23:37
-27.9	Orb.BWG	11/5/99 22:37	3.43	11/6/99 2:03
-27.6	Orb.HEF	11/6/99 6:25	3.39	11/6/99 9:48
-27.4	Lander	11/6/99 11:12	4.00	11/6/99 15:12
-27.3	Orb.BWG	11/6/99 14:05	3.34	11/6/99 17:26
-27.0	Orb.HEF	11/6/99 21:40	3.30	11/7/99 0:59
-26.8	Lander	11/7/99 2:23	4.00	11/7/99 6:23
-26.7	Orb.BWG	11/7/99 5:10	3.25	11/7/99 8:25
-26.3	Orb.HEF	11/7/99 12:33	3.21	11/7/99 15:46
-26.2	Lander	11/7/99 17:10	4.00	11/7/99 21:10
-26.0	Orb.BWG	11/7/99 19:51	3.18	11/7/99 23:02
-25.7	Orb.HEF	11/8/99 3:03	3.13	11/8/99 6:11
-25.6	Lander	11/8/99 7:35	4.00	11/8/99 11:35
-25.4	Orb.BWG	11/8/99 10:09	3.10	11/8/99 13:15
-25.2	Orb.HEF	11/8/99 17:11	3.05	11/8/99 20:14
-25.0	Lander	11/8/99 21:38	4.00	11/9/99 1:38
-24.9	Orb.BWG	11/9/99 0:07	3.02	11/9/99 3:09
-24.6	Orb.HEF	11/9/99 6:58	2.98	11/9/99 9:57
-24.4	Lander	11/9/99 11:21	4.00	11/9/99 15:21
-24.3	Orb.BWG	11/9/99 13:44	2.94	11/9/99 16:41
-24.0	Orb.HEF	11/9/99 20:26	2.91	11/9/99 23:20
-23.8	Lander	11/10/99 0:44	4.00	11/10/99 4:44
-23.7	Orb.BWG	11/10/99 3:02	2.87	11/10/99 5:54
-23.5	Orb.HEF	11/10/99 9:33	2.84	11/10/99 12:24
-23.3	Lander	11/10/99 13:48	4.00	11/10/99 17:48
-23.2	Orb.BWG	11/10/99 15:59	2.81	11/10/99 18:48
-22.9	Orb.HEF	11/10/99 22:22	2.78	11/11/99 1:09
-22.8	Lander	11/11/99 2:33	4.00	11/11/99 6:33
-22.7	Orb.BWG	11/11/99 4:40	2.75	11/11/99 7:24
-22.4	Orb.HEF	11/11/99 10:54	2.72	11/11/99 13:37
-22.2	Lander	11/11/99 15:01	4.00	11/11/99 19:01
-22.2	Orb.BWG	11/11/99 17:04	2.68	11/11/99 19:45
-21.9	Orb.HEF	11/11/99 23:09	2.65	11/12/99 1:48
-21.7	Lander	11/12/99 3:12	4.00	11/12/99 7:12
-21.7	Orb.BWG	11/12/99 5:10	2.62	11/12/99 7:47
-21.4	Orb.HEF	11/12/99 11:06	2.59	11/12/99 13:41
-21.2	Lander	11/12/99 15:05	4.00	11/12/99 19:05
-21.2	Orb.BWG	11/12/99 16:59	2.56	11/12/99 19:32
-20.9	Orb.HEF	11/12/99 22:47	2.53	11/13/99 1:19
-20.8	Lander	11/13/99 2:43	4.00	11/13/99 6:43
-20.7	Orb.BWG	11/13/99 4:31	2.50	11/13/99 7:01
-20.4	Orb.HEF	11/13/99 10:11	2.47	11/13/99 12:39
-20.3	Lander	11/13/99 14:03	4.00	11/13/99 18:03
-20.2	Orb.BWG	11/13/99 15:47	2.44	11/13/99 18:13
-20.0	Orb.HEF	11/13/99 21:19	2.41	11/13/99 23:44
-19.8	Lander	11/14/99 1:08	4.00	11/14/99 5:08
-19.8	Orb.BWG	11/14/99 2:48	2.39	11/14/99 5:11
-19.5	Orb.HEF	11/14/99 8:13	2.36	11/14/99 10:35

**Integrated Tracking Schedule
Near-Simultaneous Tracking
Open Primary [Starting E-30d]**

Days	s/c.	Start	Track 1	End
to	antenna	Track	duration	Track
Entry			h	
-19.4	Lander	11/14/99 11:59	4.00	11/14/99 15:59
-19.3	Orb.BWG	11/14/99 13:34	2.34	11/14/99 15:54
-19.1	Orb.HEF	11/14/99 18:52	2.31	11/14/99 21:11
-18.9	Lander	11/14/99 22:35	4.00	11/15/99 2:35
-18.9	Orb.BWG	11/15/99 0:06	2.28	11/15/99 2:23
-18.6	Orb.HEF	11/15/99 5:17	2.25	11/15/99 7:33
-18.5	Lander	11/15/99 8:57	4.00	11/15/99 12:57
-18.4	Orb.BWG	11/15/99 10:24	2.22	11/15/99 12:38
-18.2	Orb.HEF	11/15/99 15:28	2.20	11/15/99 17:40
-18.1	Lander	11/15/99 19:04	4.00	11/15/99 23:04
-18.0	Orb.BWG	11/15/99 20:28	2.17	11/15/99 22:38
-17.8	Orb.HEF	11/16/99 1:24	2.15	11/16/99 3:33
-17.7	Lander	11/16/99 4:57	4.00	11/16/99 8:57
-17.6	Orb.BWG	11/16/99 6:17	2.13	11/16/99 8:24
-17.4	Orb.HEF	11/16/99 11:06	2.10	11/16/99 13:12
-17.3	Lander	11/16/99 14:36	4.00	11/16/99 18:36
-17.2	Orb.BWG	11/16/99 15:53	2.08	11/16/99 17:58
-17.0	Orb.HEF	11/16/99 20:36	2.06	11/16/99 22:40
-16.9	Lander	11/17/99 0:04	4.00	11/17/99 4:04
-16.8	Orb.BWG	11/17/99 1:17	2.04	11/17/99 3:20
-16.6	Orb.HEF	11/17/99 5:55	2.02	11/17/99 7:56
-16.5	Lander	11/17/99 9:20	4.00	11/17/99 13:20
-16.4	Orb.BWG	11/17/99 10:31	2.00	11/17/99 12:31
-16.2	Orb.HEF	11/17/99 15:02	1.98	11/17/99 17:01
-16.1	Lander	11/17/99 18:25	3.95	11/17/99 22:22
-16.1	Orb.BWG	11/17/99 19:32	1.95	11/17/99 21:29
-15.9	Orb.HEF	11/17/99 23:58	1.93	11/18/99 1:54
-15.7	Lander	11/18/99 3:18	3.87	11/18/99 7:10
-15.7	Orb.BWG	11/18/99 4:21	1.91	11/18/99 6:16
-15.5	Orb.HEF	11/18/99 8:42	1.89	11/18/99 10:36
-15.4	Lander	11/18/99 12:00	3.78	11/18/99 15:46
-15.3	Orb.BWG	11/18/99 13:00	1.87	11/18/99 14:52
-15.2	Orb.HEF	11/18/99 17:15	1.85	11/18/99 19:06
-15.0	Lander	11/18/99 20:30	3.69	11/19/99 0:12
-15.0	Orb.BWG	11/18/99 21:27	1.83	11/18/99 23:17
-14.8	Orb.HEF	11/19/99 1:36	1.81	11/19/99 3:25
-14.7	Lander	11/19/99 4:49	3.57	11/19/99 8:23
-14.6	Orb.BWG	11/19/99 5:42	1.79	11/19/99 7:30
-14.5	Orb.HEF	11/19/99 9:47	1.77	11/19/99 11:33
-14.3	Lander	11/19/99 12:57	3.44	11/19/99 16:24
-14.3	Orb.BWG	11/19/99 13:49	1.75	11/19/99 15:34
-14.1	Orb.HEF	11/19/99 17:48	1.73	11/19/99 19:32
-14.0	Lander	11/19/99 20:56	3.29	11/20/99 0:14
-14.0	Orb.BWG	11/19/99 21:44	1.71	11/19/99 23:27
-13.8	Orb.HEF	11/20/99 1:38	1.70	11/20/99 3:19
-13.7	Lander	11/20/99 4:43	3.19	11/20/99 7:55
-13.6	Orb.BWG	11/20/99 5:30	1.68	11/20/99 7:10
-13.5	Orb.HEF	11/20/99 9:19	1.66	11/20/99 10:58
-13.4	Lander	11/20/99 12:22	3.05	11/20/99 15:25
-13.3	Orb.BWG	11/20/99 13:05	1.65	11/20/99 14:43
-13.2	Orb.HEF	11/20/99 16:49	1.63	11/20/99 18:27
-13.0	Lander	11/20/99 19:51	2.94	11/20/99 22:47
-13.0	Orb.BWG	11/20/99 20:31	1.61	11/20/99 22:08
-12.9	Orb.HEF	11/21/99 0:11	1.59	11/21/99 1:47
-12.7	Lander	11/21/99 3:11	2.81	11/21/99 6:00
-12.7	Orb.BWG	11/21/99 3:49	1.58	11/21/99 5:24
-12.6	Orb.HEF	11/21/99 7:24	1.56	11/21/99 8:57
-12.4	Lander	11/21/99 10:21	2.69	11/21/99 13:03
-12.4	Orb.BWG	11/21/99 10:57	1.55	11/21/99 12:30
-12.3	Orb.HEF	11/21/99 14:27	1.53	11/21/99 15:59

**Integrated Tracking Schedule
Near-Simultaneous Tracking
Open Primary [Starting E-30d]**

Days to Entry	s/c. antenna	Start Track	Track 1 duration h	End Track
-12.1	Lander	11/21/99 17:23	2.61	11/21/99 19:59
-12.1	Orb.BWG	11/21/99 17:56	1.52	11/21/99 19:27
-12.0	Orb.HEF	11/21/99 21:23	1.50	11/21/99 22:53
-11.9	Lander	11/22/99 0:17	2.47	11/22/99 2:45
-11.8	Orb.BWG	11/22/99 0:48	1.49	11/22/99 2:17
-11.7	Orb.HEF	11/22/99 4:09	1.48	11/22/99 5:38
-11.6	Lander	11/22/99 7:02	2.40	11/22/99 9:26
-11.6	Orb.BWG	11/22/99 7:31	1.47	11/22/99 8:59
-11.4	Orb.HEF	11/22/99 10:50	1.46	11/22/99 12:17
-11.3	Lander	11/22/99 13:41	2.36	11/22/99 16:03
-11.3	Orb.BWG	11/22/99 14:10	1.45	11/22/99 15:37
-11.1	Orb.HEF	11/22/99 17:27	1.45	11/22/99 18:54
-11.0	Lander	11/22/99 20:18	2.31	11/22/99 22:36
-11.0	Orb.BWG	11/22/99 20:44	1.44	11/22/99 22:11
-10.9	Orb.HEF	11/23/99 0:00	1.43	11/23/99 1:26
-10.8	Lander	11/23/99 2:50	2.23	11/23/99 5:04
-10.7	Orb.BWG	11/23/99 3:15	1.42	11/23/99 4:40
-10.6	Orb.HEF	11/23/99 6:28	1.41	11/23/99 7:52
-10.5	Lander	11/23/99 9:16	2.17	11/23/99 11:27
-10.5	Orb.BWG	11/23/99 9:39	1.40	11/23/99 11:03
-10.3	Orb.HEF	11/23/99 12:51	1.39	11/23/99 14:14
-10.2	Lander	11/23/99 15:38	2.08	11/23/99 17:43
-10.2	Orb.BWG	11/23/99 16:00	1.38	11/23/99 17:22
-10.1	Orb.HEF	11/23/99 19:07	1.37	11/23/99 20:29
-10.0	Lander	11/23/99 21:53	2.03	11/23/99 23:54
-9.9	Orb.BWG	11/23/99 22:14	1.36	11/23/99 23:35
-9.8	Orb.HEF	11/24/99 1:18	1.35	11/24/99 2:39
-9.7	Lander	11/24/99 4:03	4.00	11/24/99 8:03
-9.7	Orb.BWG	11/24/99 4:23	1.34	11/24/99 5:43
-9.6	Orb.BWG	11/24/99 7:24	1.33	11/24/99 8:44
-9.4	Orb.HEF	11/24/99 10:26	1.32	11/24/99 11:45
-9.3	Lander	11/24/99 13:09	3.96	11/24/99 17:06
-9.3	Orb.BWG	11/24/99 13:26	1.31	11/24/99 14:44
-9.2	Orb.BWG	11/24/99 16:24	1.30	11/24/99 17:42
-9.1	Orb.HEF	11/24/99 19:21	1.30	11/24/99 20:39
-9.0	Lander	11/24/99 22:03	3.88	11/25/99 1:56
-8.9	Orb.BWG	11/24/99 22:17	1.29	11/24/99 23:34
-8.8	Orb.BWG	11/25/99 1:13	1.28	11/25/99 2:30
-8.7	Orb.HEF	11/25/99 4:07	1.27	11/25/99 5:23
-8.6	Lander	11/25/99 6:47	3.82	11/25/99 10:37
-8.6	Orb.BWG	11/25/99 7:01	1.27	11/25/99 8:17
-8.5	Orb.BWG	11/25/99 9:53	1.26	11/25/99 11:08
-8.3	Orb.HEF	11/25/99 12:44	1.25	11/25/99 13:59
-8.2	Lander	11/25/99 15:23	3.76	11/25/99 19:09
-8.2	Orb.BWG	11/25/99 15:35	1.24	11/25/99 16:50
-8.1	Orb.BWG	11/25/99 18:24	1.24	11/25/99 19:38
-8.0	Orb.HEF	11/25/99 21:12	1.23	11/25/99 22:26
-7.9	Lander	11/25/99 23:50	3.69	11/26/99 3:32
-7.9	Orb.BWG	11/26/99 0:01	1.22	11/26/99 1:14
-7.8	Orb.BWG	11/26/99 2:47	1.21	11/26/99 3:59
-7.6	Orb.HEF	11/26/99 5:32	1.20	11/26/99 6:44
-7.5	Lander	11/26/99 8:08	3.59	11/26/99 11:44
-7.5	Orb.BWG	11/26/99 8:15	1.19	11/26/99 9:27
-7.4	Orb.BWG	11/26/99 10:58	1.18	11/26/99 12:09
-7.3	Orb.HEF	11/26/99 13:39	1.17	11/26/99 14:50
-7.2	Lander	11/26/99 16:14	3.52	11/26/99 19:45
-7.2	Orb.BWG	11/26/99 16:19	1.17	11/26/99 17:29
-7.1	Orb.BWG	11/26/99 18:57	1.16	11/26/99 20:07
-7.0	Orb.HEF	11/26/99 21:36	1.15	11/26/99 22:45
-6.9	Lander	11/27/99 0:09	3.45	11/27/99 3:36

Integrated Tracking Schedule
Near-Simultaneous Tracking
Open Primary [Starting E-30d]

Orbiter Tracking [Starting E-30d]	Days		Track 1	
	to	s/c.	Start	End
Entry	antenna	Track	h	Track
-6.9	Orb.BWG	11/27/99 0:11	1.14	11/27/99 1:20
-6.8	Orb.BWG	11/27/99 2:47	1.13	11/27/99 3:55
-6.6	Orb.HEF	11/27/99 5:23	1.13	11/27/99 6:30
-6.5	Lander	11/27/99 7:54	3.38	11/27/99 11:17
-6.5	Orb.BWG	11/27/99 7:55	1.12	11/27/99 9:02
-6.4	Orb.BWG	11/27/99 10:28	1.11	11/27/99 11:35
-6.3	Orb.HEF	11/27/99 13:01	1.11	11/27/99 14:07
-6.2	Orb.BWG	11/27/99 15:31	1.10	11/27/99 16:37
-6.2	Lander	11/27/99 15:31	3.32	11/27/99 18:50
-6.1	Orb.BWG	11/27/99 18:01	1.09	11/27/99 19:06
-6.0	Orb.HEF	11/27/99 20:30	1.09	11/27/99 21:36
-5.9	Orb.BWG	11/27/99 22:59	1.08	11/28/99 0:03
-5.9	Lander	11/27/99 23:00	3.25	11/28/99 2:15
-5.8	Orb.BWG	11/28/99 1:26	1.07	11/28/99 2:30
-5.7	Orb.HEF	11/28/99 3:51	1.06	11/28/99 4:55
-5.6	Orb.BWG	11/28/99 6:15	1.05	11/28/99 7:18
-5.6	Lander	11/28/99 6:19	3.17	11/28/99 9:29
-5.5	Orb.BWG	11/28/99 8:38	1.04	11/28/99 9:40
-5.4	Orb.HEF	11/28/99 11:01	1.03	11/28/99 12:03
-5.3	Orb.BWG	11/28/99 13:22	1.02	11/28/99 14:23
-5.3	Lander	11/28/99 13:27	3.10	11/28/99 16:32
-5.2	Orb.BWG	11/28/99 15:42	1.02	11/28/99 16:43
-5.1	Orb.HEF	11/28/99 18:00	1.01	11/28/99 19:00
-5.0	Orb.BWG	11/28/99 20:17	1.00	11/28/99 21:17
-5.0	Lander	11/28/99 20:24	3.01	11/28/99 23:25
-4.9	Orb.BWG	11/28/99 22:34	0.99	11/28/99 23:33
-4.8	Orb.HEF	11/29/99 0:49	0.99	11/29/99 1:49
-4.7	Orb.BWG	11/29/99 3:03	0.98	11/29/99 4:02
-4.7	Lander	11/29/99 3:12	2.89	11/29/99 6:06
-4.6	Orb.BWG	11/29/99 5:17	0.97	11/29/99 6:16
-4.6	Orb.HEF	11/29/99 7:30	0.96	11/29/99 8:28
-4.5	Orb.BWG	11/29/99 9:41	0.50	11/29/99 10:11
-4.4	Orb.BWG	11/29/99 11:52	0.50	11/29/99 12:22
-4.3	Lander	11/29/99 12:52	4.00	11/29/99 16:52
-4.3	Orb.BWG	11/29/99 14:02	0.50	11/29/99 14:32
-4.2	Orb.BWG	11/29/99 16:10	0.50	11/29/99 16:40
-4.1	Orb.HEF	11/29/99 18:17	0.50	11/29/99 18:47
-4.0	Orb.BWG	11/29/99 20:24	0.50	11/29/99 20:54
-4.0	Lander	11/29/99 21:52	4.00	11/30/99 1:52
-3.9	Orb.BWG	11/29/99 22:28	0.50	11/29/99 22:58
-3.8	Orb.BWG	11/30/99 0:31	0.50	11/30/99 1:01
-3.8	Orb.BWG	11/30/99 2:34	0.50	11/30/99 3:04
-3.7	Orb.HEF	11/30/99 4:34	0.50	11/30/99 5:04
-3.6	Orb.BWG	11/30/99 6:32	0.50	11/30/99 7:02
-3.6	Lander	11/30/99 6:52	4.00	11/30/99 10:52
-3.5	Orb.BWG	11/30/99 8:31	0.50	11/30/99 9:01
-3.4	Orb.BWG	11/30/99 10:29	0.50	11/30/99 10:59
-3.4	Orb.HEF	11/30/99 12:25	0.50	11/30/99 12:55
-3.3	Orb.BWG	11/30/99 14:21	0.50	11/30/99 14:51
-3.2	Lander	11/30/99 15:52	4.00	11/30/99 19:52
-3.2	Orb.BWG	11/30/99 16:17	0.50	11/30/99 16:47
-3.1	Orb.BWG	11/30/99 18:14	0.50	11/30/99 18:44
-3.0	Orb.BWG	11/30/99 20:08	0.50	11/30/99 20:38
-3.0	Orb.HEF	11/30/99 22:03	0.50	11/30/99 22:33
-2.9	Orb.BWG	11/30/99 23:58	0.50	12/1/99 0:28
-2.8	Lander	12/1/99 0:52	4.00	12/1/99 4:52
-2.8	Orb.BWG	12/1/99 1:53	0.50	12/1/99 2:23
-2.7	Orb.BWG	12/1/99 3:47	0.50	12/1/99 4:17
-2.6	Orb.BWG	12/1/99 5:41	0.50	12/1/99 6:11
-2.5	Orb.BWG	12/1/99 8:09	1.35	12/1/99 9:30

Integrated Tracking Schedule			Days	Track 1	
Near-Simultaneous Tracking			to s/c.	Start	End
Open Primary [Starting E-30d]			Entry antenna	Track	Track
				duration	h
Start Transfer to Map	-2.5	Lander	12/1/99 9:52	4.00	12/1/99 13:52
	-2.4	Orb.BWG	12/1/99 11:37	1.00	12/1/99 12:37
	-2.3	Orb.BWG	12/1/99 13:36	1.00	12/1/99 14:36
	-2.2	Orb.HEF	12/1/99 15:34	1.00	12/1/99 16:34
	-2.1	Orb.BWG	12/1/99 17:33	1.00	12/1/99 18:33
	-2.1	Lander	12/1/99 18:52	4.00	12/1/99 22:52
	-2.1	Orb.BWG	12/1/99 19:31	1.00	12/1/99 20:31
	-2.0	Orb.BWG	12/1/99 21:30	1.00	12/1/99 22:30
	-1.9	Orb.BWG	12/1/99 23:29	1.00	12/2/99 0:29
	-1.8	Orb.HEF	12/2/99 1:27	1.00	12/2/99 2:27
	-1.7	Orb.BWG	12/2/99 3:26	1.00	12/2/99 4:26
	-1.7	Lander	12/2/99 3:52	4.00	12/2/99 7:52
	-1.6	Orb.BWG	12/2/99 5:24	1.00	12/2/99 6:24
	-1.6	Orb.BWG	12/2/99 7:23	1.00	12/2/99 8:23
Last Near Simultaneous track	-1.5	Orb.HEF	12/2/99 9:22	1.00	12/2/99 10:22
	-1.4	Orb.BWG	12/2/99 11:20	1.00	12/2/99 12:20
	-1.3	Lander	12/2/99 12:52	4.00	12/2/99 16:52
	-1.3	Orb.BWG	12/2/99 13:19	1.00	12/2/99 14:19
	-1.2	Orb.BWG	12/2/99 15:18	1.00	12/2/99 16:18
	-1.1	Orb.BWG	12/2/99 17:16	1.00	12/2/99 18:16
	-1.1	Orb.BWG	12/2/99 19:15	1.00	12/2/99 20:15
	-1.0	Orb.BWG	12/2/99 21:13	1.00	12/2/99 22:13
	-1.0	Lander	12/2/99 21:52	4.00	12/3/99 1:52
	-0.9	Orb.BWG	12/2/99 23:12	1.00	12/3/99 0:12
	-0.8	Orb.BWG	12/3/99 1:11	1.00	12/3/99 2:11
	-0.7	Orb.BWG	12/3/99 3:09	1.00	12/3/99 4:09
	-0.7	Orb.BWG	12/3/99 5:08	1.00	12/3/99 6:08
Final Track pre TCM-5	-0.6	Lander	12/3/99 6:52	4.00	12/3/99 10:52
	-0.6	Orb.BWG	12/3/99 7:07	1.00	12/3/99 8:07
	-0.5	Orb.BWG	12/3/99 9:05	1.00	12/3/99 10:05
	-0.4	Orb.BWG	12/3/99 11:04	1.00	12/3/99 12:04
	-0.3	Lander	12/3/99 12:57	0.50	12/3/99 13:27
	-0.3	Orb.BWG	12/3/99 13:02	1.00	12/3/99 14:02
	-0.3	TCM-5	12/3/99 13:32	0.58	12/3/99 14:07
TCM-5	-0.2	Orb.BWG	12/3/99 15:01	1.00	12/3/99 16:01
	-0.2	Lander	12/3/99 15:52	1.00	12/3/99 16:52
DSN-3	-0.2	Orb.BWG	12/3/99 17:00	1.00	12/3/99 18:00
	-0.1	Orb.BWG	12/3/99 18:58	1.00	12/3/99 19:58
DSN-4	0.0	Lander	12/3/99 20:27	0.25	12/3/99 20:42
	0.0	Landing	12/3/99 20:56	0.01	12/3/99 20:56
	0.0	Orb.BWG	12/3/99 20:57	1.00	12/3/99 21:57

E-30d

Near-Simultaneous Tracking:

1hr 24 min. separation between tracks



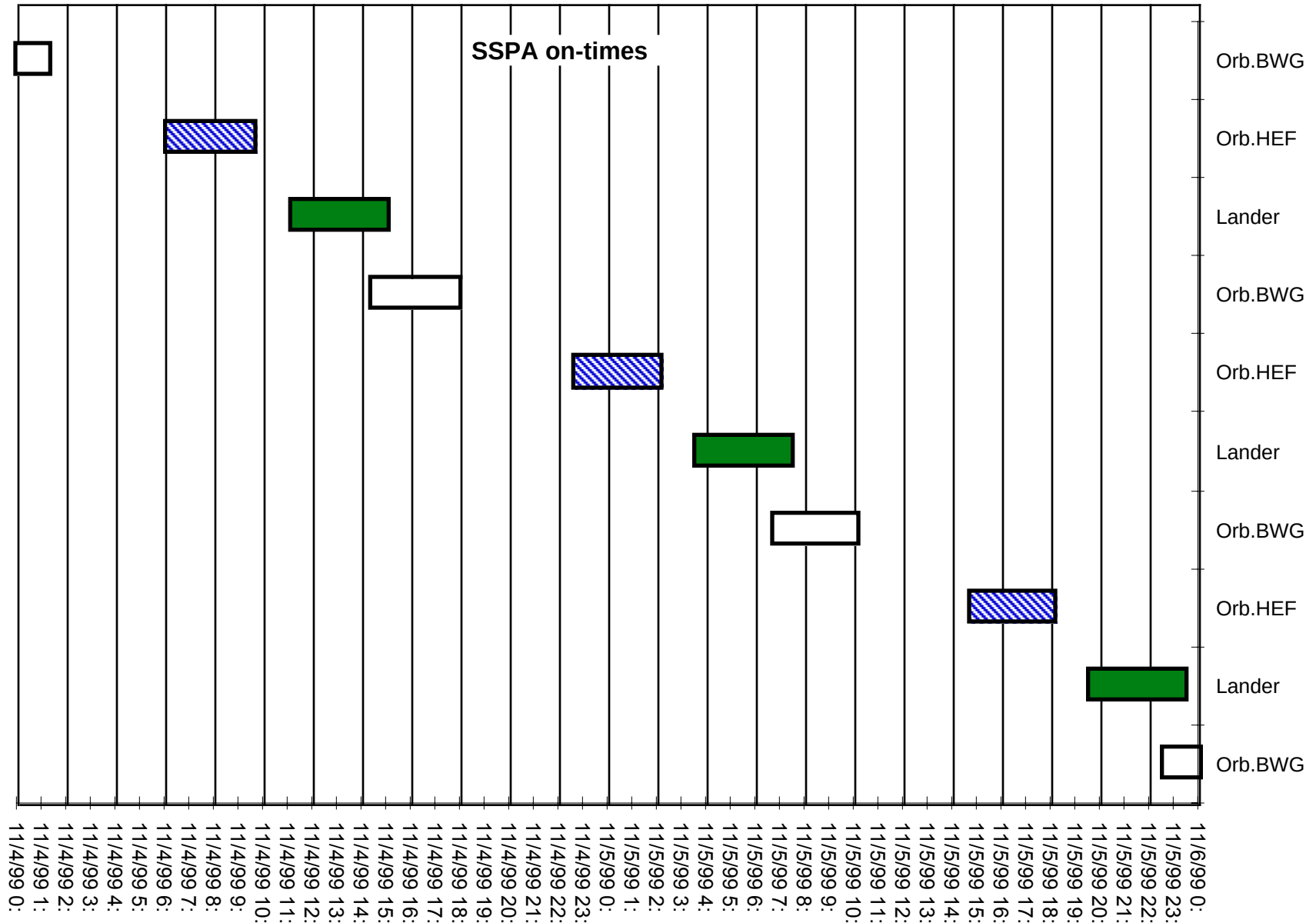
Lander HEF



Orbiter HEF



Orbiter BWG Track



E-20d Near-Simultaneous Tracking:

1hr 24 min. separation between tracks



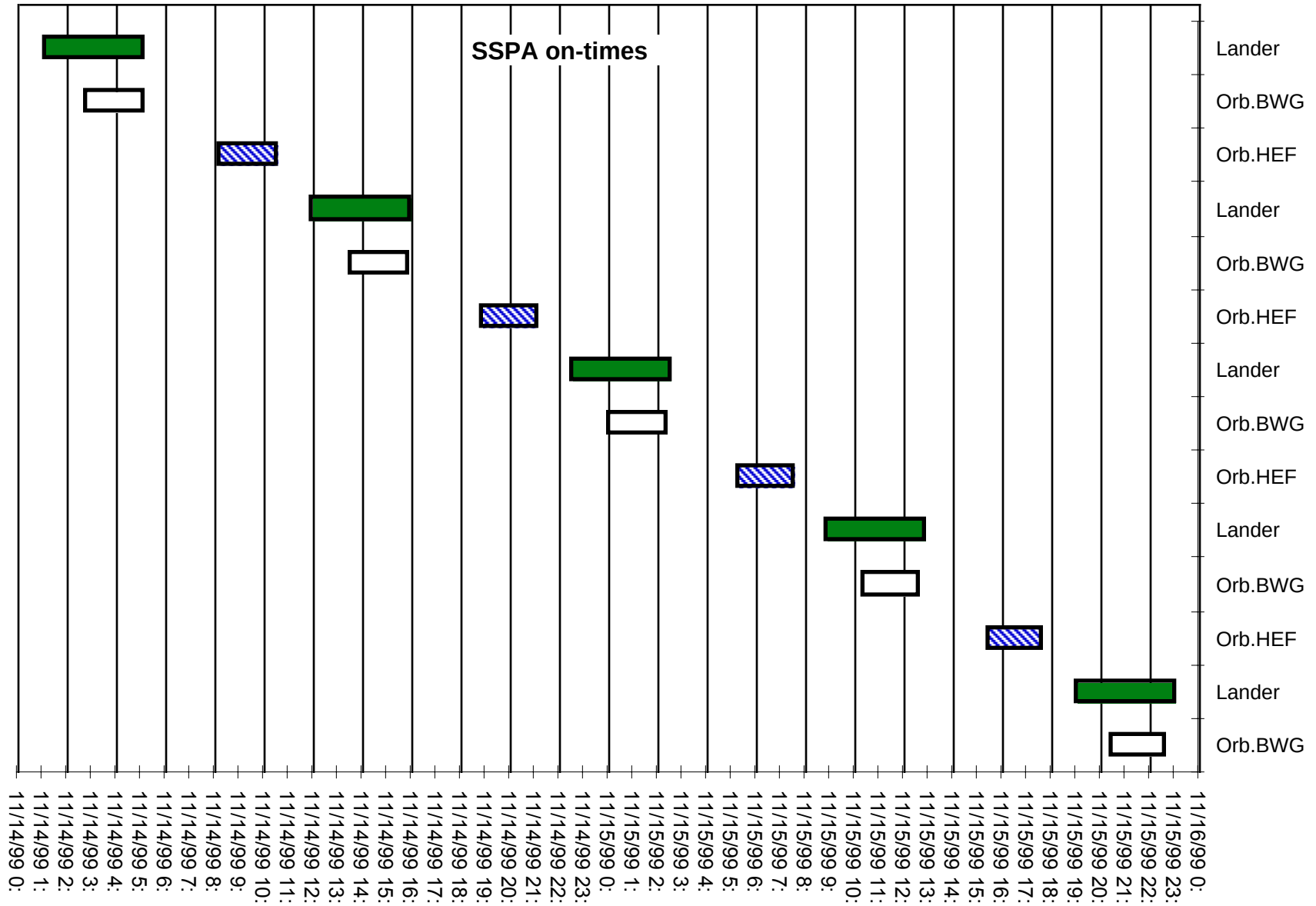
Lander HEF



Orbiter HEF



Orbiter BWG Track



E-10d Near-Simultaneous Tracking:

1hr 24 min. separation between tracks



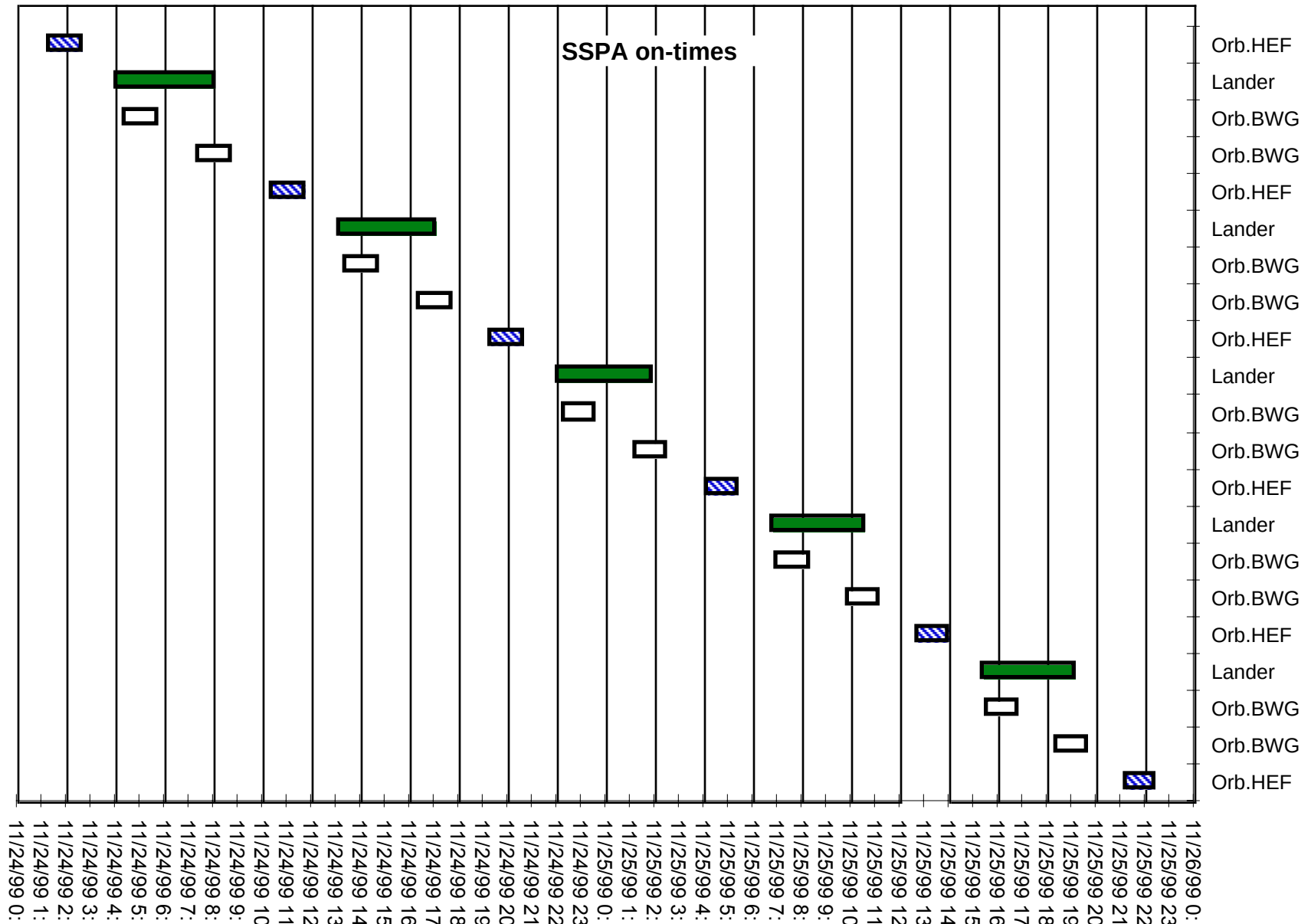
Lander HEF



Orbiter HEF



Orbiter BWG Track



E-4d

Near-Simultaneous Tracking:

1hr 24 min. separation between tracks



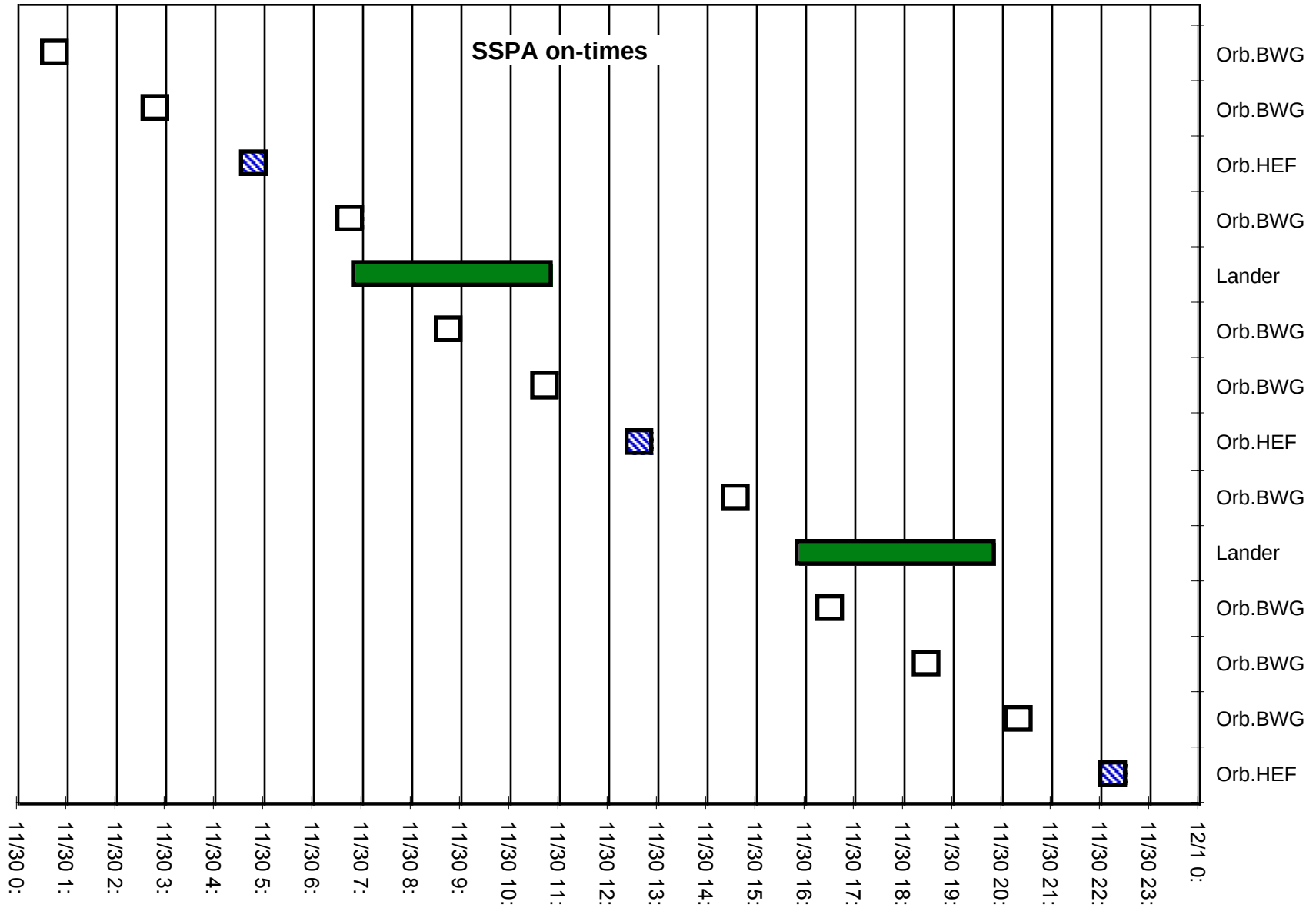
Lander HEF



Orbiter HEF



Orbiter BWG Track



E-3d Near-Simultaneous Tracking:

1hr 24 min. separation between tracks



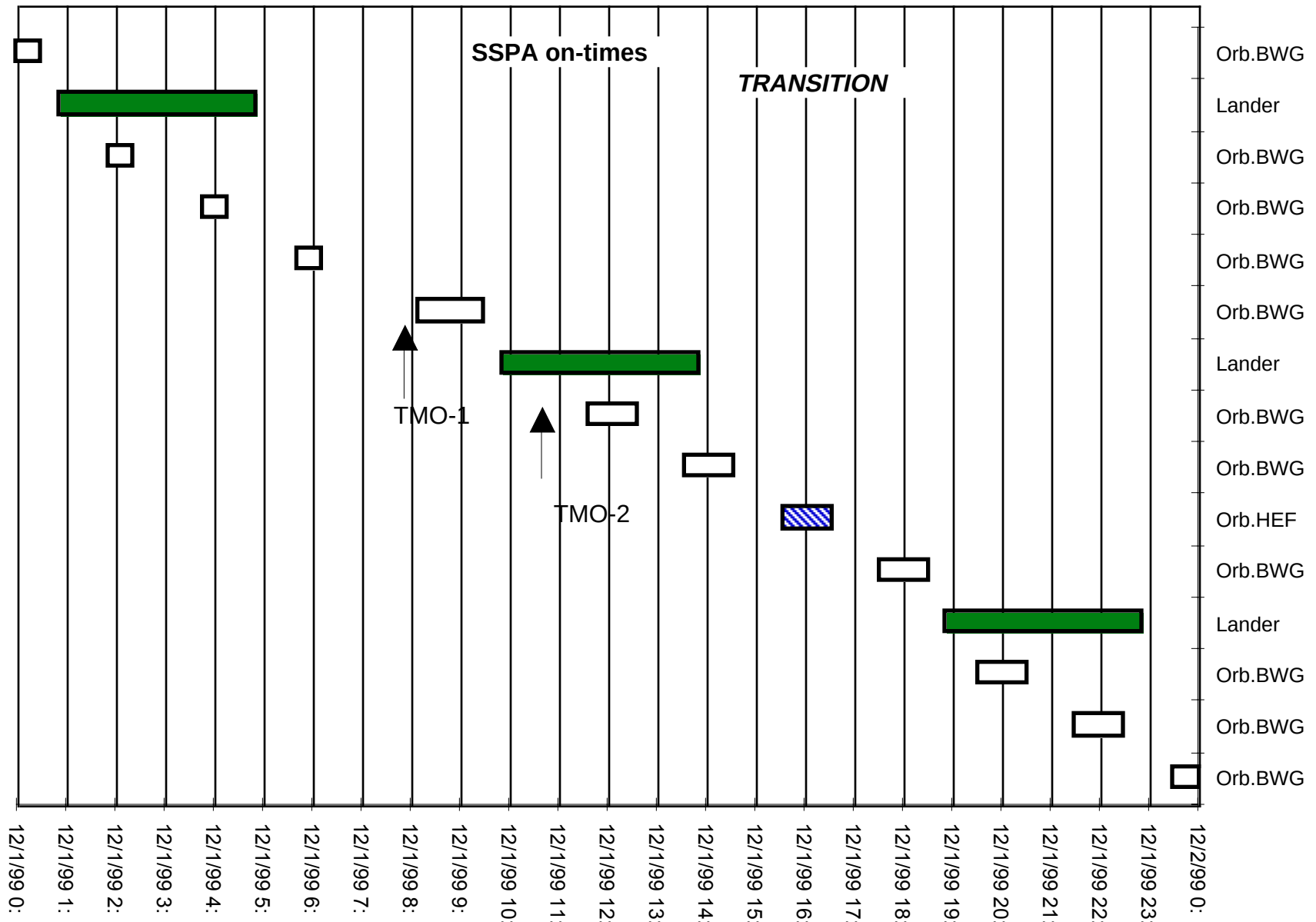
Lander HEF



Orbiter HEF

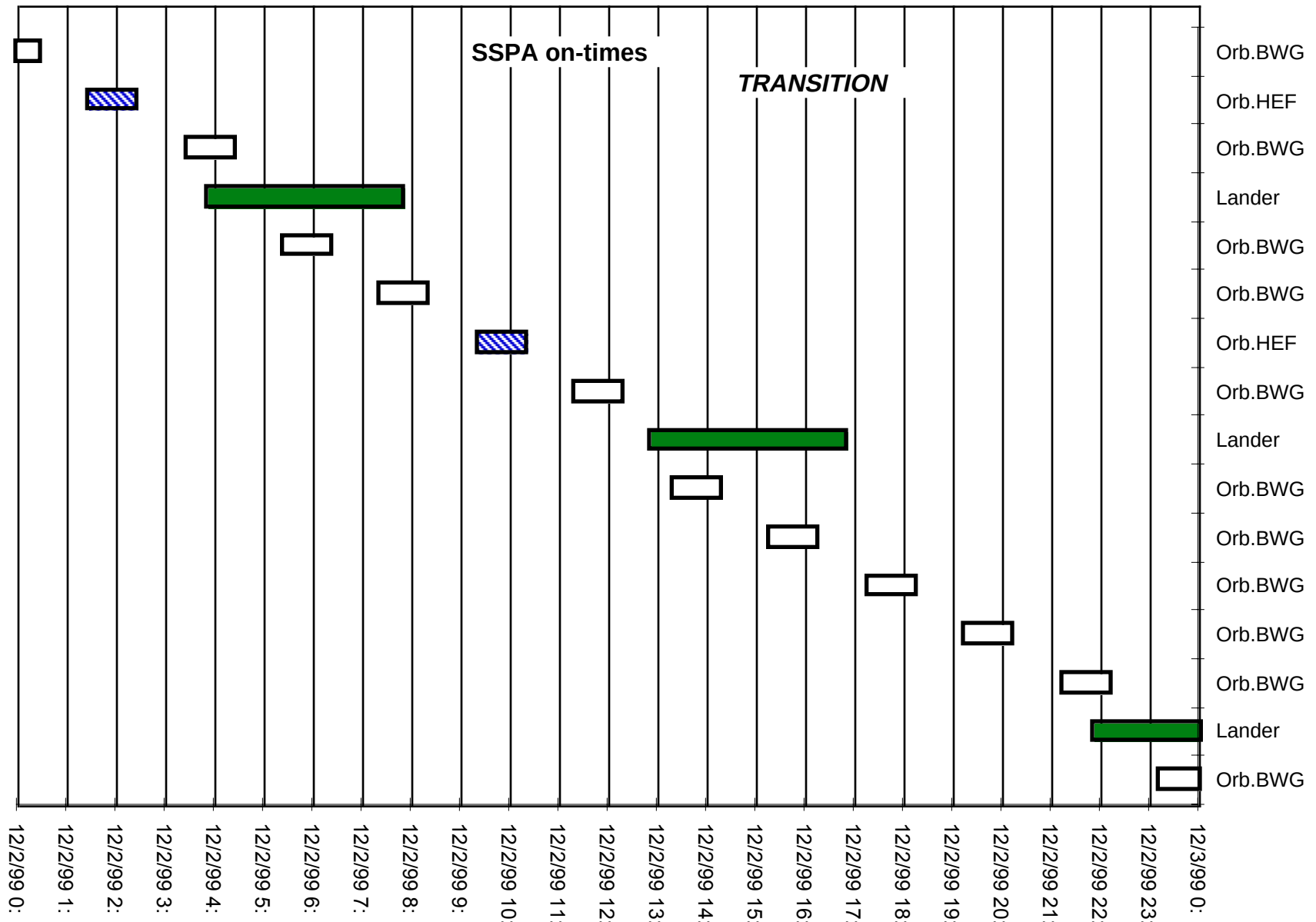


Orbiter BWG Track (Optional)



E-2d **End Near-Simultaneous Tracking:** 1hr 24 min. separation between tracks

Lander HEF
 Orbiter HEF
 Orbiter BWG Track (Optional)



E-1d



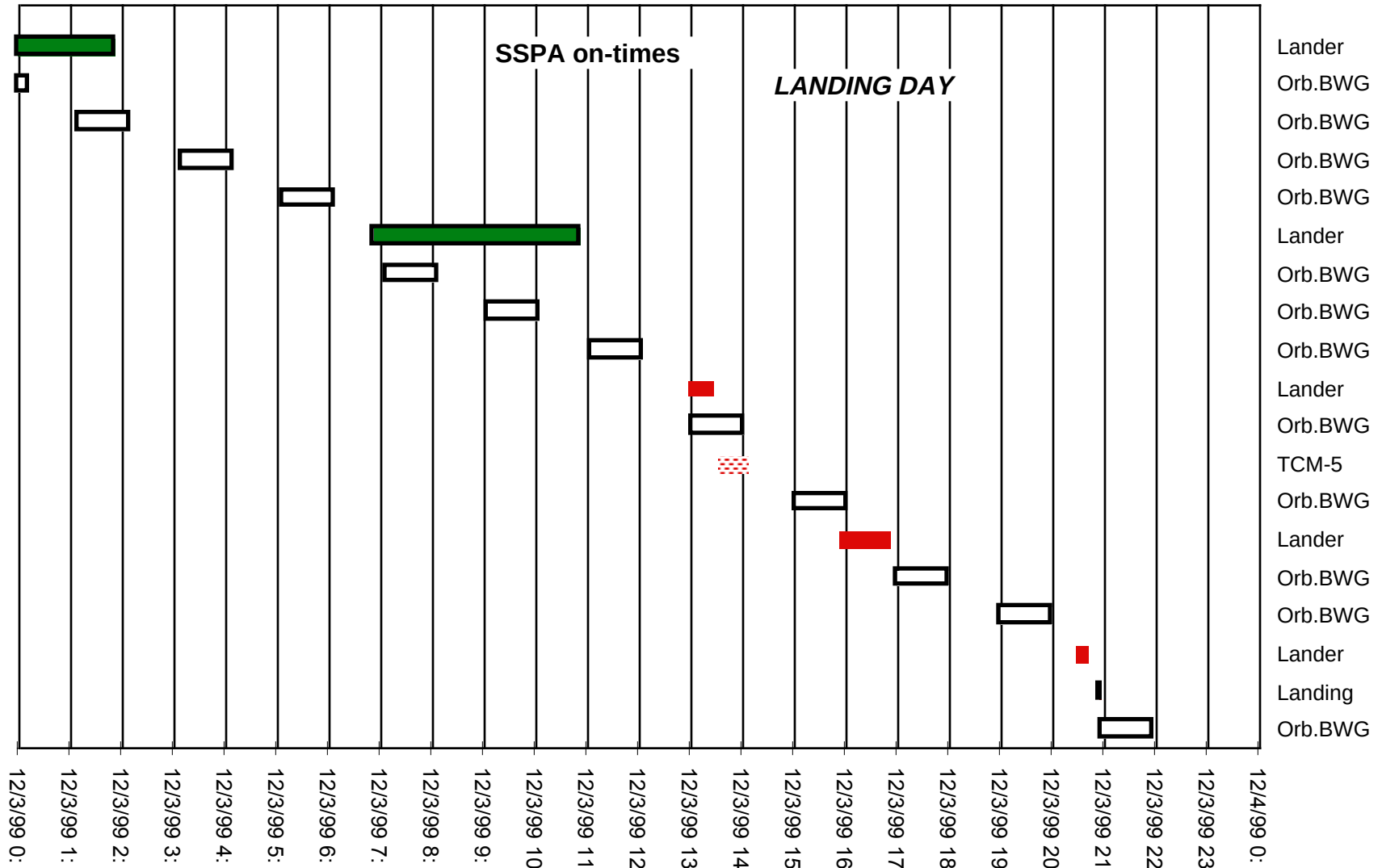
Lander HEF



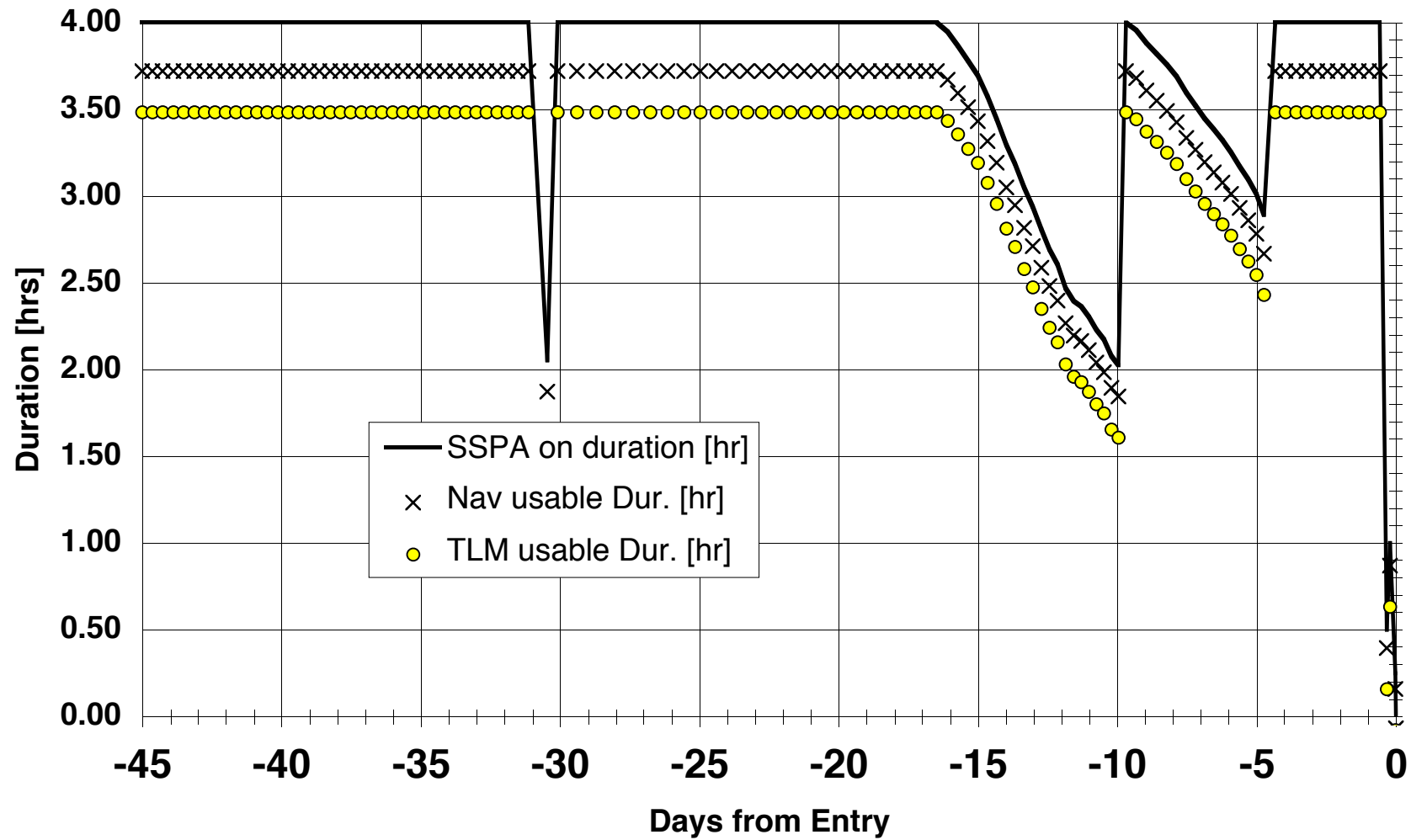
Orbiter HEF



Orbiter BWG Track (Optional)



LANDER TRACK DURATIONS DURING LANDER APPROACH



B.10 Lander Data Rates

Orbiter and Lander Communication Strategy during the Mission [Memo MSP-SE-97-0162]

Interoffice Memo



Memo No.: MSP-SE-97-0162

Date: 3/31/97

To: P. Knocke

cc: MSP

From: K. Nii

Subject: Orbiter and Lander Communication Strategy during Cruise

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This memo documents the Mission Operations plan for communication strategies with the orbiter and lander during the Cruise portion of the mission.

Orbiter Cruise Comm Strategy Overview:

Each mission phase drives one or more subsystem performance parameter. After separation, key engineering data are broadcast to available X-band sites to support post-flight anomaly investigation. As the S/C approaches the first DSN station, the 34 m antenna will be used to acquire and track the Orbiter. Coherent two way ranging is key during daily telecommunication passes throughout all the phases. The Orbiter transmits 2.1 kbps on the MGA and receives 125 bps on the LGA during the S/C Init and Cruise Phases. Each DSN contact nominally lasts four hours. The Orbiter transfers from the MGA/LGA to the HGA at Launch + 80 days. During the rest of Cruise the Orbiter transmits at 2100 bps and receives at 125 bps. At MOI - 45 days, the orbiter will transition to a communicating strategy of 4 hours on and 5 hours off.

When not in planned communication with the ground the orbiter will be in receive mode on the LGA at 7.8125 bps.

Lander Cruise Comm Strategy Overview:

Each mission phase drives one or more subsystem performance parameter. After separation, key engineering data are broadcast to available X-band sites to support post-flight anomaly investigation. As the S/C approaches the first DSN station, the 34 m antenna will be used to acquire and track the Lander. Coherent two way ranging is key during daily telecommunication passes throughout the Cruise phase. The lander uses the cruise MGA to transmit and receive for the entire cruise phase. DSN contacts are planned to occur once/day for all of cruise until EDL-46 days. At this time the lander will transition to a four hours on five hours off communication strategy.

When not in planned communication with the ground the lander will be in receive mode on the LGA at 7.8125 bps.

Orbiter

Possible Transmit Rates: MGA/HGA 40, 2100, 5688, 9954, 33180, 71100, 110600 bps

8 kbps UHF

Possible Receive Rates: LGA 7.8125, 125 bpsHGA 7.8125, 125, 500, 1000* bps (* No ranging)

128 kbps UHF

Phase:	Nominal Transmit Rates:	Nominal Receive Rates:
Initial Acquisition	2.1K bits per second	125 bits per second
Cruise	2.1 kbps	125 bps

Lander

Possible Transmit Rates: Cruise MGA 40, 100, 2100 bits per second (bps)

Landed MGA 40, 395 (R=1/2), 700 (R=1/6), 1400 bps

8 kbps, 128 kbps UHF (nominal)

Possible Receive Rates: Cruise MGA 7.8125, 125, 500 bpsLanded MGA 7.8125, 125, 500 bps

8 kbps UHF (nominal) (128 kbps possible)

Phase:	Transmit	Receive
Initial Acquisition	2.1 kbits per second	125 bits per second
Cruise	100 bps	125 bps
Approach (EDL-46 days)	40 bps	7.8125 bps

Orbiter DSN Cruise Contact Plan (Open of Launch period):

# Days	Mission Day	Frequency	Antenna	Operations
80	1-80	1/day	LGA/MGA	Cruise (4 hours)
164	81-244	1/day	HGA	Cruise (4 hours)
45	245-289	3/day*	HGA	Approach (*4 hours on, 5 hours off) Includes TCM-4

Orbiter DSN Cruise Contact Plan (Close of Launch period):

# Days	Mission Day	Frequency	Antenna	Operations
80	1-80	1/day	LGA/MGA	Cruise (4 hours)
160	81-240	1/day	HGA	Cruise (4 hours)
45	241-285	3/day*	HGA	Approach (*4 hours on, 5 hours off) Includes TCM-4

Lander DSN Cruise Contact Plan (Open of Launch period):

# Days	Mission Day	Frequency	Antenna	Operations
301	1-302	1/day	MGA	Cruise (4 hours)
46	303-347	3/day*	MGA	Approach (*4 hours on, 5 hours off) Includes TCM-4

Lander DSN Cruise Contact Plan (Close of Launch period):

# Days	Mission Day	Frequency	Antenna	Operations
289	1-290	1/day	MGA	Cruise (4 hours)
46	291-335	3/day*	MGA	Approach (*4 hours on, 5 hours off) Includes TCM-4

original signed by

Kendall M. Nii

B.11 Lander Approach Targeting Data **This Section under Change Control**

[To be Supplied] This section contains approach data to be used for EDL analyses.