# Interface Control Document

Between the

# Lunar Prospector Project

and the

# Flight Dynamics Analysis Branch

*Final*

December 31, 1997

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This document is controlled by the individuals listed below, whose signatures constitute concurrence that the contents represent the latest agreements and understandings among the parties involved.

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# PREFACE

The purpose of this interface control document (ICD) is to provide complete information concerning the products to be transferred between the Lunar Prospector Mission Control Center (MCC) and the Flight Dynamics Analysis Branch (FDAB) of Goddard Space Flight Center (GSFC) in support of the Lunar Prospector mission. The contents of this document are complete to a level sufficient to develop and operate the interface.

This ICD is currently being maintained by the Spacecraft Operations Branch, Ames Research Center (ARC). Questions and proposed changes concerning this document should be addressed to:

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## TABLE OF CONTENTS

## List of Figures

**Figure**
----------



## List of Tables

**Table**
----------

# 1.0 Introduction

## 1.1 Purpose and Scope

This interface control document (ICD) defines the complete interface between the National Aeronautics and Space Administration (NASA) Ames Research Center (ARC) Lunar Prospector (LP) Project Office and the Goddard Space Flight Center (GSFC) Flight Dynamics Analysis Branch (FDAB) in support of the Lunar Prospector (LP) mission. This ICD covers products exchanged between the LP Mission Control Center (MCC) located at ARC and the Flight Dynamics Analysis Branch (FDAB) at GSFC. The ICD also includes products provided by the FDAB to other ground elements (e.g. the NASA Jet Propulsion Laboratory) at the direction of the LP Project Office.

## 1.2 Mission Phases

There are four Lunar Prospector mission phases identified for the purpose of this ICD:

- Prelaunch:
  Includes all pre-launch activities including spacecraft testing and mission simulations up to launch
- Transfer Orbit:
  Includes launch, translunar injection (TLI) and transfer orbit operations up to lunar orbit insertion
- Lunar Orbit Insertion (LOI):
  Includes lunar orbit insertion operations leading to the nominal 100 km lunar mapping orbit
- Mapping:
  Includes science and extended mission operations

This ICD addresses primarily the operational exchange of products between the FDAB and the LP Project during the Transfer Orbit, Lunar Orbit Insertion and Mapping phases of the mission. Prelaunch product deliveries for the purpose of testing/simulations are expected, but are not explicitly covered in this ICD. Where applicable, a pre-launch delivery of a final nominal set of predicted products will be delivered no later than three days prior to launch.

## 1.3 Mission-Specific Characteristics

The Lunar Prospector spacecraft will be launched from a Lockheed Martin Athena II launch vehicle out of the Eastern Test Range (ETR). Following insertion into a 100 nm circular parking orbit and a long (42 minute) coast, a Star-37FM solid motor will inject the spacecraft into a direct transfer orbit to the moon. The four day (105 hr) cruise to the moon will be followed by a series of LOI maneuvers which will place the spacecraft first into a 12-hour orbit, then a 3.5-hour orbit and finally a 100 km circular polar mapping orbit. The nominal mission life-time is one year, with a possible 6 month extended mission in a 100 km by 10 km lunar orbit.

# 2.0 Facilities/Systems

## 2.1 Interface Overview

Figure 2.1 provides an overview of the Lunar Prospector ground system and key interfaces. The Lunar Prospector Mission Control Center (MCC) will be the focal point of LP operations. Command, telemetry, and tracking will be provided by NASA's Deep Space Network (DSN), operated by the Jet Propulsion Laboratory (JPL). Provisions are also being made to obtain TDRS support for telemetry and tracking for the time period immediately following injection into the lunar transfer orbit. Goddard Space Flight Centers' Flight Dynamics Analysis Branch will provide station acquisition data, orbit determination, and orbit maneuver support for the LP mission.

## 2.2 Lunar Prospector Mission Control Center

The LP MCC will be located at NASA Ames Research Center. A flight operations team (FOT) at the LP MCC will be responsible for mission planning, scheduling, commanding, and data distribution functions in support of the LP mission.

## 2.3 Flight Dynamics Analysis Branch Payload Operations Room

The FDAB operates a multi-mission Payload Operations Room (POR) at Goddard Space Flight Center which is used for critical mission support. The FDAB will provide orbit maneuver planning and operations support to the LP MCC. The FDAB will also generate acquisition data in support of DSN and TDRS (as required for initial acquisition support) events. Tracking data collected throughout the mission will be used by the FDAB to generate orbit predictions for use in maneuver planning and attitude determination operations, and definitive orbit ephemeris for use in science data processing. The FDAB will also generate a number of mission planning products in support of FOT operations in the MCC.

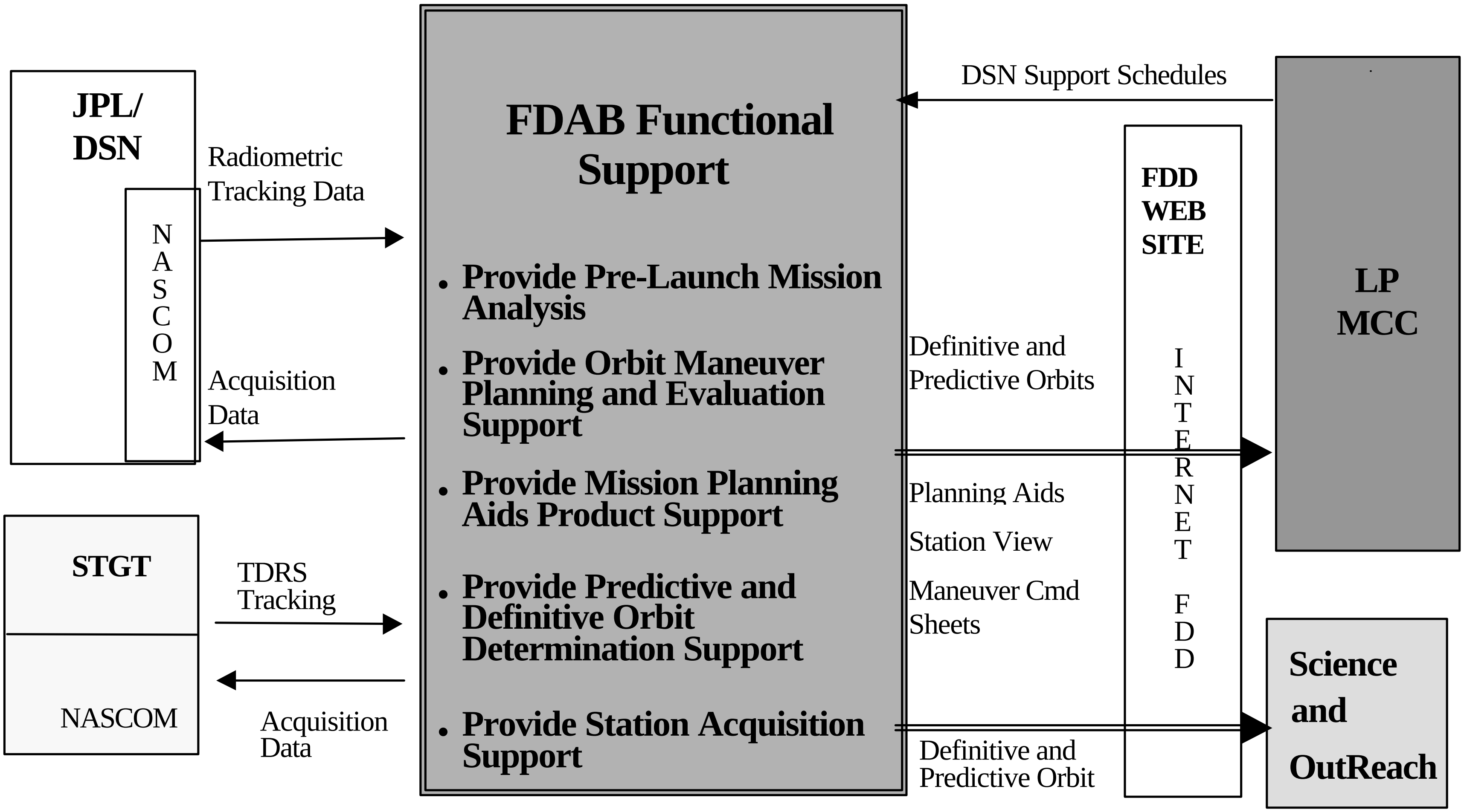


**Figure 2-1: Lunar Prospector Ground System**

## 2.4 Deep Space Network

The DSN will be used by the LP mission for command, telemetry, and tracking (1 mm / sec) support. Continuous support will be provided by the 26 meter antennas at Canberra (DS46), Madrid (DS66) and Goldstone (DS16) during the transfer phase. DSN 34 meter antennas will be used as backups to the 26 meter antennas and for prime support during certain critical operations (e.g. Lunar Orbit Insertion).

## 2.5 Tracking and Data Relay Satellite

TDRS support for two-way tracking and telemetry will be scheduled for the period immediately following injection into the transfer orbit and lasting until two minutes prior to the nominally scheduled first DSN station contact (i.e. from TLI to approximately TLI + 20 minutes). This support will provide an early status on the s / c health and safety and help establish the need for any emergency orbit correction maneuver prior to spacecraft acquisition by the DSN. Beyond this period, TDRS forward link support will be dropped with the return link (telemetry) maintained through the end of the LP TDRS visibility period (i.e. approximately 25 minutes beyond the start of the first DSN contact). No TDRS support is planned beyond this initial acquisition period.

# 3.0 Product Support

## 3.1 Product Summary Chart

Table 3-1 summarizes all products to be transferred between the Flight Dynamics Analysis Branch and other elements of the Lunar Prospector ground system. A detailed description of each product including its associated mission support phase, format, accuracy, delivery schedule, time span, transmission medium and volume estimate is provided in the following sections.

## 3.2 Products Supplied by the FDAB

The products supplied by the FDAB for Lunar Prospector support have been grouped as follows:

- **Attitude Maneuver Command Sheet**
  Inputs required by the MCC for generating attitude maneuver commands
- **Orbit Maneuver Command Sheet**
  Inputs required by the MCC for generating orbit maneuver commands
- **Orbit Maneuver Reports**
  Detailed plans for or results of an LP orbit maneuver
- **Mission Planning Aids**
  Products for use in the planning and scheduling of LP MCC operations
- **Orbit Determination and Prediction Products**
  Orbit ephemerides and Doppler characteristics
- **Tracking Data Products**
  Products used in station acquisition operations

Each of these categories of FDAB products is described in the following sections.

| Product Name | ICD Section | Organization From | To | Description | Mission Phase | Accuracy/ Completeness | Delivery Schedule | Time Span | Transmission Medium | Volume Estimate |
|---|---|---|---|---|---|---|---|---|---|---|
| **Attitude Maneuver Command Sheet** | | | | | | | | | | |
| Delta-V Spin Axis Pointing [**AM2**] | 3.2.1.1 | FDAB | LP MCC | +z axis pointing along thrust direction | LOI | .1 deg | 4 hrs prior to att. manv. | One Maneuver | Fax / voice backup | <10 kbytes |
| Mapping Orbit Spin Axis Pointing [**AM3**] | 3.2.1.2 | FDAB | LP MCC | +z axis pointing normal to Ecliptic plane | Mapping | .1 deg | 1 week prior to att. manv. | One Maneuver | Fax / voice backup | <10 kbytes |
| **Orbit Maneuver Command Sheet** | | | | | | | | | | |
| Axial Orbit Maneuver [**OM1**] | 3.2.2.1 | FDAB | LP MCC | Maneuver start time, duration, direction, and ΔV Magnitude | LOI Mapping | As required to achieve and maintain 100km ± 20km 90 ± .5 deg inc lunar orbit | [Appendix B] | One Maneuver | Fax / voice backup | <10 kbytes |
| Vector Orbit Maneuver [**OM2**] | 3.2.2.2 | FDAB | LP MCC | Maneuver start time, ΔV magnitude, and Thrust direction | Transfer Mapping | “ | [Appendix B] | One maneuver | Fax / voice backup | <10 kbytes |
| **Orbit Maneuver Reports** | | | | | | | | | | |
| Orbit Maneuver Planning Package [**OR1**] | 3.2.3.1 | FDAB | LP MCC | Burn parameters, pre / post burn conditions | All | Consistent with Ephem Accuracy [OD2] | [Appendix B] | N / A | Fax / e-mail voice backup | <10 kbytes |
| Post-Maneuver Report [**OR2**] | 3.2.3.2 | FDAB | LP MCC | Post-maneuver orbit state, thrust correction factors, propellant remaining | All | Consistent with Ephem Accuracy [OD2] | [Appendix B] | N / A | Fax / e-mail voice backup | <100 kbytes |
| **Mission Planning Aids** | | | | | | | | | | |
| Station View Periods [**PA1**] | 3.2.4.1 | FDAB | LP MCC | Entry / Exit times of DSN & TDRS contacts | All | 1 min | Weekly | 4 weeks | Internet: FDAB Web Site | < 500 kbytes |
| Shadow Times [**PA2**] | 3.2.4.2 | FDAB | LP MCC | Earth and Moon shadow entry / exits | All | 1 min | Weekly | 4 weeks | Internet: FDAB Web Site | < 500 kbytes |
| Lunar Eclipse Times [**PA3**] | 3.2.4.3 | FDAB | LP MCC | Lunar eclipse entry / exits | Mapping | 1 min | Weekly | 4 weeks | Internet: FDAB Web Site | < 10 kbytes |

Table 3-1: Product Summary Chart (1 of 2)

| Product Name | ICD Section | Organization From | To | Description | Mission Phase | Accuracy/ Completeness | Delivery Schedule | Time Span | Transmission Medium | Volume Estimate |
|---|---|---|---|---|---|---|---|---|---|---|
| **Orbit Determination and Prediction Products** | | | | | | | | | | |
| Definitive Orbit Ephemeris **[OD1]** | 3.2.5.1 | FDAB | LP MCC | ASCII files of computed LP state vectors | LOI Mapping | 1 km (1-σ) (using updated lunar model) | Weekly | 1 week | Internet: FDAB Web Site | 1.5 Megabytes |
| Predicted Orbit Ephemeris **[OD2]** | 3.2.5.2 | FDAB | LP MCC | ASCII files of predicted LP state vectors | All | 500 km after 4 weeks | Weekly | 4 weeks | Internet: FDAB Web Site | 6 Megabytes |
| Doppler Residual Information **[OD3]** | 3.2.5.3 | FDAB | LP MCC | Prelim. Assessment of TLI and LOI burn | Transfer | Best Available | 5 minutes following receipt | 1 maneuver | Voice | N/A |
| Solar-Lunar-Planetary (SLP) File **[OD4]** | 3.2.5.4 | FDAB | LP MCC | Ephemeris for sun, moon, planets | All | Based on JPL DE 200 Ephem | Updates as available | 1992-2011 | Internet: FDAB Web Site | 3.5 Megabytes |
| **Tracking Data Products** | | | | | | | | | | |
| DSN Station Acquisition Data **[TD1]** | 3.2.6.1 | FDAB | JPL/ DSN | Earth centered P-files Moon centered P-files | All | Consistent with Ephem Accuracy [OD2] | Weekly | 4 weeks | Nascom | 3 Megabytes |
| TDRS Acquisition Data **[TD2]** | 3.2.6.2 | FDAB | STGT | IIRV | Transfer | 3σ Athena II dispersions | Prelaunch | 2 hrs | Nascom | <10 kbytes |
| **Operations Planning Data** | | | | | | | | | | |
| LP Operating Constraints **[PD1]** | 3.3.1 | LP MCC | FDAB | Spacecraft constraints affecting orbit ops | All | N/A | As Available | N/A | Fax / e-mail | <10 kbytes |
| LP Operations Timeline **[PD2]** | 3.3.2 | LP MCC | FDAB | Nominal Ops time-line with updates | All | N/A | As Available | N/A | Fax / e-mail | <100 kbytes |
| LP Maneuver Conditions **[PD3]** | 3.3.3 | LP MCC | FDAB | Pre/Post maneuver s/c state (e.g. tank temps, pressure, thrust time) | All | N/A | On -Request | N/A | Fax / e-mail | <10 kbytes |
| Ground Station Schedules **[PD4]** | 3.3.4 | LP MCC | FDAB | Nominal station schedules & updates | All | N/A | Weekly | 1 Week | e-mail / Fax | <10 kbytes |

Table 3-1: Product Summary Chart (2 of 2)

### 3.2.1 Attitude Maneuver Command Sheet

The FDAB will provide attitude maneuver command sheets to the LP MCC in support of spin axis reorientation maneuvers. FDAB attitude maneuver command sheets will contain information that will be used by the MCC to calculate and prepare thruster commands to reorient the LP spin axis. Attitude maneuver command sheets will be prepared in support of the following two types of attitude maneuvers:

1. establish spin axis pointing during delta-V maneuvers
2. establish spin axis pointing during the science mapping orbit

The command sheet for each type of attitude maneuver will contain similar information necessary to reorient the +z axis of the LP spacecraft to the required attitude. Target attitudes will be described in terms of mean of J2000 unit vectors relative to the ecliptic plane as described in Appendix A. Each type of maneuver is described in the following sections.

#### 3.2.1.1 Delta-V Spin Axis Pointing

##### 3.2.1.1.1 Description

Prior to arriving at the moon, the LP spin axis (+z) will need to be reoriented along the anti-velocity vector at periselene in preparation for LOI orbit maneuvers. The FDAB will provide an attitude maneuver command sheet identifying the required pointing direction of the LP +z axis in the form of a unit vector in ecliptic mean of J2000 coordinates.

##### 3.2.1.1.2 Mission Phase

The FDAB will provide an attitude maneuver command sheet establishing the +z axis pointing direction required for axial burns using the A1/A2 thrusters during LOI. Under nominal conditions, the target attitude provided will be maintained throughout the entire LOI sequence that results in a 100 km circular lunar orbit. However, in the event of non-nominal LOI burns, updated attitude maneuver command sheets may be required to adjust delta-V pointing prior to each LOI maneuver.

##### 3.2.1.1.3 Format

Figure 3.1 shows a sample format of the attitude maneuver command sheet.

##### 3.2.1.1.4 Accuracy

The delta-V spin axis pointing vector contained in the command sheet will be accurate to within 0.1 deg of the negative velocity vector at periselene.

##### 3.2.1.1.5 Delivery Schedule

Delta-V spin axis pointing command sheets will be delivered according to the schedule in Appendix B.

##### 3.2.1.1.6 Time Span

Nominally, a single attitude maneuver command sheet will be required to establish the delta-V attitude during all LOI orbit maneuvers. Updated command sheets will be delivered as necessary in the event of non-nominal burns.

##### 3.2.1.1.7 Transmission Medium

The attitude maneuver command sheet will be delivered via Fax transmission with voice backup.

##### 3.2.1.1.8 Volume Estimate

The attitude maneuver command sheet volume will not exceed 10 kbytes.

Lunar Prospector

ATTITUDE MANEUVER COMMAND SHEET

**Maneuver Description:** ______________________________

______________________________

______________________________

**Maneuver Type:**

☐ Delta-V Attitude Reor

☐ Mapping Orbit Attitude Reor ☐ Other: ________________

**Desired +Z Axis Pointing**

RA = [ ] deg

Dec = [ ] deg

$\hat{X}$ = [ ]

$\hat{Y}$ = [ ]

$\hat{Z}$ = [ ]

**Expected Maneuver Start Time:**

Expected GMT of Maneuver: ______________________ (YYMMDD.HHMM)

**Coordinate System:**

☐ Ecliptic, Mean of J2000 ☐ Other: ________________

**Sun Angle Conditions:**

Pre-Maneuver Observed Sun Angle: __________ Deg

Post-Maneuver Predicted Sun Angle: __________ Deg

**Comments:** ______________________________

______________________________

______________________________

| Prepared By: (GSFC FDE) | QA By: (ARC FDE) | Approved By: (ARC MM) |
|---|---|---|
| Signature / Date | Signature / Date | Signature / Date |

**Figure 3-1: Attitude Maneuver Command Sheet**

#### 3.2.1.2 Mapping Orbit Spin Axis Pointing

##### 3.2.1.2.1 Description

Upon completing all LOI orbit maneuvers, the LP spin axis will be reoriented along the normal to the ecliptic plane. The FDAB will provide an attitude maneuver command sheet identifying the required mapping orbit pointing direction of the LP +z axis in the form of a unit vector in ecliptic mean of J2000 coordinates. The initial direction of the +z-axis pointing (i.e. along positive or negative normal to the ecliptic) is chosen to minimize the attitude turn angles from the cruise, LOI and mapping orbit attitudes. For the current baseline trajectory with a north ecliptic cruise pointing attitude and a periselene location in the northern lunar hemisphere, a placement of the +z-axis along the positive normal to the ecliptic is planned. Once in the lunar mapping orbit, it is possible (although not currently planned) that other pointing attitudes (e.g. +z-axis along negative ecliptic orbit normal, or along the positive/negative normal to the moon's orbit plane) may be required.

##### 3.2.1.2.2 Mission Phase

The FDAB will provide the attitude maneuver command sheet establishing the mapping orbit spin axis pointing direction initially at the completion of the transfer phase. Changes to the mapping orbit pointing attitude will be supported as necessary.

##### 3.2.1.2.3 Format

Figure 3.1 shows a sample format of the attitude maneuver command sheet.

##### 3.2.1.2.4 Accuracy

The target mapping orbit spin axis pointing vector contained in the command sheet will be accurate to within 0.1 deg of the normal to the ecliptic plane.

##### 3.2.1.2.5 Delivery Schedule

The FDAB will deliver an attitude maneuver command sheet for establishing the required mapping orbit spin axis pointing no later than 4 hours prior to the last LOI maneuver (a preliminary command sheet will be delivered prelaunch). Thereafter, attitude maneuver command sheets will be delivered one week prior to scheduled reorientation maneuvers.

##### 3.2.1.2.6 Time Span

Each attitude maneuver command sheet will cover a single attitude maneuver.

##### 3.2.1.2.7 Transmission Medium

The attitude maneuver command sheet will be delivered via Fax transmission with voice backup.

##### 3.2.1.2.8 Volume Estimate

The attitude maneuver command sheet volume will not exceed 10 kbytes.

### 3.2.2 Orbit Maneuver Command Sheet

The FDAB will provide orbit maneuver command sheets to the LP MCC in support of all orbit maneuvers. The FDAB orbit maneuver command sheets will contain information that will be used by the MCC to calculate and prepare thruster commands to carry out LP orbit maneuvers. Two types of orbit maneuvers will be carried out:

1. Axial Orbit Maneuvers
2. Vector Orbit Maneuvers

LP orbit maneuvers will nominally consist of three mid-course correction maneuvers in the transfer phase, three LOI maneuvers, and regular trim maneuvers (possibly as often as 3 to 5 weeks) in the mapping phase. Upon obtaining an updated lunar potential model, an attempt may be made to establish a quasi-frozen orbit which would decrease the frequency of orbit maintenance maneuvers. The LP propulsion modeling conditions used in preparing orbit maneuver command sheets are described in Reference 5. Axial and Vector orbit maneuver are discussed in the following sections.

#### 3.2.2.1 Axial Orbit Maneuvers

##### 3.2.2.1.1 Description
Axial orbit maneuver command sheets will contain the following key information:

a. Orbit maneuver start time (GMT):
   Year, month, day, hour, minute, and second of maneuver start
b. Estimated orbit maneuver duration in seconds
c. Delta-v magnitude:
   Magnitude of velocity change in meter/sec
d. Selected thrusters
e. +z axis attitude assumed

Additionally, when the specified target attitude is different from the current spacecraft attitude, a delta-V spin axis pointing command sheet (section 3.2.1.2) will be supplied in order to define the required attitude reorientation maneuver necessary to establish the proper delta-V thrust direction.

##### 3.2.2.1.2 Mission Phase
Axial orbit maneuvers will nominally be performed during the LOI phase and on occasion during the mapping phase (when LP orbit geometry permits).

##### 3.2.2.1.3 Format
Figure 3.2 shows a sample format of the LP axial orbit maneuver command sheet.

##### 3.2.2.1.4 Accuracy
The accuracy of information contained in an orbit maneuver command sheet will be consistent with orbit prediction accuracies (see Section 3.2.5.2.4), and as necessary to achieve the required lunar mapping orbit conditions: 100 km ± 20 km altitude and 90 ± .5 deg inclination.

##### 3.2.2.1.5 Delivery Schedule
The FDAB will deliver axial orbit maneuver command sheets according the schedule in Appendix B.

##### 3.2.2.1.6 Time Span
Each axial orbit maneuver command sheet will cover a single orbit maneuver.

##### 3.2.2.1.7 Transmission Medium
Orbit maneuver command sheets will be delivered via Fax transmission with voice backup.

##### 3.2.2.1.8 Volume Estimate
The orbit maneuver command sheet volume will not exceed 10 kbytes.

Lunar Prospector

AXIAL ORBIT MANEUVER COMMAND SHEET

**Maneuver Description:** ______________________________

______________________________

______________________________

**Delta -V Magnitude:**

$|\Delta V|$ = ______________ (Meters / Seconds)

**S/C +Z Spin Axis Attitude (Ecliptic, Mean of J2000):**

RA = ☐ deg ☐ Attitude Maneuver Command Sheet Attached

Dec = ☐ deg

**Axial Maneuver Parameters:**

A.) GMT Start Time: ______________ (YYMMDD.HHMMSS)

B.) Estimated Maneuver Duration: ☐☐☐☐.☐ (Seconds)

C.) Thrusters Selected:

☐ A1 / A2 (-z face)

☐ A3 / A4 (+z face)

**Comments:** ______________________________

______________________________

______________________________

______________________________

| Prepared By: (GSFC FDE) | QA By: (ARC FDE) | Approved By: (ARC MM) |
|---|---|---|
| Signature / Date | Signature / Date | Signature / Date |

**Figure 3-2: Axial Orbit Maneuver Command Sheet**

### 3.2.2.2 Vector Orbit Maneuvers

#### 3.2.2.2.1 Description

Vector orbit maneuver command sheets will consist of two parts, an impulsive burn sheet and a finite burn sheet. The command sheets will contain the following key information:

Impulsive Burn Sheet (page 1):

a. Start time of Impulsive orbit maneuver time:
   Year, month, day, hour, minute, and second of impulsive vector maneuver
b. Delta-v magnitude:
   Magnitude of velocity change in meters / sec
c. Delta-V thrust direction:
   Delta-V thrust unit vector in ecliptic mean of J2000 coordinates

Finite Burn Sheet (page 2):

d. Axial burn component start time, duration, DV magnitude and thruster selection
e. Tangential burn component start time, duration, DV magnitude, and thrust direction

#### 3.2.2.2.2 Mission Phase

Vector orbit maneuvers will be performed during the transfer and mapping orbit phases.

#### 3.2.2.2.3 Format

Figure 3.3 shows a sample format of the vector orbit maneuver command sheet.

#### 3.2.2.2.4 Accuracy

The accuracy of information contained in an orbit maneuver command sheet will be consistent with orbit prediction accuracies (see Section 3.2.5.2.4), and as necessary to achieve the required lunar mapping orbit conditions: 100 km ± 20 km altitude and 90 ± .5 deg inclination.

#### 3.2.2.2.5 Delivery Schedule

The FDAB will deliver vector orbit maneuver command sheets according the schedule in Appendix B.

#### 3.2.2.2.6 Time Span

Each vector orbit maneuver command sheet will cover a single orbit maneuver.

#### 3.2.2.2.7 Transmission Medium

Orbit maneuver command sheets will be delivered via Fax transmission with voice backup.

#### 3.2.2.2.8 Volume Estimate

The command sheet volume will not exceed 10 kbytes.

Lunar Prospector
VECTOR ORBIT MANEUVER COMMAND SHEET

**Maneuver Description:** ______________________________

______________________________

______________________________

**Ideal/Impulsive Vector Maneuver Parameters:**

A.) Vector Maneuver Start GMT: ______________ (YYMMDD.HHMMSS)
(i.e. Impulsive maneuver time) + / - _____ sec

B.) Delta-V Magnitude: ______________ (Meters / Seconds)

C.) Delta-V Thrust Direction:

RA = [ ] deg

Dec = [ ] deg

[Ecliptic mean of J2000 coordinates]

**Comments:** ______________________________

______________________________

______________________________

______________________________

| Prepared By: ________ Signature / Date (GSFC FDE) | QA By: ________ Signature / Date (ARC FDE) | Approved By: ________ Signature / Date (ARC MM) |
|---|---|---|

**Figure 3-3: Vector Orbit Maneuver Command Sheet (1 of 2)**

Lunar Prospector

VECTOR ORBIT MANEUVER COMMAND SHEET: PLANNING INFORMATION

S/C +z Spin Axis Attitude (Ecliptic, Mean of J2000): RA = [ ] deg, Dec = [ ] deg

**Axial Component:**

A.) GMT Start Time: ____________________ (YYMMDD.HHMMSS) +/- ___ sec

B.) Estimated Axial Maneuver Duration: [ ][ ][ ][ ].[ ] (Seconds)

C.) Thrusters Selected:

[ ] A1/A2 (-z face)

[ ] A3/A4 (+z face)

D.) Delta-V Magnitude: ____________________ (Meters/Seconds)

**Tangential Component:**

A.) GMT Start Time: ____________________ (YYMMDD.HHMMSS) +/- ____ sec

B.) Estimated Tangential Maneuver Duration: [ ][ ][ ][ ].[ ] (Seconds)
[Note: nominal pulse width = .833 sec]

C.) Delta-V Magnitude: ____________________ (Meters/Seconds)

D.) Tangential Thrust Direction:

RA = [ ] deg

Dec = [ ] deg

[Ecliptic mean of J2000 coordinates]

Approximate Sun Azimuth Angle: [ ]

Estimated # of Pulses: [ ]

**Figure 3-3: Vector Orbit Maneuver Command Sheet (2 of 2)**

### 3.2.3 Orbit Maneuver Reports

The FDAB will provide the LP MCC with two orbit maneuver reports to be used in planning and analyzing the effects of LP orbit maneuvers:

1. Orbit Maneuver Planning Package
2. Post-Maneuver Report

Orbit maneuver reports will be prepared in close consultation with the MCC and will require coordination regarding the type, timing, characteristics and observed results of each orbit maneuver (Section 3.3.3).

#### 3.2.3.1 Orbit Maneuver Planning Package

##### 3.2.3.1.1 Description
Prior to each orbit maneuver, the FDAB will provide the LP MCC with an orbit maneuver planning package containing preliminary information concerning an upcoming maneuver.

##### 3.2.3.1.2 Mission Phase
Orbit maneuver planning packages will be provided for all orbit maneuvers in the transfer, LOI and mapping orbit phases.

##### 3.2.3.1.3 Format
The orbit maneuver planning package will contain the following information:

- o preliminary orbit/attitude maneuver command sheets
- o estimated pre-maneuver and post-maneuver orbit state vectors
- o estimates of propellant used and propellant remaining
- o estimate of post-burn tank pressure
- o primary and backup ground station coverage

In addition to the above items, the planning package will also include a set of applicable mission planning aids covering the post-maneuver period as described in section 3.2.4 .

##### 3.2.3.1.4 Accuracy
The accuracy of information contained in the orbit maneuver planning package will be consistent with orbit prediction accuracies (see Section 3.2.5.2.4), and as necessary to achieve the required lunar mapping orbit conditions: 100 km ± 20 km altitude and 90 ± .5 deg inclination.

##### 3.2.3.1.5 Delivery Schedule
The FDAB will deliver the orbit maneuver planning package according the schedule in Appendix B.

##### 3.2.3.1.6 Time Span
The orbit maneuver planning package will cover a single orbit maneuver. Predicted post-maneuver planning aids associated with the package will extend through periselene in the transfer orbit, and for 48 hrs during LOI and mapping orbit maneuvers.

##### 3.2.3.1.7 Transmission Medium
The orbit maneuver planning package will be delivered as fax or e-mail.

##### 3.2.3.1.8 Volume Estimate
Information contained in the orbit maneuver planning package will not exceed 100 kbytes.

#### 3.2.3.2 Post-Maneuver Report

##### 3.2.3.2.1 Description

following each orbit maneuver, the FDAB will provide the LP MCC with a post-maneuver report which summarizes and evaluates the results of a recently executed orbit maneuver. The FDAB will use post-maneuver tracking data along with observed maneuver conditions (e.g. computed attitude, actual maneuver start/stop times, etc.) to analyze the results of the burn. The FDAB will also compute a thrust calibration scale factor to be used in improving the modeling of subsequent maneuvers.

##### 3.2.3.2.2 Mission Phase

Post-maneuver reports will be provided for all orbit maneuvers in the transfer, LOI and mapping orbit phases.

##### 3.2.3.2.3 Format

The post-maneuver report will contain the following information:

- o summary of maneuver results
- o computed post-burn orbit vector
- o estimates of propellant used and propellant remaining
- o estimate of post-burn tank pressure
- o predicted maneuver $\Delta V$
- o actual maneuver $\Delta V$
- o estimate of the thrust calibration factor

##### 3.2.3.2.4 Accuracy

The accuracy of information contained in the post-maneuver report will be consistent with orbit determination accuracy (see Section 3.2.5.1)

##### 3.2.3.2.5 Delivery Schedule

The FDAB will deliver the post-maneuver report according the schedule in Appendix B.

##### 3.2.3.2.6 Time Span

The post-maneuver report will cover a single orbit maneuver.

##### 3.2.3.2.7 Transmission Medium

The post-maneuver report will be delivered as a hardcopy, fax or e-mail.

##### 3.2.3.2.8 Volume Estimate

Information contained in the post-maneuver report will not exceed 100 kbytes.

### 3.2.4 Mission Planning Aids

The FDAB will provide the LP MCC with the following mission planning aids in support of operations planning and scheduling activities:

1. Station View Periods
2. Shadow Times
3. Lunar Eclipse Times

These products will be provided as individual ASCII files and as a merged time ordered ASCII file made available to the LP MCC as ASCII files on the Flight Dynamics Lunar Prospector product Web site: *http://fdd.gsfc.nasa.gov/LP*

#### 3.2.4.1 Station View Periods

##### 3.2.4.1.1 Description

The FDAB will provide LP station view periods consisting of acquisition of signal (AOS) and loss of signal (LOS) times for all stations supporting the LP mission. The station views will consist of line-of-site predictions taking into account station locations and antenna masks, and the predicted position of the LP spacecraft. The MCC will use this information to schedule real-time station contacts with the spacecraft for command, telemetry, and tracking operations.

##### 3.2.4.1.2 Mission Phase

The FDAB will provide station views for all phases of the LP mission.

##### 3.2.4.1.3 Format

Figure 3.4 shows a sample format of FDAB station view period data.

##### 3.2.4.1.4 Accuracy

Station view periods accuracy will be consistent with predicted ephemeris accuracy as defined in Section 3.2.5.2 .

##### 3.2.4.1.5 Delivery Schedule

During the mapping orbit phase, station view period files will be updated on the FDAB LP web site by midnight Eastern time of each Tuesday. Appendix B provides a schedule of station view period file delivery in support of orbit maneuvers during the transfer, LOI and mapping phases.

##### 3.2.4.1.6 Time Span

The duration of the station view period files will be identical to that of the predicted ephemeris (as defined in Section 3.2.5.2).

##### 3.2.4.1.7 Transmission Medium

Station view period files will be available for electronic down-link through the Flight Dynamics Lunar Prospector product Web site (URL: *http://fdd.gsfc.nasa.gov/LP*).

##### 3.2.4.1.8 Volume Estimate

LP station view period files will not exceed 500 kbytes.

| GMT TIME YYYYMMDD.HHMMSS | NUM | SHADOW BODY | EVENT TYPE | STATUS | DURATION (MN) | ELEVATION (DEG) | AZIMUTH (DEG) | ARG LAT (DEG) |
|---|---|---|---|---|---|---|---|---|
| 19980106.024818 | 1 | | DS24 | AOS | | 6.00 | 263.60 | 39.04 |
| 19980106.025031 | 4 | | DS16 | AOS | | 12.71 | 263.14 | 43.20 |
| 19980106.041551 | 1 | | DS24 | MAXEL | | 68.85 | 254.93 | 90.13 |
| 19980106.041551 | 4 | | DS16 | MAXEL | | 68.85 | 254.92 | 90.13 |
| 19980106.062314 | 5 | | DS46 | AOS | | -0.01 | 48.96 | 103.82 |
| 19980106.071709 | 2 | | DS42 | AOS | | 7.09 | 42.41 | 106.77 |
| 19980106.111228 | 5 | | DS46 | MAXEL | | 25.05 | 357.33 | 114.20 |
| 19980106.111228 | 2 | | DS42 | MAXEL | | 25.06 | 357.33 | 114.20 |
| 19980106.111512 | 1 | | DS24 | LOS | 506.90 | 6.01 | 295.80 | 114.25 |
| 19980106.113602 | 4 | | DS16 | LOS | 525.51 | 2.57 | 298.24 | 114.69 |
| 19980106.145737 | 3 | | DS61 | AOS | | 7.69 | 65.22 | 118.04 |
| 19980106.150336 | 6 | | DS66 | AOS | | 8.68 | 66.07 | 118.13 |
| 19980106.151600 | 2 | | DS42 | LOS | 478.85 | 4.65 | 308.48 | 118.29 |
| 19980106.154638 | 5 | | DS46 | LOS | 563.39 | -0.01 | 303.89 | 118.69 |
| 19980106.214645 | 3 | | DS61 | MAXEL | | 73.35 | 179.38 | 122.33 |
| 19980106.214645 | 6 | | DS66 | MAXEL | | 73.34 | 179.38 | 122.33 |
| 19980106.223617 | 4 | | DS16 | AOS | | 3.62 | 64.15 | 122.73 |
| 19980106.224934 | 1 | | DS24 | AOS | | 6.01 | 65.90 | 122.83 |
| 19980107.042748 | 3 | | DS61 | LOS | 810.18 | 7.91 | 292.85 | 125.12 |
| 19980107.043202 | 6 | | DS66 | LOS | 808.44 | 7.18 | 293.47 | 125.14 |
| 19980107.052848 | 4 | | DS16 | MAXEL | | 77.78 | 179.55 | 125.48 |
| 19980107.052848 | 1 | | DS24 | MAXEL | | 77.78 | 179.55 | 125.48 |
| 19980107.070813 | 5 | | DS46 | AOS | | -0.01 | 59.61 | 126.04 |
| 19980107.080555 | 2 | | DS42 | AOS | | 9.59 | 50.69 | 126.35 |
| 19980107.115402 | 5 | | DS46 | MAXEL | | 30.39 | 359.51 | 127.50 |
| 19980107.115403 | 2 | | DS42 | MAXEL | | 30.40 | 359.51 | 127.50 |
| 19980107.120438 | 1 | | DS24 | LOS | 795.07 | 6.01 | 292.79 | 127.55 |
| 19980107.122155 | 4 | | DS16 | LOS | 825.63 | 2.82 | 295.09 | 127.63 |
| 19980107.152956 | 3 | | DS61 | AOS | | 6.21 | 66.70 | 128.50 |
| 19980107.153818 | 6 | | DS66 | AOS | | 7.66 | 67.96 | 128.54 |
| 19980107.155758 | 2 | | DS42 | LOS | 472.05 | 7.04 | 305.57 | 128.63 |
| 19980107.163936 | 5 | | DS46 | LOS | 571.38 | -0.01 | 299.18 | 128.81 |
| 19980107.221212 | 3 | | DS61 | MAXEL | | 71.30 | 179.69 | 130.23 |
| 19980107.221213 | 6 | | DS66 | MAXEL | | 71.30 | 179.69 | 130.23 |
| 19980107.230428 | 4 | | DS16 | AOS | | 3.80 | 66.45 | 130.45 |
| 19980107.231620 | 1 | | DS24 | AOS | | 6.01 | 68.06 | 130.50 |
| 19980108.044801 | 3 | | DS61 | LOS | 798.08 | 6.97 | 291.66 | 131.85 |
| 19980108.044822 | 6 | | DS66 | LOS | 790.06 | 6.91 | 291.71 | 131.85 |
| 19980108.054658 | 4 | | DS16 | MAXEL | | 76.05 | 179.77 | 132.09 |
| 19980108.054658 | 1 | | DS24 | MAXEL | | 76.05 | 179.76 | 132.09 |
| 19980108.071630 | 5 | | DS46 | AOS | | 0.00 | 62.19 | 132.47 |
| 19980108.081415 | 2 | | DS42 | AOS | | 9.94 | 53.23 | 132.70 |
| 19980108.120733 | 5 | | DS46 | MAXEL | | 32.29 | 359.73 | 133.69 |
| 19980108.120736 | 2 | | DS42 | MAXEL | | 32.29 | 359.72 | 133.69 |
| 19980108.121601 | 1 | | DS24 | LOS | 779.69 | 6.00 | 291.12 | 133.72 |
| 19980108.123344 | 4 | | DS16 | LOS | 809.28 | 2.67 | 293.53 | 133.80 |
| 19980108.154629 | 3 | | DS61 | AOS | | 6.21 | 68.40 | 134.68 |
| 19980108.155111 | 6 | | DS66 | AOS | | 7.04 | 69.11 | 134.69 |
| 19980108.161710 | 2 | | DS42 | LOS | 482.93 | 7.25 | 303.44 | 134.81 |
| 19980108.165845 | 5 | | DS46 | LOS | 582.25 | -0.01 | 297.07 | 135.01 |
| 19980108.222249 | 3 | | DS61 | MAXEL | | 70.02 | 179.76 | 136.62 |
| 19980108.222249 | 6 | | DS66 | MAXEL | | 70.01 | 179.76 | 136.62 |
| 19980108.231825 | 4 | | DS16 | AOS | | 3.94 | 68.03 | 136.93 |

**Figure 3-4: Sample FDAB Station View Period Data**

#### 3.2.4.2 Shadow Times

##### 3.2.4.2.1 Description
The FDAB will provide predictions of times when the LP spacecraft is in the shadow of the Earth (early in the transfer phase) and moon (during the LOI and mapping phase). Both penumbra and umbra entry and exit times are provided.

##### 3.2.4.2.2 Mission Phase
The FDAB will provide shadow predictions for all phases of the LP mission.

##### 3.2.4.2.3 Format
Figure 3.5 shows a sample format of FDAB shadow predictions.

##### 3.2.4.2.4 Accuracy
Shadow entry and exit time accuracy will be consistent with predicted ephemeris accuracy as defined in Section 3.2.5.2 .

##### 3.2.4.2.5 Delivery Schedule
During the mapping orbit phase, LP shadow files will be updated on the FDAB LP web site by midnight Eastern time of each Tuesday. Appendix B provides a schedule of LP shadow file delivery in support of orbit maneuvers during the transfer, LOI and mapping phases.

##### 3.2.4.2.6 Time span
The duration of shadow predictions will be identical to that of the predicted ephemeris (as defined in Section 3.2.5.2).

##### 3.2.4.2.7 Transmission Medium
LP shadow predictions will be available for electronic down-link through the Flight Dynamics Lunar Prospector product Web site (URL: *http://fdd.gsfc.nasa.gov/LP*).

##### 3.2.4.2.8 Volume Estimate
LP shadow prediction files will not exceed 500 kbytes.

PAGE 1

EVENT SUMMARY DATA

| GMT TIME YYYYMMDD.HHMMSS | NUM | SHADOW BODY | EVENT TYPE | STATUS | DURATION (MN) | ELEVATION (DEG) | AZIMUTH (DEG) | ARG LAT (DEG) |
|---|---|---|---|---|---|---|---|---|
| 19980114.000000 | 1 | MOON | PENUMBRA | ENTER | | | | |
| 19980114.000000 | 2 | MOON | UMBRA | ENTER | | | | |
| 19980114.001200 | 2 | MOON | UMBRA | EXIT | 12.00 | | | |
| 19980114.001234 | 1 | MOON | PENUMBRA | EXIT | 12.57 | | | |
| 19980114.014223 | 1 | MOON | PENUMBRA | ENTER | | | | |
| 19980114.014257 | 2 | MOON | UMBRA | ENTER | | | | |
| 19980114.020956 | 2 | MOON | UMBRA | EXIT | 26.98 | | | |
| 19980114.021029 | 1 | MOON | PENUMBRA | EXIT | 28.10 | | | |
| 19980114.034013 | 1 | MOON | PENUMBRA | ENTER | | | | |
| 19980114.034047 | 2 | MOON | UMBRA | ENTER | | | | |
| 19980114.040752 | 2 | MOON | UMBRA | EXIT | 27.08 | | | |
| 19980114.040825 | 1 | MOON | PENUMBRA | EXIT | 28.20 | | | |
| 19980114.053804 | 1 | MOON | PENUMBRA | ENTER | | | | |
| 19980114.053837 | 2 | MOON | UMBRA | ENTER | | | | |
| 19980114.060548 | 2 | MOON | UMBRA | EXIT | 27.18 | | | |
| 19980114.060621 | 1 | MOON | PENUMBRA | EXIT | 28.28 | | | |
| 19980114.073554 | 1 | MOON | PENUMBRA | ENTER | | | | |
| 19980114.073628 | 2 | MOON | UMBRA | ENTER | | | | |
| 19980114.080344 | 2 | MOON | UMBRA | EXIT | 27.27 | | | |
| 19980114.080418 | 1 | MOON | PENUMBRA | EXIT | 28.40 | | | |
| 19980114.093345 | 1 | MOON | PENUMBRA | ENTER | | | | |
| 19980114.093419 | 2 | MOON | UMBRA | ENTER | | | | |
| 19980114.100141 | 2 | MOON | UMBRA | EXIT | 27.37 | | | |
| 19980114.100214 | 1 | MOON | PENUMBRA | EXIT | 28.48 | | | |
| 19980114.113137 | 1 | MOON | PENUMBRA | ENTER | | | | |
| 19980114.113210 | 2 | MOON | UMBRA | ENTER | | | | |
| 19980114.115938 | 2 | MOON | UMBRA | EXIT | 27.47 | | | |
| 19980114.120011 | 1 | MOON | PENUMBRA | EXIT | 28.57 | | | |
| 19980114.132929 | 1 | MOON | PENUMBRA | ENTER | | | | |
| 19980114.133002 | 2 | MOON | UMBRA | ENTER | | | | |
| 19980114.135735 | 2 | MOON | UMBRA | EXIT | 27.55 | | | |
| 19980114.135808 | 1 | MOON | PENUMBRA | EXIT | 28.65 | | | |
| 19980114.152721 | 1 | MOON | PENUMBRA | ENTER | | | | |
| 19980114.152754 | 2 | MOON | UMBRA | ENTER | | | | |
| 19980114.155533 | 2 | MOON | UMBRA | EXIT | 27.65 | | | |
| 19980114.155606 | 1 | MOON | PENUMBRA | EXIT | 28.75 | | | |
| 19980114.172514 | 1 | MOON | PENUMBRA | ENTER | | | | |
| 19980114.172546 | 2 | MOON | UMBRA | ENTER | | | | |
| 19980114.175331 | 2 | MOON | UMBRA | EXIT | 27.75 | | | |
| 19980114.175403 | 1 | MOON | PENUMBRA | EXIT | 28.82 | | | |
| 19980114.192306 | 1 | MOON | PENUMBRA | ENTER | | | | |
| 19980114.192339 | 2 | MOON | UMBRA | ENTER | | | | |
| 19980114.195129 | 2 | MOON | UMBRA | EXIT | 27.83 | | | |
| 19980114.195201 | 1 | MOON | PENUMBRA | EXIT | 28.92 | | | |

**Figure 3-5: Sample FDAB Shadow Predictions**

#### 3.2.4.3 Lunar Eclipse Times

##### 3.2.4.3.1 Description
The FDAB will provide predictions of times during the mapping orbit when the LP spacecraft is in the shadow of the Earth as a result of a lunar eclipse. The opportunity for a lunar eclipse occurs every six months when the lunar orbit line of nodes lines up with the sun. Both penumbra and umbra entry and exit times are provided. For LP launch dates occurring after the September 1997, a total (umbra) lunar eclipse will not occur until July 28, 1999.

##### 3.2.4.3.2 Mission Phase
The FDAB will provide shadow predictions pre-launch and during the mapping phase of the LP mission.

##### 3.2.4.3.3 Format
Figure 3.6 shows a sample format of FDAB lunar eclipse predictions. Eclipse entrance / exit times as shown in Figure 3-6a will be delivered on a weekly basis and should indicate "No Data" if no lunar eclipses are predicted. For periods when lunar eclipses are predicted, an additional eclipse report will be generated (Figure 3-6b) indicating the percent shadowing expected throughout the eclipse.

##### 3.2.4.3.4 Accuracy
Lunar eclipse time accuracy will be consistent with predicted ephemeris accuracy as defined in Section 3.2.5.2 .

##### 3.2.4.3.5 Delivery Schedule
During the mapping orbit phase, LP lunar eclipse will be updated on the FDAB LP web site by midnight Eastern time of each Tuesday. Appendix B provides a schedule of LP lunar eclipse file delivery in support of orbit maneuvers during the transfer, LOI and mapping phases.

##### 3.2.4.3.6 Time span
The duration of LP lunar eclipse predictions will be identical to that of the predicted ephemeris (as defined in Section 3.2.5.2).

##### 3.2.4.3.7 Transmission Medium
LP lunar eclipse predictions will be available for electronic down-link through the Flight Dynamics Lunar Prospector product Web site (URL: *http://fdd.gsfc.nasa.gov/LP*).

##### 3.2.4.3.8 Volume Estimate
LP lunar eclipse prediction files will not exceed 10 kbytes.

PAGE 1

EVENT SUMMARY DATA

| GMT TIME YYYYMMDD.HHMMSS | NUM | SHADOW BODY | EVENT TYPE | STATUS | DURATION (MN) | ELEVATION (DEG) | AZIMUTH (DEG) | ARG LAT (DEG) |
|---|---|---|---|---|---|---|---|---|
| 19980313.030746 | 1 | EARTH | PENUMBRA | ENTER | | | | |
| 19980313.040025 | 1 | EARTH | PENUMBRA | EXIT | 52.65 | | | |
| 19980313.044545 | 1 | EARTH | PENUMBRA | ENTER | | | | |
| 19980313.053738 | 1 | EARTH | PENUMBRA | EXIT | 51.88 | | | |

**Figure 3-6a: Sample FDAB Lunar Eclipse Predictions (Entrance/Exit Time)**

1FDF 13 SHADOW SUMMARY CREATED (YYMMDD.HHMM) 971226.1100 UTC

COMMENT: LP Eclipses
EPHEM: ecl0398a.EPH

| UTC TIME (YYMMDD.HHMMSS) | SHADOW BODY | EVENT TYPE | STATUS | DURATION (MIN) | PERCENT DARKNESS | LATITUDE (DEG) | LONGITUDE (DEG) | HEIGHT (KM) |
|---|---|---|---|---|---|---|---|---|
| 980313.003858 | MOON | PENUMBRA | ENTER | | | 4.844 | 351.369 | 399121.185 |
| 980313.003926 | MOON | UMBRA | ENTER | | | 4.840 | 351.251 | 399138.208 |
| 980313.004000 | MOON | UMBRA | | | 100.000 | 4.836 | 351.104 | 399158.689 |
| 980313.005000 | MOON | UMBRA | | | 100.000 | 4.727 | 348.573 | 399398.275 |
| 980313.010000 | MOON | UMBRA | | | 100.000 | 4.577 | 346.088 | 399384.504 |
| 980313.011000 | MOON | UMBRA | | | 100.000 | 4.420 | 343.666 | 399124.871 |
| 980313.011006 | MOON | UMBRA | EXIT | 30.678 | | 4.419 | 343.641 | 399121.117 |
| 980313.011034 | MOON | PENUMBRA | EXIT | 31.610 | | 4.412 | 343.530 | 399103.936 |
| 980313.023651 | MOON | PENUMBRA | ENTER | | | 4.542 | 322.746 | 399211.264 |
| 980313.023719 | MOON | UMBRA | ENTER | | | 4.539 | 322.627 | 399227.738 |
| 980313.024000 | MOON | UMBRA | | | 100.000 | 4.516 | 321.944 | 399314.287 |
| 980313.025000 | MOON | UMBRA | | | 100.000 | 4.396 | 319.420 | 399494.613 |
| 980313.030000 | MOON | UMBRA | | | 100.000 | 4.241 | 316.948 | 399424.273 |
| 980313.030745 | EARTH | PENUMBRA | ENTER | | | 4.120 | 315.076 | 399209.528 |
| 980313.030754 | MOON | UMBRA | EXIT | 30.585 | | 4.118 | 315.040 | 399204.169 |
| 980313.030822 | MOON | PENUMBRA | EXIT | 31.520 | | 4.111 | 314.928 | 399187.379 |
| 980313.031000 | EARTH | PENUMBRA | | | 2.937 | 4.088 | 314.540 | 399126.287 |
| 980313.032000 | EARTH | PENUMBRA | | | 30.401 | 3.970 | 312.192 | 398686.461 |
| 980313.033000 | EARTH | PENUMBRA | | | 49.543 | 3.914 | 309.880 | 398229.614 |
| 980313.034000 | EARTH | PENUMBRA | | | 43.703 | 3.929 | 307.574 | 397885.035 |
| 980313.035000 | EARTH | PENUMBRA | | | 19.546 | 4.003 | 305.238 | 397750.442 |
| 980313.040000 | EARTH | PENUMBRA | | | 0.152 | 4.108 | 302.848 | 397864.665 |
| 980313.040025 | EARTH | PENUMBRA | EXIT | 52.662 | | 4.113 | 302.748 | 397874.527 |
| 980313.043445 | MOON | PENUMBRA | ENTER | | | 4.239 | 294.120 | 399297.127 |
| 980313.043513 | MOON | UMBRA | ENTER | | | 4.236 | 294.001 | 399313.102 |

END OF DATA

**Figure 3-6b: Sample FDAB Lunar Eclipse Predictions (Percent Shadow)**

### 3.2.5 Orbit Determination and Prediction Products

The FDAB will provide the LP MCC with the following orbit determination / prediction products in support of attitude determination and science data processing operations:

1. Definitive Orbit Ephemeris
2. Predicted Orbit Ephemeris
3. Orbit Maneuver Assessment Based on Doppler Residuals
4. Solar-Lunar-Planetary File

These products will be made available to the LP MCC as files placed on the Flight Dynamics Web sites. With the exception of the SLP file, all data will be in the form of ASCII files. SLP files are available as binary files for use on UNIX, DOS or DEC platforms.

#### 3.2.5.1 Definitive Orbit Ephemeris

##### 3.2.5.1.1 Description
The FDAB will use tracking data collected from ground stations to compute an LP definitive orbit ephemeris. Weekly deliveries of LP definitive orbit ephemeris will form a continuous history of LP position and velocity in the mapping orbit for use in science data processing by LP science investigators. Following the availability of an updated lunar potential model (within the first or second month of the mission), the FDAB will likely be required to begin using the new model as well as re-generate the LP definitive orbit determination history. LP definitive orbit ephemeris files will contain spacecraft position and velocity vectors in moon-centered, Earth equator, mean-of-J2000 coordinates. A definitive ephemeris will also be provided which covers the transfer orbit (in Earth-centered coordinates) and LOI phases of the mission, on a best available accuracy basis.

##### 3.2.5.1.2 Mission Phase
LP definitive orbit ephemeris will be delivered during the mapping orbit phase only, upon completion of all LOI maneuvers.

##### 3.2.5.1.3 Format
Appendix C provides a sample format of an FDAB definitive orbit ephemeris file, an item by item description of the ASCII ephem contents and a mapping of each parameter to its corresponding location in the standard binary GSFC ephem (this is provided as a cross reference since the standard binary ephem is documented better --- see reference 3 for additional information).

##### 3.2.5.1.4 Accuracy
Final LP definitive orbit ephemeris files (processed with the updated lunar potential model) will be accurate to within +/- 1 km (1 sigma) in position and +/- 1 m/sec in velocity (1 sigma). Prior to the receipt of the updated lunar potential model, definitive ephemeris position accuracy is expected to be within 5 km 1 sigma.

##### 3.2.5.1.5 Delivery Schedule
LP definitive orbit ephemeris files will be updated weekly on the FDAB LP product web site by midnight Eastern time of each Tuesday. Appendix B provides a delivery schedule of definitive orbit ephemeris file following orbit maneuvers in the mapping phase.

##### 3.2.5.1.6 Time Span
LP definitive orbit ephemeris files will cover a 1-week period.

##### 3.2.5.1.7 Transmission Medium
LP definitive orbit ephemeris files will be available for electronic down-link through the Flight Dynamics Lunar Prospector product Web site (URL: *http://fdd.gsfc.nasa.gov/LP*).

#### 3.2.5.1.8 Volume Estimate

LP weekly definitive orbit ephemeris files will not exceed 2 Mbytes.

### 3.2.5.2 Predicted Orbit Ephemeris

#### 3.2.5.2.1 Description

The FDAB will generate predicted LP ephemeris files to be used internally for product generation and maneuver planning and for use by the LP MCC for attitude determination. The predicted LP ephemeris will consist of an ASCII file of spacecraft position and velocity vectors in Earth equator, mean-of-J2000 coordinates. During the transfer orbit period FDAB predicted ephemeris files will contain Earth-centered vectors. For operations during the LOI and mapping orbit phase, the FDAB will generate moon-centered predicted ephemeris files. Three types of predicted ephems will be generated:

##### 3.2.5.2.1.1 Post Maneuver Definitive Prediction

Following orbit maneuvers, the FDAB will computed an updated orbit state based on tracking data. The post-maneuver state will be propagated out for several days and will be used to update acquisition data and planning products and to plan for follow-on maneuvers. This predicted ephemeris will not model any maneuvers planned in the future.

##### 3.2.5.2.1.2 Pre-Maneuver Planning Ephemeris

Prior to an orbit maneuver, a predicted ephemeris which models the effects of the planned maneuver will be generated. During the mapping phases, this ephemeris will begin at the expected end conditions of a maneuver and extend out for 48 hours. During the transfer orbit phase, the ephemeris will be extended to periselene.

##### 3.2.5.2.1.3 Special Ephems

Two special pre-maneuver predicted ephemeris will be generated in support of LP:

**LOI Finite Burn Ephem**: For each of the three LOI maneuvers, an ephemeris which begins 3 hours prior to the maneuver and contains finite burn modeling of the burn will be generated. This ephem will extend out approximately 48 hrs beyond the end of each LOI maneuver.

**Post-TCM #2 Entire LOI Sequence Ephem**: Two and one half days following TLI, the FDAB will generate a predicted ephemeris which extends from the post-TCM#2 burnout state through LOI #3 + 3 days. All three LOI maneuvers will be modeled as finite burns.

#### 3.2.5.2.2 Mission Phase

LP predicted orbit ephemeris will be delivered during all phases of the LP mission.

#### 3.2.5.2.3 Format

Appendix C provides a sample format of an FDAB definitive orbit ephemeris file, an item by item description of the ASCII ephem contents and a mapping of each parameter to it's corresponding location in the standard binary GSFC ephem (this is provided as a cross reference since the standard binary ephem is documented better --- see reference 3 for additional information).

### 3.2.5.2.4 Accuracy

Initially, the position uncertainty associated with LP predicted orbit ephemeris in the mapping orbit is expected to be as follows (primarily in the along track direction):

130 km after 1 week of propagation
330 km after 2 weeks of propagation
420 km after 3 weeks of propagation
500 km after 4 weeks of propagation

Orbit prediction accuracy should improve with the availability of the new lunar gravity model, after the first one or two months of the mission.

### 3.2.5.2.5 Delivery Schedule

During the mapping phase, LP predicted orbit ephemeris files will be updated weekly on the FDAB LP product web site by midnight Eastern time of each Tuesday. Appendix B provides a delivery schedule for predicted orbit ephemeris files during the mapping phase.

### 3.2.5.2.6 Time Span

#### 3.2.5.2.6.1 Post-Maneuver Definitive Prediction

LP post-maneuver definitive states will be propagated out to periselene during the transfer orbit. The post-TCM #3 definitive state will be propagated 12 hours beyond periselene (in a hyperbolic orbit). During the LOI phase, post-maneuver definitive solutions will extend out for 2 days.

#### 3.2.5.2.6.2 Pre-Maneuver Planning Ephemeris

LP pre-maneuver predicted orbit ephemeris files will extend to periselene during the transfer phase. During LOI and in the mapping orbit, pre-maneuver planning ephems will extend out for 2 days past the planned orbit maneuver.

#### 3.2.5.2.6.3 Special Ephems

See section 3.2.5.2.1.3

### 3.2.5.2.7 Transmission Medium

LP predicted orbit ephemeris files will be available for electronic down-link through the Flight Dynamics Lunar Prospector product Web site (URL: *http://fdd.gsfc.nasa.gov/LP*).

### 3.2.5.2.8 Volume Estimate

During the mapping orbit phase, LP 4-week predicted orbit ephemeris files will not exceed 8 Mbytes.

#### 3.2.5.3 Orbit Maneuver Assessment Based on Doppler Residuals

##### 3.2.5.3.1 Description
In order to provide a near-real-time assessment of the performance of critical orbit maneuvers (i.e., TLI, transfer orbit TCM and LOI burns), the FDAB will use Doppler data residual information to estimate the over/under performance of the burn. Based on the information provided by FDAB, the LP MCC will determine if an emergency orbit maneuver is required (Reference 5).

##### 3.2.5.3.2 Mission Phase
LP Doppler residual information will be provided only during the transfer orbit and LOI phases of the mission.

##### 3.2.5.3.3 Format
Information provided by the FDAB will consist of the magnitude of the estimated maneuver over/under burn, and the uncertainty associated with this estimate.

##### 3.2.5.3.4 Accuracy
The expected uncertainty of maneuver performance estimates provided by FDAB is on the order of +/- 5 m/s for the TLI burn assessment, and +/- 15% for LOI burns.

##### 3.2.5.3.5 Delivery Schedule
For critical orbit maneuvers identified, an FDAB assessment of the maneuver over/under burn condition will be delivered approximately 5 minutes following receipt of Doppler data.

##### 3.2.5.3.6 Time Span
Orbit maneuver assessments based on Doppler residuals will nominally be based on just a few minutes of tracking data.

##### 3.2.5.3.7 Transmission Medium
Preliminary orbit maneuver assessments will communicated to the LP MCC over established voice lines.

##### 3.2.5.3.8 Volume Estimate
N/A

#### 3.2.5.4 Solar-Lunar-Planetary File

##### 3.2.5.4.1 Description
The FDAB creates solar-lunar-planetary (SLP) files containing ephemerides for the sun, moon and planets which are derived from JPL DE 118 and DE 200 ephemerides. The SLP files are located on the Flight Dynamics Product Center (FDPC) web site in formats suitable for a number of different platforms (PC, UNIX, DEC) and in several coordinate systems (mean of B1950, true of date B1950, mean of J2000, true of date J2000).

##### 3.2.5.4.2 Mission Phase
SLP files will be available throughout all phases of the LP mission.

##### 3.2.5.4.3 Format
A description of the FDAB SLP file format is available on the FDPC located on the World Wide Web (URL: *http://fdd.gsfc.nasa.gov/FDD_products.html* ).

##### 3.2.5.4.4 Accuracy
The accuracy of the FDAB SLP file will be consistent with that of the JPL DE 118 and DE 200 ephemeris data.

##### 3.2.5.4.5 Delivery Schedule
Nominally, FDAB SLP files will only need to be downloaded once by the MCC prior to the LP launch. The SLP files at the FDPC may be updated periodically, based on the availability of new models from JPL. The FDAB will notify the MCC when such updates occur.

##### 3.2.5.4.6 Time Span
The SLP file will cover a 20 year period (currently 1992-2011).

##### 3.2.5.4.7 Transmission Medium
FDAB SLP files will be available for electronic down-link through the FDPC located on the World Wide Web (URL: *http://fdd.gsfc.nasa.gov/FDD_products.html* ).

##### 3.2.5.4.8 Volume Estimate
FDAB SLP files have a volume of approximately 3.5 Megabytes.

### 3.2.6 Tracking Data Products

The FDAB will provide the LP MCC with the following tracking data products in support of station acquisition data functions:

1. DSN Station Acquisition Data
2. TDRS Acquisition Data

These products, consisting of LP predicted position data, will be transmitted electronically over Nascom lines to the respective sites.

### 3.2.6.1 DSN Station Acquisition Data

#### 3.2.6.1.1 Description

The FDAB will generate predicted LP station acquisition data for the DSN sites (Canberra, Goldstone, Madrid). Acquisition data in the form of "p-files" (as defined in Appendix A of Reference 1) will be transmitted by FDAB to JPL in support of LP station events. During the transfer orbit phase, p-files will initially contain data in *Earth* centered, Earth equator, inertial mean of J2000 coordinates. P-files covering LOI and the mapping orbit will contain data in *moon* centered, Earth equator, inertial mean of J2000 coordinates. As a backup to the p-files, traditional Improved Inter-Range Vectors ($I^2RVs$) (also known as Inter-Center Vectors, ICVs to JPL) will also be provided in support of the first post-TLI station acquisition and in support LOI #1.

#### 3.2.6.1.2 Mission Phase

LP DSN station acquisition data in the form of p-files will be delivered during all phases of the LP mission.

#### 3.2.6.1.3 Format

Appendix A of Reference 1 shows a sample format of a p-file.

#### 3.2.6.1.4 Accuracy

The accuracy of information contained in LP DSN station acquisition data will be consistent with orbit prediction accuracy (see Section 3.2.5.2.4),

#### 3.2.6.1.5 Delivery Schedule

During the mapping phase of the mission, LP DSN station acquisition data will be transmitted weekly each Tuesday by COB, Eastern time. Appendix B provides a nominal schedule of LP DSN station acquisition data delivery during the transfer orbit and LOI phases of the mission.

#### 3.2.6.1.6 Time Span

The coverage span of p-file and ICVs will be consistent with the predicted ephemeris file used to generate it. See section 3.2.5.2.6 .

#### 3.2.6.1.7 Transmission Medium

LP DSN station acquisition data in the form of p-files will be transmitted using File Transfer Protocol (FTP) over Nascom . ICVs will be transmitted in real-time over Nascom.

#### 3.2.6.1.8 Volume Estimate

LP 4-week p-file transmissions will be on the order of 3 Mbytes.

### 3.2.6.2 TDRS Acquisition Data

#### 3.2.6.2.1 Description

The FDAB will generate predicted LP TDRS acquisition data for the time period immediately following TLI. While LP does not fly a TDRS transponder, an attempt will be made to receive two-way Doppler and telemetry data in order to get an early assessment of TLI performance and spacecraft health. No TDRS support is planned beyond the first few hours of the mission. TDRS acquisition data will be in the form of an $I^2RV$ in Earth centered, Earth equator, true of date rotating coordinates.

#### 3.2.6.2.2 Mission Phase

LP TDRS acquisition data will be required only during the early transfer phase.

#### 3.2.6.2.3 Format

Appendix B of Reference 1 shows a sample format of an FDAB IIRV file.

#### 3.2.6.2.4 Accuracy

LP TDRS acquisition data accuracy will be based on a propagation of the nominal LP TLI injection vector.

#### 3.2.6.2.5 Delivery Schedule

LP TDRS acquisition data will be transmitted to the Second TDRS Ground Terminal (STGT) 24 hours prior to launch.

#### 3.2.6.2.6 Time Span

Pre-launch LP TDRS acquisition data will likely consist of a single vector.

#### 3.2.6.2.7 Transmission Medium

LP TDRS acquisition data will be transmitted over Nascom to the STGT.

#### 3.2.6.2.8 Volume Estimate

LP TDRS acquisition data transmissions will be on the order of 10 kbytes.

### 3.3 Products Supplied by the LP MCC

The products supplied by the LP MCC to the FDAB for Lunar Prospector support are as follows:

1. LP Operational Constraints
2. LP Operations Timeline
3. LP Maneuver Conditions
4. Station Schedules
5. LMLV-2 Separation Vector

This data will be used by the FDAB in planning maneuvers, generating products and monitoring LP operational activity.

### 3.3.1 LP Operational Constraints

#### 3.3.1.1 Description

The LP Project will define all LP operational constraints that affect orbit, attitude and communications/tracking operations. This information is required by the FDAB pre-launch for transfer orbit design and planning purposes. Any changes to operational constraints once on orbit will also be related to the FDAB should they occur. A full list of spacecraft operating constraints is contained in Reference 4. Key constraints affecting orbit control and determination are listed in Appendix D.

#### 3.3.1.2 Mission Phase

LP operational constraints will be provided prelaunch and updated as necessary throughout the mission.

#### 3.3.1.3 Format

LP operational constraints will be documented in Reference 4 and updated via Project analysis reports and memoranda.

#### 3.3.1.4 Accuracy

N/A

#### 3.3.1.5 Delivery Schedule

Notification of LP operational constraints will be provided as they occur.

#### 3.3.1.6 Time Span

N/A

#### 3.3.1.7 Transmission Medium

On orbit, the LP project will notify the FDAB of changes by e-mail or faxed change pages to Reference 4.

#### 3.3.1.8 Volume Estimate

N/A

### 3.3.2 LP Operational Timeline

#### 3.3.2.1 Description

The LP Project will establish an operational timeline of key activities from launch through the LOI phase. The LP timeline will contain inputs from FDAB concerning orbit maneuver times and station coverage and will include other key spacecraft activities that might impact FDAB maneuver planning (e.g. attitude maneuvers, boom deployments, etc.). During the mission, the FDAB will rely on the timeline and information concerning any required updates to the timeline, for scheduling operations and shift personnel.

#### 3.3.2.2 Mission Phase

The LP operational timeline will be delivered pre-launch with updates throughout the transfer and LOI phases.

#### 3.3.2.3 Format

The LP operational timeline will include a description of key events and associated times in GMT.

#### 3.3.2.4 Accuracy

N/A

#### 3.3.2.5 Delivery Schedule

A draft timeline will be delivered 3 months before launch. During the transfer and LOI phases, updates will be provided as necessary.

#### 3.3.2.6 Time Span

The LP operational timeline will be cover key events in the transfer and LOI phases.

#### 3.3.2.7 Transmission Medium

Following launch, the LP project will notify the FDAB of changes to the timeline by e-mail or faxed change pages.

#### 3.3.2.8 Volume Estimate

The timeline volume will not exceed 500 kbytes.

### 3.3.3 LP Maneuver Conditions

#### 3.3.3.1 Description

The LP Project will provide the FDAB with all requested information concerning the pre- and post-maneuver state of the spacecraft. This information will include tank temperatures and pressures, observed average inertial attitude during the maneuver, estimated nutation angle, thrusters used, actual maneuver start/stop times, and any anomalies observed during the maneuver.

#### 3.3.3.2 Mission Phase

LP maneuver conditions will be supplied by the LP MCC on request for all maneuvers throughout the mission.

#### 3.3.3.3 Format

Figure 3.7 provides a sample form to be used in documenting LP maneuver conditions.

#### 3.3.3.4 Accuracy

N/A

#### 3.3.3.5 Delivery Schedule

LP pre- and post-maneuver conditions will be supplied as scheduled in the timeline, or on request.

#### 3.3.3.6 Time Span

LP maneuver conditions will cover a single orbit maneuver.

#### 3.3.3.7 Transmission Medium

LP maneuver conditions forms will be transmitted to FDAB via fax with voice backup.

#### 3.3.3.8 Volume Estimate

The volume of LP maneuver condition forms will be on the order of 10 kbytes.

# LP MCC Pre-Maneuver Conditions Form

| | | |
|---|---|---|
| 1. Estimated Maneuver Start Time: | | YYMMDD.HHMMSS |
| 2. Pre-Maneuver Percent Propellant Remaining: | | Percent |
| 3. Pre-Maneuver Propellant Mass: | | kg |
| 4. Pre-Maneuver Tank Pressure: | | Psia |
| 5. Pre-Maneuver Tank Temperature: | | deg C |
| 6. Pre-Maneuver S/C Attitude: | Ra | deg |
| [s/c +z axis pointing in Ecliptic mean of J2000 Coordinates] | Dec | deg |
| 7. Pre-Maneuver S/C Spin Rate: | | Rpm |

8. Comments:

Completed by: ______________________ Date/GMT: ______________________
LP Dynamics Engineer

**Figure 3-7: LP Maneuver Condition Form**

### 3.3.4 Station Schedules

#### 3.3.4.1 Description
The LP Project will provide the FDAB with copies of all scheduled LP station events. The FDAB will use this information to support acquisition data generation and tracking data receipt operations. The source of LP scheduling information will be the JPL scheduling web site which may also be accessed directly [ *http://dsn.jpl.nasa.gov:80/nss/sch/query.html* ] .

#### 3.3.4.2 Mission Phase
The LP station schedules will be supplied to FDAB during all phases of the LP mission.

#### 3.3.4.3 Format
Station schedules will consist of a list of scheduled stations and the predicted times in GMT of the events.

#### 3.3.4.4 Accuracy
N / A

#### 3.3.4.5 Delivery Schedule
LP station schedules will be delivered to FDAB on a weekly basis each Thursday by COB pacific time.

#### 3.3.4.6 Time Span
LP station schedules will cover a 1 week period.

#### 3.3.4.7 Transmission Medium
LP station schedules will be transmitted to FDAB via e-mail with fax backup.

#### 3.3.4.8 Volume Estimate
The volume of LP station schedules will be on the order of 10 kbytes.

## References


1. DSN Document 820-13, TRK-2-29A, Appendix A: P-File (EXPORT) (Spacecraft Ephemeris File)
2. Draft LMLV ICD between LMM&SC and LM Astronautics for the launch of the Lunar Prospector Payload on an LMLV-2 Launch Vehicle, Lockheed-Martin Corp., 4/96
3. Flight Dynamics Division (FDD) Generic Data Product Formats Interface Control Document, 553-FDD-91/028, June 1991
4. LP Command/Constraints Document, ARC/LP-103, 12/97
5. Lunar Prospector January 6, 1998 Trajectory Profile, LPKG023, NASA/ARC, 10/23/97

# Appendix A

## Ecliptic Mean of J2000 Coordinate Definition

**Ecliptic Mean of J2000 Coordinate Definition**

The nominal Lunar Prospector reference attitude coordinate frame is Ecliptic, mean of J2000. The spacecraft attitude will be nominally be expressed in terms of right ascension and declination of the spin axis attitude measured relative to this reference frame, as shown in Figure A-1.

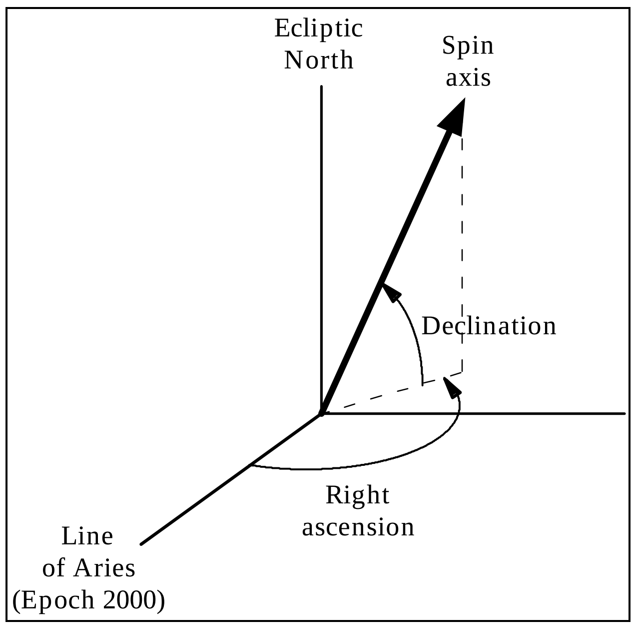


**Figure A-1: LP Attitude Reference Frame**

# Appendix B

**Lunar Prospector Orbit Maneuver Product Delivery Schedule**

# Appendix B: Lunar Prospector Orbit Maneuver Product Delivery Schedule

| Time From Maneuver | Required Products | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cruise Spin Axis Pointing Cmd. Sheet | Delta-V Spin Axis Pointing Cmd. Sheet | Mapping Orbit Spin Axis Point. Cmd. | Axial Orbit Manvr. Command Sheet | Vector orbit Manvr. Command Sheet | Orbit Maneuver Planning Package | Post-Maneuver Report | Station View Periods | Shadow Times | Lunar Eclipse Times | Definitive Orbit Ephemeris | Predicted Orbit Ephemeris | Doppler Residual Information | SLP File | DSN Station Acquisition Data | TDRS Acquisition Data | LP Operating Constraints | LP Operations Timeline | LP Maneuver Conditions | Ground Station Schedules |
| | **AM1** | **AM2** | **AM3** | **OM1** | **OM2** | **OR1** | **OR2** | **PA1** | **PA2** | **PA3** | **OD1** | **OD2** | **OD3** | **OD4** | **TD1** | **TD2** | **PD1** | **PD2** | **PD3** | **PD4** |
| **Trajectory Correction Maneuver #1** | | | | | | | | | | | | | | | | | | | | |
| M - 2 hrs | | | | | | | | | | | | | | | | | | | * | |
| M - 1 hr | | | | | * | | | | | | | | | | | | | | | |
| M – 0.5 hr | | | | | | | | * | | | | * | | | * | | | | | |
| M + 7 hrs | | | | | | | (P) | * | * | | | * | | | * | | | | * | |
| M + 16 hrs | | | | | | | * | * | * | | | * | | | | | | | | |
| **Trajectory Correction Maneuver #2** | | | | | | | | | | | | | | | | | | | | |
| M - 6 hrs | | | | | | | | | | | | | | | | | | | * | |
| M – 3 hrs | | | | | * | * | | | | | | | | | | | | | | |
| M - 2 hrs | | | | | | | | * | * | | | * | | | * | | | | | |
| M + 8 hrs | | | | | | | (P) | * | * | | | * | | | * | | | | * | |
| M + 18 hrs | | | | | | | * | | | | | * | | | | | | | | |
| **Trajectory Correction Maneuver #3** | | | | | | | | | | | | | | | | | | | | |
| M - 6 hrs | | | | | | | | | | | | | | | | | | | * | |
| M – 3 hrs | | | | | * | * | | | | | | | | | | | | | | |
| M - 2 hrs | | | | | | | | * | * | | | * | | | * | | | | | |
| M + 12 hrs | | | | | | | (P) | * | * | | | * | | | * | | | | * | |
| M + 18 hrs | | | | | | | * | | | | | * | | | | | | | | |

| Time From Maneuver | Required Products | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cruise Spin Axis Pointing Cmd. Sheet | Delta-V Spin Axis Pointing Cmd. Sheet | Mapping Orbit Spin Axis Point. Cmd. | Axial Orbit Manvr. Command Sheet | Vector orbit Manvr. Command Sheet | Orbit Maneuver Planning Package | Post-Maneuver Report | Station View Periods | Shadow Times | Lunar Eclipse Times | Definitive Orbit Ephemeris | Predicted Orbit Ephemeris | Doppler Residual Information | SLP File | DSN Station Acquisition Data | TDRS Acquisition Data | LP Operating Constraints | LP Operations Timeline | LP Maneuver Conditions | Ground Station Schedules |
| | **AM1** | **AM2** | **AM3** | **OM1** | **OM2** | **OR1** | **OR2** | **PA1** | **PA2** | **PA3** | **OD1** | **OD2** | **OD3** | **OD4** | **TD1** | **TD2** | **PD1** | **PD2** | **PD3** | **PD4** |
| **LOI Maneuver #1** | | | | | | | | | | | | | | | | | | | | |
| M - 6 hrs | | | | | | | | | | | | | | | | | | | * | |
| M – 3 hrs | | | | | * | * | | * | * | | | * | | | * | | | | | |
| M + 7 hrs | | | | | | | (P) | * | * | | | * | | | * | | | | * | |
| M + 18 hrs | | | | | | | * | | | | | * | | | | | | | * | |
| **LOI Maneuver #2** | | | | | | | | | | | | | | | | | | | | |
| M – 3 hrs | | | | | * | * | | * | * | | | * | | | * | | | | | |
| M + 4 hrs | | | | | | | (P) | * | * | | | * | | | * | | | | * | |
| M + 18 hrs | | | | | | | * | | | | | * | | | | | | | * | |
| **LOI Maneuver #3** | | | | | | | | | | | | | | | | | | | | |
| M – 3 hrs | | | | | * | * | | * | * | | | * | | | * | | | | | |
| M + 3 hrs | | | | | | | (P) | * | * | | | * | | | * | | | | * | |
| M + 24 hrs | | | | | | | * | * | * | | | * | | | * | | | | | |
| **Mapping Orbit Vector Burns** | | | | | | | | | | | | | | | | | | | | |
| M - 1 week | | | | | (P) | * | | * | * | * | | | | | | | | | | * |
| M - 1 day | | | | | * | * | | * | * | * | | * | | | * | | | * | * | |
| M - 4 hrs | | | | | | | | | | | | | | | | | | | * | |
| M + 4 hrs | | | | | | | (P) | * | * | | | * | | | * | | | | * | |
| M + 1 day | | | | | | | * | * | * | * | * | * | | | * | | | | | |

**FDAB Lunar Prospector Acquisition Data Delivery Schedule**

**L-30 days**: Latest Nominal Pfiles and Vectors
(if significantly different from prior delivery)

**L- 3 days**: Latest Nominal Pfiles and Vectors (Friday Jan 2)
(if significantly different from prior delivery)

**Launch Day**: Updated TLI burnout vector if launch slipped to the backup launch date.

**L+ 3.5 hours**: An improved estimate of the post-TLI definitive state (may help DSS 24 stay on track).

**L+ 5 hours**: A predicted post-TCM #1 orbit vector to provide Canberra sites with planned post-maneuver conditions (for support of AOS @ L+6.5 hrs)

**L+ 12.5 hours**: Improved post TCM#1 definitive state vector

**TCM #2 - 2 hrs**: A predicted post TCM#2 state vector.

**TCM #2 + 8 hrs**: A definitive post TCM#2 state vector.

**L + 2.5 days**:
- Updated definitive post TCM#2 state vector.
- Special nominal LOI #1 through LOI #3 p-file

**TCM #3 - 2 hrs**: A predicted post TCM#3 state vector.

**TCM #3 + 12 hrs**: A definitive post TCM#3 state vector.

**LOI#1 - 3 hrs**: Predicted post LOI#1 state vector.

**LOI#1 + 7 hrs**: A definitive post LOI#1 state vector.

**LOI#2 - 3 hrs**: Predicted post LOI#2 state vector.

**LOI#2 + 4 hrs**: A definitive post LOI#2 state vector.

**LOI#3 - 3 hrs**: Predicted post LOI#3 state vector.

**LOI#3 + 3 hrs** Post-LOI #3 definitive state vector

**LOI#3 + 1 day**: Post-LOI #3 definitive state vector

## Mapping Orbit Maneuver Delivery Schedule

**M – 1 day**: Predicted post Maneuver state vector

**M + 4 hrs**: Post-Maneuver definitive state vector

**M + 1 day**: Post-Maneuver definitive state vector

<u>Notes:</u>

1. Parallel acquisition data in the form of ICVs will be provided for the first post-TLI acquisition (pre-launch nominal), post-TCM #3 definitive (through periselene + 12 hrs in hyperbolic orbit) and predicted post- LOI #1.
2. With the exception of the L+2.5 day special p-file and the TCM #3 + 12 hour set of products, all p-files during the transfer orbit will be propagated out to periselene; the special p-file at L+2.5 day will be propagated through LOI #3 + 3 days; the TCM #3 + 12 hour acquisition data will extend out to 12 hours beyond periselene with no LOI burn modeled.
3. All solutions labeled as "definitive" will not model any maneuvers that are planned to occur in the future.
4. Except for the L+2.5 special p-file and the predicted LOI p-files, all solutions labeled as "predicted" will begin with the predicted burn-out condition of the upcoming burn and will not model any maneuvers that are planned to occur in the future.
5. Predicted post LOI#1, 2, and 3 p-files will each extend out for 2 days
6. The post-LOI #3 + 3 hr definitive p-file will be 2 days long, while the LOI #3 + 1 day definitive p-file will be 4 weeks long.
7. For all LOI maneuvers, the predicted post-LOI p-file will begin at least 3 hour prior to the start of the maneuver and will include a finite burn maneuver model.
8. In the event of a launch slip within the 4 minute Athena II launch window, the FDD will not update acquisition data for the DSN. Instead, JPL will adjust the time of the nominal LP injection vector in Earth rotating coordinates by the corresponding delay in the time of launch.
9. For all maneuvers, in the event of an off-nominal burn (this probably needs to be quantified, e.g. greater than 10 or 20% hot/cold), a post-burn definitive state vector will be computed and p-files sent to JPL as soon as possible.
10. In the mapping phase, 4-week p-file deliveries will be made weekly by midnight on Tuesday Eastern time.

# Appendix C

## Flight Dynamics Analysis Branch ASCII Ephemeris Format

## Flight Dynamics Analysis Branch ASCII Ephemeris Format

This Appendix provides a sample format and an item-by-item description of the Flight Dynamics Analysis Branch ASCII Ephemeris File. Figure C-1 contains a sample format of the ASCII ephem. Table C-1 describes each item in the ephem in the order it appears in the file, provides a sample of the content of each item, and provides a reference byte number that relates each item to a description of the corresponding standard binary FDAB ephem found in reference 3.

Note that certain ephem header items may contain slightly different data values depending on the software used to generate the ephemeris (this applies only to predicted ephems for use by the MCC and outreach and not to definitive ephems). Ephem item numbers for parameters of the ASCII ephem file that appear differently depending on whether GTDS or Swingby is used have been highlighted in Table C-1. For those fields, a sample of the Swingby parameter output is provided (in brackets ) for comparison with GTDS sample output (no brackets).

```
                              EPHEMERIS FILE INFORMATION:
-----------------------------
SATELLITE ID NUMBER =   9701231
RUN TITLE =                   GTDS  EPHEM    PROGRAM
TAPE IDENTIFIER = GTDS
EPHEMERIS START TIME (YYMMDD.)    =    971110.0000000000000000
EPHEMERIS START TIME (SEC OF DAY) =         0.0000000000000000
EPHEMERIS END TIME (YYMMDD.)      =    971208.0000000000000000
EPHEMERIS END TIME (SEC OF DAY)   =         0.0000000000000000
EPHEMERIS DELTA-T (SECONDS)       =        60.0000000000000000
ORBIT THEORY (COWELL OR BROUWER)  = COWELL
INTEGRATION STEP (2=FIXED)        =    1
COORDINATE SYSTEM           = 2000
COORD. SYSTEM INDICATOR     =    4
YYMMDD OF FILE CREATION     = 960522.0
HHMMSS.SSS OF FILE CREATION = 103502.540

INITIAL CONDITION INFORMATION:
------------------------------------------------

ELEMENT EPOCH (MM/DD/YY  HH:MM:SS.SSS) =  11/10/97   0: 0: 0.000
INITIAL CARTESIAN ELEMENTS :    X (KM) =       1837.805016481795
                                Y (KM) =       1.472059524027177
                                Z (KM) =       6.240228097916514
                           VX (KM/SEC) =     -0.4503771458298482E-02
                           VY (KM/SEC) =     -0.6774321496919897
                           VZ (KM/SEC) =       1.486291536496388
INITIAL KEPLERIAN ELEMENTS :    A (KM) =       1837.999999999991
                                    E  =      0.1000000001124601E-03
                               I (DEG) =       114.5024778271466
                            RAAN (DEG) =      0.1345633798985469
                              AP (DEG) =      0.1137799872744821
                              MA (DEG) =      0.1000000002640287
INITIAL BROUWER MEAN ELEMENTS : A (KM) =       1837.584134710013
                                    E  =      0.8642387559830815E-02
                               I (DEG) =       114.5073844065443
                            RAAN (DEG) =      0.1357509087898923
                              AP (DEG) =       269.8544298148346
                              MA (DEG) =       90.35970836388816
CENTRAL BODY INDICATOR (1=EARTH)          =     2.0
DRAG PERTURBATION (0=YES,1=NO)            =     1.0
SOLAR RADIATION PERTURBATION (0=YES,1=NO) =     0.0
SUN POINT MASS PERTURBATION (0=YES,1=NO)  =     0.0
MOON POINT MASS PERTURBATION (0=YES,1=NO) =     0.0
```

**Figure C-1:   Sample Lunar Prospector Ephemeris (1 of 2)**

```
SPACECRAFT AREA (M**2)           =       2.000000000000000
SPACECRAFT MASS (KG)             =       357.0000000000000
DRAG COEFFICIENT                 =       2.000000000000000
SOLAR REFLECTIVITY COEFFICIENT   =       1.500000000000000
ATMOSPHERIC DENSITY MODEL        =
RHO1  =      0.0000000000000000E+00
RHO2  =      0.0000000000000000E+00
RHO3  =      0.0000000000000000E+00
RHO4  =      0.5235987755983000


OTHER INFORMATION:
-------------------------------

ECCENTRIC ANOMALY AT EPOCH (DEG)      =      0.1000100012590757
TRUE ANOMALY AT EPOCH (DEG)           =      0.1000200027542403
ANOMALISTIC PERIOD (MINUTES)          =       117.8487214361935
GREENWICH HOUR ANGLE AT EPOCH (RAD)   =      0.8585408859626749
INITIAL GREENWICH HOUR ANGLE (RAD)    =      0.8585408859626749
FINAL GREENWICH HOUR ANGLE (RAD)      =       1.340215238311000
GEOCENTRIC SUN POSITION AT EPOCH (KM):  X  =      -100128435.8373314
                                        Y  =      -100384157.9028773
                                        Z  =      -43524563.63150572
YYMMDD OF EARLIEST MEASUREMENT        =       0.0
HHMMSS.SSS OF EARLIEST MEASUREMENT    =       0.000
YYMMDD OF LATEST MEASUREMENT          =       0.0
HHMMSS.SSS OF LATEST MEASUREMENT      =       0.000
LEAP SECOND DURING EPHEM (2=YES)      =     1

  EPHEMERIS:
------------------
```

| TIME FROM EPOCH (SEC) | X (KM) | Y (KM) | Z (KM) | XDOT (KM/S) | YDOT (KM/S) | ZDOT (KM/S) |
|---|---|---|---|---|---|---|
| 0.00000000000000E+00 | 0.18378050164818E+04 | 0.14720595240272E+01 | 0.62402280979165E+01 | -0.45037714582989E-02 | -0.67743214969199E+00 | 0.14862915364964E+01 |
| 0.60000000000000E+02 | 0.18349214288006E+04 | -0.39156904874524E+02 | 0.95366701281257E+02 | -0.91594147865535E-01 | -0.67654416442813E+00 | 0.14838863240472E+01 |
| 0.12000000000000E+03 | 0.18268188285428E+04 | -0.79674547468697E+02 | 0.18422207820547E+03 | -0.17842883214129E+00 | -0.67372188982322E+00 | 0.14772562236576E+01 |
| 0.18000000000000E+03 | 0.18135201542262E+04 | -0.11996500118039E+03 | 0.27255326458196E+03 | -0.26475437548500E+00 | -0.66897342391912E+00 | 0.14664175725593E+01 |
| 0.24000000000000E+03 | 0.17950634973545E+04 | -0.15991318260470E+03 | 0.36010869061182E+03 | -0.35032054530177E+00 | -0.66231636104583E+00 | 0.14514045567895E+01 |
| 0.30000000000000E+03 | 0.17715017149061E+04 | -0.19940525832216E+03 | 0.44663927112958E+03 | -0.43488566780220E+00 | -0.65377404577352E+00 | 0.14322647626097E+01 |
| 0.36000000000000E+03 | 0.17429019287102E+04 | -0.23832887299078E+03 | 0.53189902978442E+03 | -0.51821500769081E+00 | -0.64337209732020E+00 | 0.14090536630421E+01 |
| 0.42000000000000E+03 | 0.17093453080645E+04 | -0.27657326981260E+03 | 0.61564552667938E+03 | -0.60007446101580E+00 | -0.63113845124870E+00 | 0.13818340092789E+01 |
| . | . | . | . | . | . | . |
| . | . | . | . | . | . | . |
| . | . | . | . | . | . | . |

**Figure C-1: Sample Lunar Prospector Ephemeris (2 of 2)**

**Table C-1: ASCII Ephem File Contents**
(7/21/97)

| Header Item # | Label | Binary Ephem Ref. Byte # | Description | Sample Valid LP Contents |
|---|---|---|---|---|
| 1 | Satellite ID | 9-16 | Seven Digit Satellite ID | TBD |
| **2** | Run Title | 97-152 | Program used to generate ephem (Header) | GTDS Ephem Program [or Swingby] |
| **3** | Tape Identifier | 89-96 | Program used to generate ephem (Source ID) | GTDS [or blank] |
| 4 | Date of Ephemeris Start Time | 25-32 | Year, month and day of month of ephemeris start time specified as YYMMDD.0000 | 981207.0000000000000000 |
| 5 | Sec of Day of Ephemeris Start Time | 41-48 | Seconds of day count of ephemeris start time specified as SSSSS.SSS | 0.0000000000000000 |
| 6 | Date of Ephemeris End Time | 49-56 | Year, month and day of month of ephemeris end time specified as YYMMDD.0000 | 990104.0000000000000000 |
| 7 | Sec of Day of Ephemeris End Time | 65-72 | Seconds of day count of ephemeris end time specified as SSSSS.SSS | 0.0000000000000000 |
| 8 | Step Size | 73-80 | Time interval between ephemeris points in seconds | 60.0000000000000000 |
| 9 | Propagator Type | 225-232 | Propagator used to generate ephemeris (Cowell or Brouwer) | Cowell [or Swingby] |
| 10 | Integration Step | 1617-1620 | Output Interval Type indicator<br>1 = fixed step<br>2 = variable step | 1 |
| 11 | Coordinate System Indicator | 217-220 | INER = True of Reference<br>MEAN = B1950 | 2000 |

| | #1 (EBCDIC ID) | | 2000 = J2000 | |
|---|---|---|---|---|

| **Header Item #** | **Label** | **Binary Ephem Ref. Byte #** | **Description** | **Sample Valid LP Contents** |
|---|---|---|---|---|
| 12 | Coordinate System Indicator #2 (Integer ID) | 221-224 | 2 = Mean of 1950<br>3 = True of Reference<br>4 = J2000 | 4 |
| **13** | Ephem Creation Date | 1585-1592 | Ephem creation date specified as YYMMDD | 981207.0 [or 0.0] |
| **14** | Ephem Creation Time | 1593-1600 | Ephem creation time specified as HHMMSS.SSS | 073014.370 [or 0.0] |
| **15** | Epoch Date/Time of Ephem Solution | 345-392 | Date and epoch time of ephem solution specified as MM/DD/YY HH:MM:SS.SSS | 12/07/98 0: 0: 0.0 |
| 16 | Cartesian Epoch Elements | 521 | Cartesian position (km) and velocity (km/s) of epoch solution | (see Figure 3-10 of ICD) |
| 17 | Keplerian Epoch Elements | 393 | Keplerian elements [semi-major axis (km), eccentricity, inclination (deg), right ascension of ascending node (deg), argument of perigee (deg), and mean anomaly (deg)] of epoch solution | (see Figure 3-10 of ICD) |
| **18** | Brouwer Mean Epoch Elements | 161-208 | Brouwer-Lydane mean elements for epoch solution [same parameters and units as in item 17] | (elements as in Figure 3-10 of ICD) [or zeros] |
| 19 | Central Body Indicator | 153-160 | Central body used in propagation:<br>1 = Earth [during transfer orbit]<br>2 = Moon [during mapping orbit] | 1 (during transfer orbit)<br>2 (during mapping orbit) |
| 20 | Drag Perturbation Indicator | 329-336 | Atmospheric drag perturbation modeling indicator:<br>0 = modeled | 1.0 |

| | | | | |
|---|---|---|---|---|
| | | | 1 = not modeled | |

| Header Item # | Label | Binary Ephem Ref. Byte # | Description | Sample Valid LP Contents |
|---|---|---|---|---|
| 21 | Solar Radiation Perturbation Indicator | 313-320 | Solar radiation perturbation modeling indicator:<br>0 = modeled<br>1 = not modeled | 0.0 |
| 22 | Sun Point Mass Perturbation Indicator | 321-328 | Sun gravitation perturbation modeling indicator:<br>0 = modeled<br>1 = not modeled | 0.0 |
| 23 | Moon Point Mass Perturbation Indicator | 305-312 | Moon gravitation perturbation modeling indicator:<br>0 = modeled<br>1 = not modeled | 0.0 |
| 24 | Spacecraft Area | 273-280 | Cross-Sectional area of spacecraft in square meters | 1.75 |
| 25 | Spacecraft Mass | 281-288 | Mass of spacecraft in kilograms | 299 |
| **26** | Drag Coefficient | 249-256 | Drag Coefficient, $C_{DZ}$ | 2.0 [very large negative number] |
| **27** | Solar Reflectivity Coefficient | 257-264 | Spacecraft solar reflectivity coefficient, $C_R$ | 1.2 [very small positive number] |
| 28 | Atmospheric Density Model | 265-272 | Type of atmospheric density model used:<br>HAR-PRIE = Harris-Priester<br>JACCHIA = Jachhia<br>blank = none used | blank |
| 29 | RHO1 | 729-736 | Variation in drag coefficient | 0.0 |
| 30 | RHO2 | 737-744 | Time variation in atmospheric density | 0.0 |
| 31 | RHO3 | 745-752 | Diurnal variation in atmospheric density | 0.0 |
| 32 | RHO4 | 753-760 | Angle between the sun-line and the | 0.5 [0.0] |

| Header Item # | Label | Binary Ephem Ref. Byte # | Description | Sample Valid LP Contents |
|---|---|---|---|---|
| | | | apex of the diurnal atmospheric bulge | |
| **33** | Eccentric Anomaly @ Epoch | 465-472 | Eccentric anomaly in degrees of epoch solution | value as in Figure 3-10 of ICD [or zeros] |
| **34** | True Anomaly at Epoch | 441-448 | True anomaly in degrees of epoch solution | value as in Figure 3-10 of ICD [or zeros] |
| **35** | Anomalistic Period at Epoch | 473-480 | Anomalistic period in minutes of epoch solution | value as in Figure 3-10 of ICD [or zeros] |
| **36** | Greenwich Hour Angle at Epoch | 1569-1576 | Greenwich hour angle in radians of epoch solution | value as in Figure 3-10 of ICD [or zeros] |
| **37** | Initial Greenwich Hour Angle | 1601-1608 | Greenwich hour angle in radians at ephem start time | value as in Figure 3-10 of ICD [or zeros] |
| **38** | Final Greenwich Hour Angle | 1609-1616 | Greenwich hour angle in radians at ephem end time | value as in Figure 3-10 of ICD [or zeros] |
| **39** | Geocentric Sun Position at Epoch | 1025-1048 | Sun Cartesian position in kilometers at solution epoch | value as in Figure 3-10 of ICD [or zeros] |
| **40** | Date of Earliest Measurement | 1649-1656 | Date of earliest tracking data span used in OD solution (YYMMDD.0) | value as in Figure 3-10 of ICD [or zeros] |
| **41** | Time of Earliest Measurement | 1657-1664 | Time of earliest tracking data span used in OD solution (HHMMSS.SSS) | value as in Figure 3-10 of ICD [or zeros] |
| **42** | Date of Latest Measurement | 1665-1672 | Date of last tracking data span used in OD solution (YYMMDD.0) | value as in Figure 3-10 of ICD [or zeros] |
| **43** | Time of Latest Measurement | 1673-1680 | Time of last tracking data span used in OD solution (HHMMSS.SSS) | value as in Figure 3-10 of ICD [or zeros] |
| **44** | Leap Second Indicator | 1621-1624 | Indicator for leap second occurrence within ephemeris span:<br>1 = no leap second occurred<br>2 = leap second occurred | 1 or 2 [or zero] |
| Data Field | Ephemeris State Vectors | -- | State vectors consisting of:<br>o Time from Epoch in seconds | |

| | | | | |
|---|---|---|---|---|
| | | | o Cartesian spacecraft position vector in kilometers<br>o Cartesian spacecraft velocity vector in kilometers / sec | (see Figure 3-10 of ICD) |

# Appendix D

## Key Orbit Maneuver Control/Determination Operating Constraints

## Key Orbit Maneuver Control/Determination Operating Constraints

1. Orbit maneuvers using A3/A4 thrusters shall be limited to (100 – 0.14 * P) seconds in duration (where P is pressure in psi), due to possible damage to LP antennas located along the +z axis [2.7.3].
2. The LP power subsystem is designed for a maximum shadow/eclipse duration of 47 minutes. Shadows/Eclipses lasting longer than the nominal will result in a battery depth of discharge outside nominal operating limits.
3. Depending on the current spin rate, the sun azimuth firing angle required, and the thruster pulse width selected, vector maneuvers may require two revolutions per pulse vs. a single revolution per pulse. For the nominal pulse width of 0.833 seconds, and a spin rate of 12 rpm, sun azimuth firing angles less than 30 deg or greater than 330 deg require two revolutions per pulse.
4. Dual station coverage should be maintained at LOI #1 unless the cost to do so is greater than 10 m/s. As a minimum, the dual coverage period should extend up to 1 hour before LOI #1 to allow transmission of a 1 hour time delay LOI #1 command from redundant stations [2.7.13].
5. Orbit maneuvers in intermediate LOI orbits to trim inclination or periselene radius should be performed only if doing so will save a minimum of 10 m/s over correcting the orbit in the mapping orbit.
6. The nominal mapping orbit attitude is normal to the ecliptic plane for maximum solar array output, and for an Earth aspect angle between the 85 and 95 degrees --- within the limits of the medium gain antenna [2.4.2].
7. For vector maneuvers, the axial component will nominally executed first since tangential burns may induce attitude disturbances.
8. Nominally, all commands will be spaced 10 minutes apart. Therefor the minimum time between axial and tangential burns will be 10 minutes. [2.1.5]
9. In the mapping orbit, axial and tangential maneuvers will nominally occur one orbit apart, in order to allow burn placement closer to the line of apsides.
10. Nominally, during the mapping orbit, the following orbit limits will be maintained [1.2]:
    - Inclination: 90 deg ± 0.5 deg
    - Altitude: 100 km ± 20 km
11. If possible, all orbit maneuvers should be done in sunlight and in view of a station [2.2.8].
12. The Earth look angle (angle from +z axis to Earth) should always be kept below 148 deg (nominal omni antenna operating limit is 130 deg, but coverage is expected for larger angles) [2.4.1].
13. The sun look angle (angle from +z axis to sun) should always be kept between 66 degrees and 114 degrees for adequate power margin [2.6.3]
14. While in the mapping orbit, periselene raising maneuvers will nominally be performed prior to aposelene lowering, mostly as a matter of consistency [2.7.9].