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# Lunar Reconnaissance Orbiter Project

# External Systems Interface Control Document for the Lunar Reconnaissance Orbiter Ground System

**LRO GSFC CMO**

May 27, 2009

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**Goddard Space Flight Center**
**Greenbelt, Maryland**

**National Aeronautics and Space Administration**

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# LUNAR RECONNAISSANCE ORBITER PROJECT

## DOCUMENT CHANGE RECORD

Sheet: 1 of 1

| REV LEVEL | DESCRIPTION OF CHANGE | APPROVED BY | DATE APPROVED |
|---|---|---|---|
| Rev - | Initial Release, Released per 431-CCR-000210 | R. Saylor | 19 Jan 2007 |
| Rev – A | Released per 451-CCR-000383 | R. Saylor | 08/20/2007 |
| Rev – B | Release per 451-CCR-001058 | Rick Saylor | 9/16/2008 |
| Rev – C | Release per 451-CCR-001373; see associated file Proposed RevC 431-ICD-000049 Mods for list of requested changes | Rick Saylor | 5/22/2009 |

List of TBDs/TBRs

| Item No. | Location | Type | Summary | Ind./Org. | Due Date |
|---|---|---|---|---|---|
| 1 | | | | | |
| 2 | | | | | |
| 3 | | | | | |
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# 1.0 INTRODUCTION

The Interface Control Document for the Lunar Reconnaissance Orbiter Ground System (431-ICD-000049) is one of three documents produced by the Lunar Reconnaissance Orbiter (LRO) ground system team that provides the foundation for the development and operations of the ground system for all mission phases. The other documents are the Lunar Reconnaissance Orbiter Detailed Mission Requirements Document (431-RQMT-000049) and the Lunar Reconnaissance Orbiter Mission Design Handbook (431-HDBK-000486).
This document provides the Level-3 mission interface requirements and identifies the products, which are noted in that document and provided within the scope of this document.

## 1.1 PURPOSE AND SCOPE

The ICD specifies the interface that the LRO ground system (GS) has with the Space Communications Network (SCN) and the various science centers, as well as the external interfaces with other LRO mission operations center (MOC) elements.

This ICD documents the interfaces and products among the various external elements and is valid during the pre-mission phase through the end of the prime mission phase. The project will reevaluate the interfaces and required products for the LRO Extended Mission phase.

## 1.2 DOCUMENT ORGANIZATION

The document organization provides details regarding the various ground system elements and the interfaces and products between the external LRO elements and the LRO ground system.

Section 2.0 contains a brief description of the mission, ground system architecture, and identifies the various ground system elements. More detailed and specific information on the orbiter, launch vehicle, schedules, and mission phases is provided by the LRO Mission Concept of Operations (MCO).

Section 3.0 provides the cross reference of the external products to/from the LRO MOC; it provides a mapping of DMR requirements and the cross reference to other document sections, which is linked to provide more specific details.

Section 4 provides the call out of each external interface and the associated products that are transferred between LRO external elements and the LRO ground system elements.

Outstanding open items within the ICD are identified as “To Be Determined” (TBD), “To Be Supplied” (TBS), or “To Be Resolved” (TBR). Open items are documented in the List of TBDs/TBRs section in the front of the document.

## 1.3 REQUIREMENTS TRACEABILITY METHODOLOGY

The ground system interfaces specified in this document are derived from the Lunar Reconnaissance Orbiter Detailed Mission Requirements Document (431-RQMT-0000048), which identified the specific instance associated with the interface description.

## 1.4 APPLICABLE DOCUMENTS

The following LRO project documents apply only to the extent they are cited in this document.

| | |
|---|---|
| 431-RQMT-000174 | Lunar Reconnaissance Orbiter Mission Assurance Requirements |
| 431-RQMT-000048 | Lunar Reconnaissance Orbiter Detailed Mission Requirements Document |
| 431-HDBK-000052 | Lunar Reconnaissance Orbiter Telemetry and Command Formats Handbook |
| 431-HDBK-000053 | Lunar Reconnaissance Orbiter Telemetry and Command Database Handbook |
| 431-PLAN-000050 | LRO Ground System Mission Operations Support Plan (MOSP) |
| 431-SPEC-000078 | Lunar Reconnaissance Orbiter CCSDS File Delivery Protocol Specification |
| 431-HDBK-000486 | Lunar Reconnaissance Orbiter Mission Design Handbook |
| 431-RQMT-000113 | LRO Pointing and Alignment Requirements |
| 453-ICD-GN/WS1 | Interface Control Document for the White Sands One Ground Station (WS1) |
| 451-MOA-002960 | FDF-GS&O Operations Agreement |

## 1.5 REFERENCED DOCUMENTS

The following NASA and GFSC documents are used as supporting and reference documents only.

| | |
|---|---|
| NASA NPR 2810.1a | NASA Security of Information Technology; Revalidated 12 August 2004 |
| STDN-724 | Spaceflight Tracking and Data Network (STDN) Tracking and Acquisition Handbook; 1990 |
| 820-013 0163-Telecomm | DSN Space Link Extension Forward Link Service and Return Link Service; Revision A – February 15, 2004 |
| 820-13 TRK 2-33 | DSN document to define external interface for SPICE SPK, Type 13 |
| 820-13, 0168 | Service Management Interface document |
| 887-117 | SPS Portal Operation Manual |
| CCSDS 502.0-B-1 | Orbit Data Messages, September 2004 |
| RTL-ICD-T720HDR, Rev1.2 | High Data Rate Receiver Interface Control Document |

## 1.6 OTHER DOCUMENTED REFERENCES

Format data concepts specifically needed to support the laser ranging sites

http://ilrs.gsfc.nasa.gov/products_formats_procedures/crd.html
http://ilrs.gsfc.nasa.gov/products_formats_procedures/predictions/cpf.html
http://naif.jpl.nasa.gov/naif/about.html
https://spsweb.fltops.jpl.nasa.gov

## 2.0 GROUND SYSTEM OVERVIEW

The Lunar Reconnaissance Orbiter (LRO)'s primary objectives are to conduct investigations that support future human exploration of the Moon.

LRO specific objectives are:

- Characterize the lunar radiation environment, biological impacts, and potential mitigation
- Determine a high resolution global, geodetic grid of the Moon in three dimensions
- Assess in detail the resources and environments of the Moon's polar cap regions
- Perform high spatial resolution measurement of the Moon's surface

The LRO instrument complement includes six instruments. Together, all six instruments allow LRO to meet the mission objectives. The following text provides an overview description of the six instruments:

- **Lunar Orbiter Laser Altimeter (LOLA):** LOLA will determine the global topography of the lunar surface at high resolution, measuring landing site slopes and search for polar ice in shadow regions.
- **Lunar Reconnaissance Orbiter Camera (LROC):** LROC will acquire targeted images of the lunar surface capable of resolving small-scale features that could be landing site hazards. LROC will also produce wide-angle images at multiple wavelengths of the lunar poles to document the changing illumination conditions and potential resources.
- **Lunar Exploration Neutron Detector (LEND):** LEND will map the flux of neutrons from the lunar surface to search for evidence of water ice and provide measurements of space radiation environment which can be useful for future human exploration.
- **Diviner Lunar Radiometer Experiment (DLRE**): DLRE will map the temperature of the entire lunar surface at 300-meter horizontal scales to identify cold-traps and potential ice deposits.
- **Lyman-Alpha Mapping Project (LAMP):** LAMP will observe the entire lunar surface in the far ultraviolet (UV). LAMP will search for surface ice and frost in the Polar Regions and provide images of permanently shadowed regions illuminated only by starlight.
- **Cosmic Ray Telescope for Effects of Radiation (CRaTER):** CRaTER will investigate the effect of galactic cosmic rays on tissue-equivalent plastics as a constraint on models of biological response to background space radiation.

LRO will also fly a technology demonstration instrument called the Mini-Radio Frequency (RF). The purpose of the Mini-RF is to demonstrate new radar technology for future use in planetary resource mapping. The mini-RF payload will operate on a non-interference basis throughout the mission.

The LRO spacecraft bus will be built at Goddard Space Flight Center (GSFC). Integration of the measurement instruments to the orbiter system as well as orbiter environmental testing will be performed at GSFC.

The orbiter will be launched aboard an evolved expendable launch vehicle (EELV) from the Eastern Range at the Kennedy Space Center (KSC). The Launch Vehicle (LV) will inject LRO into a cis-lunar transfer orbit. LRO will be required to perform a series of Lunar Orbit Insertion (LOI) maneuvers to enter into the orbiter commissioning orbit of 30x216 kilometers (km). After orbiter commissioning is complete, LRO will be maneuvered into a 50 km circular orbit.

Once LRO is in the final mission orbit, the six instruments will start to collect measurement data for the mission. Measurement data along with housekeeping (HK) data will be dumped to the LRO Ground System (GS). Once the data are received at the MOC, the MOC is responsible for distribution of the data to the individual science operations centers (SOCs). The SOCs will receive and process the data to create level 1 data products. The LRO GS and SOCs also have the responsibility to transfer the processed data products to the Planetary Data System (PDS) for long term archival.

The details of the mission with the identification of the mission phases and the activities with each phase are provided in the Lunar Reconnaissance Orbiter Mission Design Handbook (431-HDBK-000486)

## 2.1 GROUND SYSTEM ARCHITECTURE

The LRO GS is comprised of several main elements as shown in Figure 2-1 LRO Ground System Overview Diagram:

- The LRO Space Communications Network, which consists of an S/Ka Band ground station at White Sands and various USN-provided S-Band only ground stations located throughout the world. It includes the Deep Space Network for use as a contingency/emergency network and a laser ranging facility, which is used to provide improved orbit knowledge for the orbiter. The LRO mission uses the Space Network (SN) asset for the first several hours post-launch to provide any necessary support until the first ground station coverage.
- Mission Operations Center (MOC)
- Flight Dynamics (FD), which supports maneuver planning, orbit determination, and attitude determination and sensor calibration processing
- SOC for each instrument; while not actually part of the LRO Ground System, they are identified as residing within the LRO Ground Segment
- Communications network which provides voice and data connectivity between each of these elements

LRO elected to use a combined S/Ka ground station at White Sands because of the high data volume that the Orbiter will produce and the requirements to use the Ka-band for the downlink of the measurement data. The measurement data are collected at the ground station and rate buffered to the MOC post-pass for data processing/accountability. The MOC at GSFC will distribute the measurement files along with other mission products that are needed for processing to each of the instrument SOCs. The MOC is the focal point for all orbiter operations including health and safety monitoring. All commands to the orbiter are generated at the MOC. The SOCs support instrument operations including instrument command sequence inputs, measurement data processing, transferring measurement products to the PDS, and instrument housekeeping and performance trending.

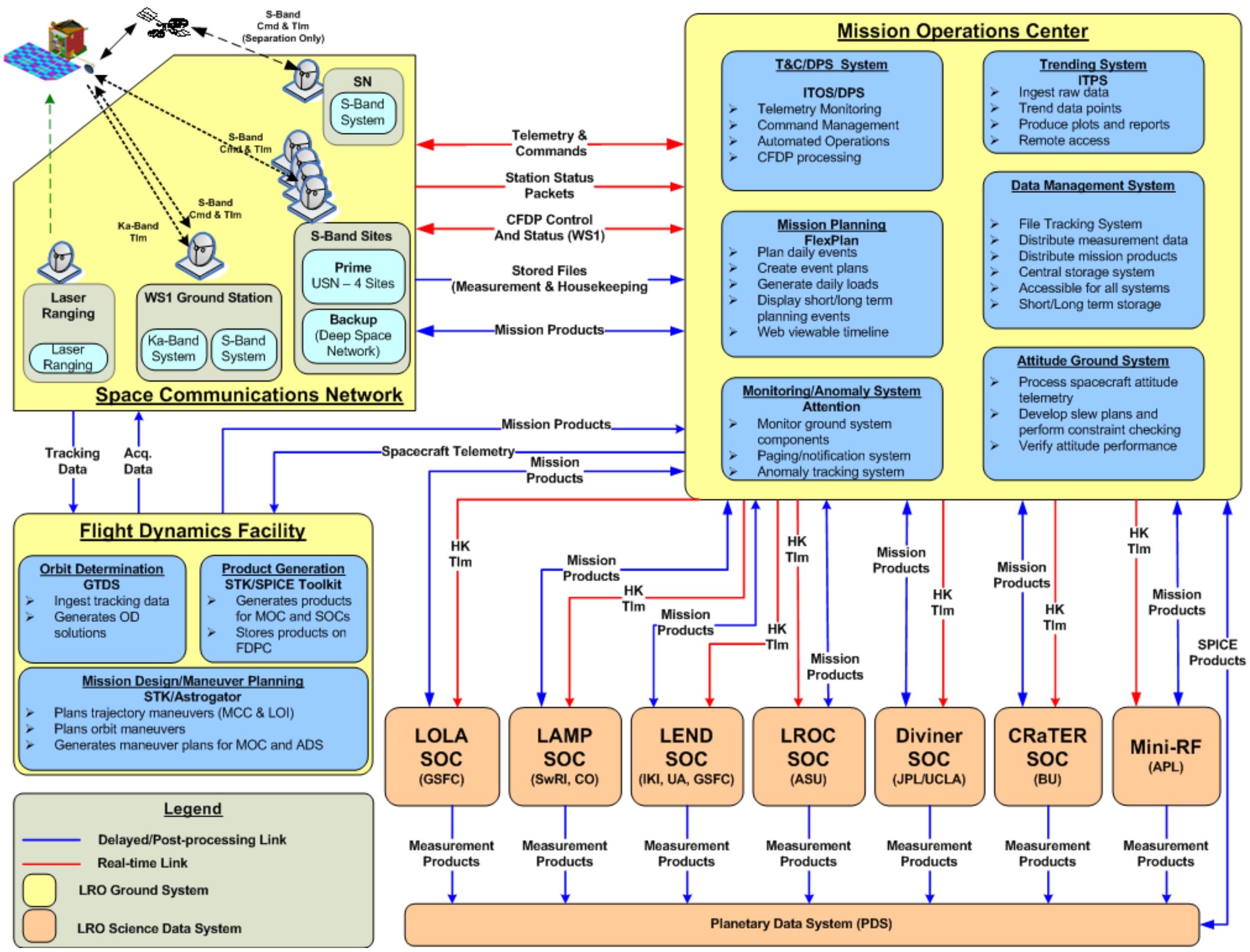



*Figure 2-1 LRO Ground System Overview Diagram*

Each LRO Ground System element, as listed in Figure 2-1, is briefly described in the following subsections.

### 2.1.1 The LRO Space Communications Network

The LRO Space Communications Network (SCN) consists of a prime and backup station located at White Sands Complex. White Sands One (WS1) is identified the prime antenna for LRO support; LRO uses the Solar Dynamics Observatory (SDO) backup antenna (STSS) in the event of WS1 facility or equipment outages of a short duration.

LRO uses the commercial S-Band ground stations to provide S-band TT&C support. The Jet Propulsion Laboratory (JPL)/DSN ground stations provide for backup/emergency support to the LRO SCN for the LRO mission, which includes maneuver support. The SN supports any post-launch contacts within the first several hours after launch that are required before either the WS1 station or the USN or DSN stations have a contact with the LRO Orbiter.

While not officially part of the SCN, there are several laser ranging sites to provide one-way laser time of flight data and support, through the LOLA SOC, the development of an improved lunar gravity model.

The WS1 ground station is capable of receiving 100 megabits per second (Mbps) downlink on Ka-Band frequency of measurement data files produced by the instruments and supporting real-time commands and telemetry on S-Band frequency. Due to susceptibility to Ka from weather, White Sands provides the optimal location due to its minimal precipitation levels. Because LRO requires near continuous tracking data for orbit determination, additional S-Band sites are needed. The S-Band only sites will provide real-time telemetry and commands capabilities along with tracking data. The S-Band stations could be used to dump low rate measurement files in a contingency mode. LRO plans to use the Deep Space Network for emergency/backup support. The emergency/backup support will utilize only the S-Band frequency.

### 2.1.2 LRO Mission Operations Center

The MOC will be located at GSFC. It is the main telemetry and command interface to the orbiter. The MOC will process housekeeping data to monitor health and safety of the orbiter. The MOC will also distribute measurement data to the individual SOCs along with other required mission products. The MOC provides data storage for all raw measurement data for the life of the mission. The MOC will receive any required instrument command sequences from the SOCs and process them before uplink. The MOC will also distribute real-time telemetry to the SOCs.

The LRO MOC provides the following types of control functions as listed below; these functional components will be further described and identified in later sections.

- Telemetry& Command (T&C) System
- Mission Planning System
- Trending System
- Attitude Ground System (AGS)
- Data Processing System
- Data Management System
- Monitoring and Alert System

### 2.1.3 The Science Operations Centers

The six SOCs and the Mini-RF technology demonstration operations center provide the hardware and software to support the following functions:

- Instrument health and safety monitoring

- Instrument command sequence generation/request
- Support orbiter calibration planning/coordination
- Measurement data processing (level 0 and higher)
- Measurement data product archiving and transfer to the PDS
- Maintain instrument flight software/tables

The SOCs themselves are not controlled and developed by the LRO ground system. The ground system responsibility ends with the interfaces to/from each of the SOCs

### 2.1.4 Flight Dynamics Facility

Flight Dynamics Facility (FDF) is hosted at GSFC; it has separate facilities that provide support for the standard orbit determination and product generation and the mission design, maneuver planning and trajectory support.

Flight dynamics (FD) supplies three FD teams, Orbit Team (made up of MOMS contractors in the FDF), Maneuver Team (made up of civil servants from Code 595,) and the Attitude Team (made up of a combination of MOMS contractors and 595 civil servants) to provide support for the LRO mission.

The Orbit Team and Maneuver Team provide LRO support from the Flight Dynamics Facility (FDF) in building 28. From the FDF facility, the Maneuver Team will have access to the orbit determination solutions, the MOC data sent to the FD Product Center (FDPC), the FDPC for outgoing maneuver plans and the FDF network for placing predicted trajectory data for planning products. For orbit determination, FD will receive the tracking data from the ground network and generate mission products. Besides pre-mission trajectory and orbit planning, FD will also monitor and plan for trajectory maneuvers during the cruise, Lunar Orbit Insertion burns, and station-keeping maneuvers; FD supplies these maneuver plans to the MOC for command uplink and Orbiter execution.

The Attitude Team will provide LRO support during early mission from the LRO MOC. FD will also provide attitude verification and planning support for slews. At a negotiated time after launch, the attitude support transitions to the LRO mission operations team.

### 2.1.5 Ground System Communications

The ground system communication network provides voice and data connectivity between each of the ground system elements. It will provide the necessary communication lines between the ground networks, MOC and SOCs.

Figure 2-2 depicts the communication architecture among the various LRO elements. It includes the space communications networks, the Kennedy Space Center (KSC), the GSFC MOC, and the seven science centers, which are located at various sites within the continental US. The communication links consist of dedicated communications lines, circuits, and routers.

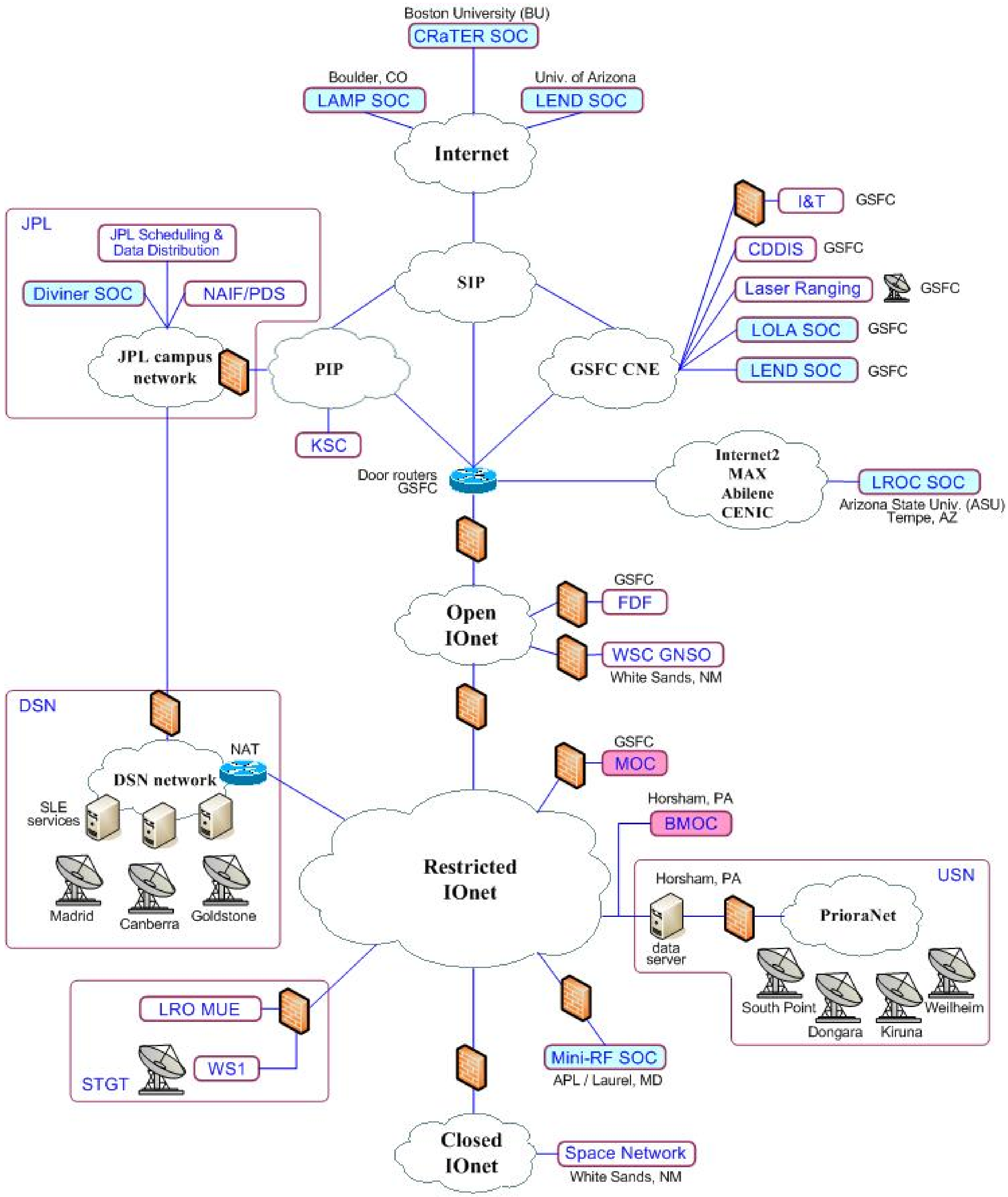



***Figure 2-2 LRO Communications Architecture***

Communication among the I&T GSE, GS elements, the various science centers, and dedicated ground station at the White Sands Complex (WSC), the JPL/DSN backup/emergency ground stations, and the commercial S-Band network is accomplished through the Nascom Division and the NASA Integrated Services Network (NISN). NISN maintains both a secure or "closed" Internet Protocol (IP) Operational Network (IONet), an unsecured or "open" IONet, and a hybrid Restricted IONet (RIONet).

All LRO MOC GS elements are on the restricted IONet; the FDF component, located at GSFC in Building 28, resides on the closed IONet; FDF provides access to other FDF-related services, which reside on the Open IONet. NISN supplies the IP access connection from the closed, restricted, and open IONets and to the Center Network Environment (CNE) Wide Area Network (WAN).

If the MOC needs to send any real-time data from the restricted IONet to any external network, the MOC will provide this data using a socket connection through a secure applications gateway, as depicted in Figure 2-2.

LRO SE personnel conducted a trade study and selected the secure copy (scp) mechanism for non real-time data transfers. All files into and out of the MOC will use this identified protocol. The LRO MOC will scp files from the MOC to an agreed upon directory locations that the external elements have identified. Conversely, the external elements will scp their files to a standard input directory structure within the LRO MOC. The MOC and external elements will negotiate these details as part of future Operations Agreements.

## 2.2 LRO MOC OPERATIONAL SYSTEMS

The LRO orbiter monitoring and control functions of the GS are performed within the LRO MOC by the Mission Operations Team (MOT). The ITOS GS element typically performs its functions in real time during an LRO spacecraft ground contact and is located within the real-time portion of the MOC. The LRO GS architecture is depicted in Figure 2–4.

LRO mission planning, command load generation, trend analysis, and attitude determination functions of the GS also are performed within the LRO MOC by the LRO MOT. These elements perform their functions using data from prior spacecraft passes and other sources. The products of these elements may be used during a LRO spacecraft ground contact and are located within the offline portion of the MOC.

This set of GS elements that support both real-time and offline functionality are defined and identified in the following table:

***Table 2-1 MOC Functional Component Information***

| Functional Element | Component | Provider | Section Reference |
|---|---|---|---|
| Telemetry and Command | ITOS | GOTS – GSFC 584 | Section 2.2.1 |
| Mission Planning | FlexPlan | COTS – GMV | Section 2.2.4 |
| Trending and Analysis | ITPS | GOTS – GSFC 583 | Section 2.2.6 |

| Functional Element | Component | Provider | Section Reference |
|---|---|---|---|
| Data Processing System | ITOS/DPS | GOTS – GSFC 584 | Section 2.2.2 |
| Data Management System | DMS | GOTS – GSFC 584 | Section 2.2.3 |
| Monitoring and Alert System | ATTENTION | COTS – Attention SW, Inc | Section 2.2.7 |
| Attitude Ground System | AGS | GOTS – Code 595 | Section 2.2.5 |

Figure 2-3 depicts a logical representation of the MOC architecture and provides the scope of what HW/SW elements are located within the MOC as well as the security boundary as noted by the routers and firewalls.

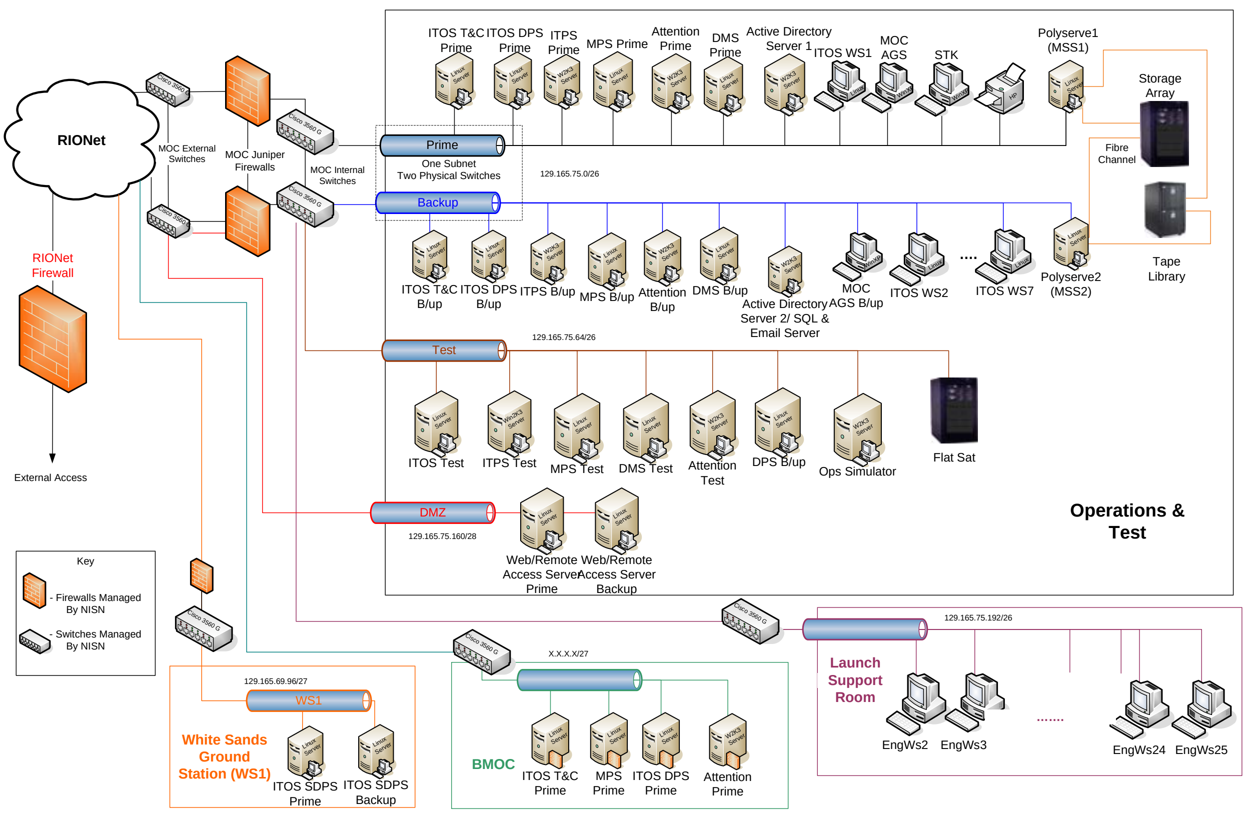



*Figure 2-3 LRO MOC Logical Architecture*

## 2.2.1 ITOS-Supported Real-time Telemetry and Commanding

The real-time telemetry and command portion of ITOS receives virtual channel (VC) telemetry identified as VC0 and VC1. ITOS processes the engineering data and displays it to the MOT for monitoring the health and safety of the LRO spacecraft. ITOS processes the VC0 data and generates attitude data files for use by the AGS. ITOS archives engineering data files for later trending analysis by ITPS. ITOS performs the following real-time functions in support of the spacecraft health and safety:

- Receive command files from FlexPlan
- Performs real-time commanding using the received files from the FlexPlan
- Transmits real-time data packets to instrument ground support equipment (IGSE) during L&EO
- Transmits real-time packet data to the various science centers
- Performs real-time commanding
- Generates log files for spacecraft health and safety monitoring by Attention
- Subsets the data packets into usable files for ingest by the ITPS
- Provides a file (or files) of attitude data to the AGS component for use in the single board computer (SBC) attitude verification, to perform sensor calibrations, and to support other attitude maneuver functions

### 2.2.2 Data Processing System

ITOS provides the functionality of the Data Processing System (DPS); this is the primary interface to the station front end units for receiving and processing files transmitted using the Consultative Committee for Space Data Systems (CCSDS) File Delivery Protocol (CFDP). The DPS is responsible for ensuring a reliable transfer of data and that the data received on the ground is in the same format in which it was stored on the spacecraft.

There will be two active units, one at the station for high data rate capture and one at the MOC for low data rate capture and uplink of table and memory files. The system located within the LRO MOC is identified as the MOC Data Processing System (MDPS); the system resident at the White Sands station is referenced as the station DPS (SDPS). The station and MOC DPS are both setup and controlled by the ITOS system at the MOC and all commanding is coordinated and funneled through the ITOS for uplink to the spacecraft.

The WS1 DPS will provide temporary data storage and deliver data products to the Data Management System after processing is complete for a file. The WS1 DPS can receive the science data in any virtual channel (nominally it is commanded to be downlinked in either VC2 or VC3, but the spacecraft could be commanded to downlink the data in any VC), and performs data accountability. The MOC DPS nominally receives spacecraft housekeeping files on VC1; however, the spacecraft can be commanded to downlink science data in VC1 also. ITOS/DPS then distributes the data to the ITOS/DMS component for eventual transmission to the appropriate science team for further data analysis.

### 2.2.3 Data Management System

The DMS performs data file management for all mission products archived in the MOC, with the added functionality of marking products required for review with electronic signatures. The DMS system interfaces directly with all MOC systems and the storage array to accomplish all desired tasks. All product flows are the result of a DMS transaction and recorded in the DMS database.

This component provides the data file archiving, data file dissemination, and provides a mechanism that can be used to track the delivery of data file products, which the LRO MOC transfers to the other LRO ground segment elements, such as the Ground Networks, the SOCs and the PDS. DMS receives the corresponding files from another source, such as FDF or the DPS components (for VC1, VC2, and VC3 data files) and performs data transfer and accountability to ensure that the files are delivered to the correct recipient and delivered error free.

### 2.2.4 Mission Planning System

FlexPlan was chosen as the mission planning system; it provides the short term daily planning and the long term projected planning for mission operations. FlexPlan receives science planning information from the science centers, maneuver planning data from FDF, and spacecraft health and safety commands from the operations team. The LRO mission planner uses the FlexPlan to generate and maintain daily planning activities as well as spacecraft command files that are forwarded to the ITOS for uplink to the spacecraft.

### 2.2.5 Attitude Ground System

The AGS provides the attitude determination validation and attitude sensor calibration; it is a COTS/GOTS system developed by the Flight Dynamics Branch at GSFC. It receives the on-board attitude quaternion data from the LRO spacecraft via DMS, performs sensor calibration, applies biases and misalignment information to the data, and validates the on-board calculated attitude solutions from the spacecraft.

The AGS creates the unified set of commanded attitude quaternion data that is associated with all orbiter off-nadir slews or for orbit-adjust maneuvers and momentum management requests.

### 2.2.6 Trending and Analysis System

The LRO Ground System and Operations team choose the Integrated Trending and Plotting System (ITPS) as the trending system; it provides the capability to ingest, store, analyze and display spacecraft health and safety data. ITPS will ingest and archive all mission housekeeping and engineering data to perform full data analysis and will also process the data to provide a reduced resolution data containing min/max/mean & standard deviation.

### 2.2.7 Monitoring and Alert System

The LRO Ground System and Operations team choose the Attention COTS product as the Monitoring and Alert System. This system is resident in the LRO MOC and it provides a comprehensive solution for spacecraft and ground system monitoring. The system interfaces with all MOC ground components, monitoring system events and software tasks. Upon recognizing anomalous events, the Monitor and Alert System initiates the pre-defined notification and reporting procedures to ensure that a proper response is received. The MAS ensures that data are accumulated to support the MOT in their research activities and to assists the MOT to correct the anomalous behavior. For spacecraft supports the monitoring system creates pass summaries to keep a record of all supports including commands sent; procedures executed, and specified event messages. The monitoring system compares entries in these pass log files against a predefined set of limits and checks. If an event or data value is flagged as a problem, the monitoring system issues a notification to one of a selected group of operations personnel of a spacecraft anomaly and providing an informative, textual message identifying the anomaly situation.

## 2.3 FLIGHT DYNAMICS FACILITY

The FDF provides the prime support for all orbit determination, generation of predictive and definitive orbital products, and generation of acquisition data. The FDF is located in Building 28 at GSFC.

During all phases of the LRO mission, the FDF receives the station-tracking data, which includes two-way Doppler tracking, laser ranging data, and ranging data. FDF determines the spacecraft orbit and generates predicted and definitive spacecraft ephemerides. The predicted ephemeris is used to provide acquisition data to all ground stations. FDF will supply the operations team with all mission planning aids. The laser ranging data will not be used for day-to-day navigation support of the mission. It will be used during post-processing (likely several months after real-time) to improve the orbital solutions at higher accuracy.

The FDF provides processing and control for all maneuvers and generates the trajectory maneuver commands for all mission phases.

## 2.4 MISSION OPERATIONS TEAM

The MOT personnel are responsible for managing the health and safety of the spacecraft following initial acquisition. They are the focal point of LRO GS operations during the life of the mission. In this capacity, they

- Coordinate the various operational entities
- Conduct operational tests with the spacecraft during the prelaunch phase
- Conduct operational testing of the LRO MOC facility systems
- Lead the GS operations efforts for the life of the mission

## 2.5 FLIGHT SOFTWARE MAINTENANCE FACILITY

The Flight Software and Maintenance Facility (FSMF) interfaces with the LRO program's I&T GSE system. It is responsible for maintaining the onboard flight software (FSW) starting approximately 60 days after launch until the end of the mission.

## 2.6 LRO SPACE COMMUNICATIONS NETWORK

The LRO mission requires support from a variety of networks identified as the Space Communications Network (SCN):

1. The Ka and S-Band antennas located at WS1 will provide the prime station support for the LRO mission. LRO uses the Solar Dynamics Observatory (SDO) backup antenna, which is collocated at the White Sands area. LRO will use the SDO/LRO STSS S-Band backup Station, as negotiated with SDO, in the event that there is an outage of the WS1 antenna.
2. A second network will provide commercial S-band support for the LRO mission. The LRO mission contracted this support to the Universal Space Network (USN). The USN

Network Management Center (NMC) is located in Horsham, Pennsylvania. For the LRO mission, USN uses two prime remote ground stations (RGSs) located at Dongara, Australia and Weilham, Germany. USN maintains two backup stations to support the LRO mission; these stations are located at South Point, Hawaii, and Kiruna, Sweden.

3. The DSN, operated by the JPL located in Pasadena, California, maintains three stations at Goldstone, California; Madrid, Spain; and Canberra, Australia. DSN is designated for emergency/backup support for telemetry, tracking, and command interface during the initial acquisition, during any orbit maneuvers, or at any other times when a spacecraft emergency is identified.
4. Laser Ranging facility, which is located in Greenbelt, Maryland, provides one-way laser time of flight data and supports, through the LOLA SOC, the development of an improved lunar gravity model. In support of using the Laser Ranging facility, the LRO MOC will provide some products to the Crustal Dynamics Data Information System (CDDIS); this facility acts as a clearing house to provide LRO data to potential other laser ranging sites around the world.

The Space Network (SN) will be used for launch support and for post separation coverage. The SN shall provide S-band (DG2 mode 2) telemetry and command services post separation through the first two hours of the mission.

## 3.0 LRO GS EXTERNAL INTERFACE PRODUCT SYNOPSIS

This section provides a listing of all external products used by, generated by, or stored by the LRO MOC or other Ground Segment Elements, such as FDF to DSN interface products. Table 3-1 provides a comprehensive listing of all LRO external interfaces defined to date. This table reflects the product name, identifies who created the product and who uses the product, and provides a cross-reference to a DMR identifier to track where this interface product originates and who uses this interface product within their processing flow. It also provides a mapping to another document section in which a user can lookup more details regarding a product. As reference within this table and throughout this document, there may appear to be missing product identifiers. These Product IDs were deleted as a result of combining some products into a common format.

***Table 3-1 LRO External Interface Products Cross Reference***

| No. | ID | Product Name | Source | Destination(s) | | | | | | | | | | | | | | | | | | | | Section Reference | DMR Reference |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | CRaTER | DLRE | LAMP | LEND | LOLA | LROC | Mini-RF | KSC | CDDIS | MDPS | MOC/DMS | MOC/ITOS | NAIF/PDS | FDF | DSN | SCN | SDPS | SCN/GNSO | USN | SN | | |
| 1 | CRaTER-1 | LRO Operations Activity Request | CRaTER | | | | | | | | | | | ● | | | | | | | | | | Section 4.3.1 | DMR-51, DMR-52, DMR-218, DMR-77, DMR-573 |
| 2 | DLRE-1 | LRO Operations Activity Request | DLRE | | | | | | | | | | | ● | | | | | | | | | | Section 4.3.1 | DMR-51, DMR-52, DMR-218, DMR-77, DMR-573 |
| 3 | DLRE-2 | DLRE FSW Loads | DLRE | | | | | | | | | | | ● | | | | | | | | | | Section 4.3.3 | DMR-51, DMR-52, DMR-573 |
| 4 | DSN-1 | DSN Tracking Data | DSN | | | | | | | | | | | | | | ● | | | | | | | Section 4.2.12 | DMR-354, DMR-52, |

| No. | ID | Product Name | Source | Destination(s) | | | | | | | | | | | | | | | | | | | | Section Reference | DMR Reference |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | CRaTER | DLRE | LAMP | LEND | LOLA | LROC | Mini-RF | KSC | CDDIS | MDPS | MOC/DMS | MOC/ITOS | NAIF/PDS | FDF | DSN | SCN | SDPS | SCN/GNSO | USN | SN | | |
| 5 | DSN-2<br>DSN-3 | Real-Time VC0 or VC1 telemetry data | DSN | | | | | | | | | | | | ● | | | | | | | | | Section 4.2.13 | DMR-52, DMR-348, DMR-365 |
| 6 | DSN-4 | DSN Station Status Packets | DSN | | | | | | | | | | | | ● | | | | | | | | | Section 4.2.15 | DMR-52, DMR-346, DMR-374 |
| 7 | DSN-5<br>DSN-6 | Archived VC0 or VC1Telemetry Data | DSN | | | | | | | | | | | | ● | | | | | | | | | Section 4.2.14 | DMR-52, DMR-348 |
| 8 | FDF-3 | LRO Beta Angle Predict File | FDF/OD | | | | | | | | | | | ● | | | | | | | | | | Section 4.1.8 | DMR-51, DMR-52, DMR-594 |
| | | | MOC/DMS | ● | ● | ● | ● | ● | ● | ● | | | | | | | | | | | | | | | |
| 9 | FDF-4 | LRO Definitive Ephemeris File | FDF/OD | | | | | | | | | | | ● | | | | | | | | | | Section 4.1.9 | DMR-52, DMR-595 |
| 10 | FDF-5 | DSN Predict-Grade SPK Data | FDF/OD | | | | | | | | | | | | | | | ● | | | | | | Section 4.1.3 | DMR-596, DMR-325 |
| 11 | FDF-41 | DSN Long Term Scheduling Grade SPK Data | FDF/OD | | | | | | | | | | | | | | | ● | | | | | | Section 4.1.4 | DMR-701 |

| No. | ID | Product Name | Source | Destination(s): CRaTER | DLRE | LAMP | LEND | LOLA | LROC | Mini-RF | KSC | CDDIS | MDPS | MOC/DMS | MOC/ITOS | NAIF/PDS | FDF | DSN | SCN | SDPS | SCN/GNSO | USN | SN | Section Reference | DMR Reference |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12 | FDF-6 | INP2 Station Acquisition Data | FDF/OD | | | | | | | | | | | ● | | | | | | | ● | | | Section 4.1.1 | DMR-571, DMR-325 |
| | | | GNSO | | | | | | | | | | | | | | | | | | | ● | | | |
| 13 | FDF-10 | OEM Station Acquisition Data | FDF/OD | | | | | | | | | | | ● | | | | | | | ● | | | Section 4.1.2 | DMR-571, DMR-325 |
| | | | GNSO | | | | | | | | | | | | | | | | | | | ● | | | |
| 14 | FDF-7 | Laser Ranging Site Prediction Data | FDF/OD | | | | | | | | | | | ● | | | | | | | | | | Section 4.1.5 | DMR-52, DMR-597, DMR-625, DMR-650, DMR-653 |
| | | | DMS | | | | | ● | | | | | | | | | | | | | | | | | |
| 15 | FDF-8 | Space Network Acquisition Data | FDF/OD | | | | | | | | | | | | | | | | | | | | ● | Section 4.1.6 | DMR-641, DMR-325 |
| 16 | FDF-9 | Ground Station View Period Predicts | FDF/OD | | | | | | | | | | | ● | | | | | | | ● | | | Section 4.1.7 | DMR-52, DMR-598 |
| 17 | FDF-13 | Lunar Orbit Ascending and Descending Node Predicts | FDF/OD | | | | | | | | | | | ● | | | | | | | | | | Section 4.1.12 | DMR-52, DMR-599 |
| | | | MOC/DMS | ● | ● | ● | ● | ● | ● | ● | | | | | | | | | | | | | | | |

| No. | ID | Product Name | Source | Destination(s) | | | | | | | | | | | | | | | | | | | | Section Reference | DMR Reference |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | CRaTER | DLRE | LAMP | LEND | LOLA | LROC | Mini-RF | KSC | CDDIS | MDPS | MOC/DMS | MOC/ITOS | NAIF/PDS | FDF | DSN | SCN | SDPS | SCN/GNSO | USN | SN | | |
| 18 | FDF-14 | Lunar Orbit Terminator Crossing Predicts | FDF/OD | | | | | | | | | | | ● | | | | | | | | | | Section 4.1.13 | DMR-52, DMR-600 |
| | | | MOC/DMS | ● | ● | ● | ● | ● | ● | ● | | | | | | | | | | | | | | | |
| 19 | FDF-15 | Mission Eclipse Predicts | FDF/OD | | | | | | | | | | | ● | | | | | | | | | | Section 4.1.14 | DMR-52, DMR-601 |
| | | | MOC/DMS | ● | ● | ● | ● | | ● | ● | | | | | | | | | | | | | | | |
| 20 | FDF-16 | Lunar Ephemeris | FDF/OD | | | | | | | | | | | ● | | | | | | | | | | Section 4.1.15 | DMR-52, DMR-602 |
| 21 | FDF-17 | Orbiter Thruster Maneuver Plans | FDF/Man | | | | | | | | | | | ● | | | | | | | | | | Section 4.1.17 | DMR-52, DMR-603 |
| 22 | FDF-18 | Post-Separation Report | FDF/OD | | | | | | | | | | | ● | | | | | | | | | | Section 4.1.19 | DMR-52, DMR-606 |
| 23 | FDF-19 | Orbiter Post Maneuver Report | FDF/Man | | | | | | | | | | | ● | | | | | | | | | | Section 4.1.18 | DMR-52, DMR-605 |
| | | | MOC/DMS | | | | | ● | | | | | | | | | | | | | | | | | |
| 24 | FDF-20 | Predicted LRO Ephemeris File | FDF/OD | | | | | | | | | | | ● | | | | | | | | | | Section 4.1.20 | DMR-52, DMR-607 |

| No. | ID | Product Name | Source | Destination(s) | | | | | | | | | | | | | | | | | | | | Section Reference | DMR Reference |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | CRaTER | DLRE | LAMP | LEND | LOLA | LROC | Mini-RF | KSC | CDDIS | MDPS | MOC/DMS | MOC/ITOS | NAIF/PDS | FDF | DSN | SCN | SDPS | SCN/GNSO | USN | SN | | |
| 25 | FDF-21 | Predicted Lunar Ground Track File | FDF/OD | | | | | | | | | | | ● | | | | | | | | | | Section 4.1.21 | DMR-52, DMR-608 |
| | | | MOC/DMS | ● | ● | ● | ● | ● | ● | ● | | | | | | | | | | | | | | | |
| 26 | FDF-22 | Definitive Lunar Ground Track File | FDF/OD | | | | | | | | | | | ● | | | | | | | | | | Section 4.1.22 | DMR-52, DMR-680 |
| | | | MOC/DMS | ● | ● | ● | ● | ● | ● | ● | | | | | | | | | | | | | | | |
| 27 | FDF-23 | Orbiter State Vector Table | FDF/OD | | | | | | | | | | | ● | | | | | | | | | | Section 4.1.16 | DMR-52, DMR-613 |
| 28 | FDF-25 | Thruster Calibration Data | FDF/Man | | | | | | | | | | | ● | | | | | | | | | | Section 4.1.23 | DMR-52, DMR-610 |
| 29 | FDF-29 | LRO Definitive SPICE SPK File | FDF/OD | | | | | | | | | | | ● | | | | | | | | | | Section 4.1.10 | DMR-52, DMR-614 |
| | | | MOC/DMS | ● | ● | ● | ● | ● | ● | ● | | | | | | | | | | | | | | | |
| 30 | FDF-30 | LRO Predictive SPICE SPK File | FDF/OD | | | | | | | | | | | ● | | | | | | | | | | Section 4.1.11 | DMR-52, DMR-615 |
| | | | MOC/DMS | ● | ● | ● | ● | ● | ● | ● | | | | | | | | | | | | | | | |
| 31 | FDF-36 | FDF Reprocessed SPICE Definitive Ephemeris Data SPK | FDF | | | | | | | | | | | ● | | | | | | | | | | Section 4.1.24 | DMR-52, DMR-617 |
| | | | MOC/DMS | ● | ● | ● | ● | ● | ● | ● | | | | | | | | | | | | | | | |

| No. | ID | Product Name | Source | Destination(s) | | | | | | | | | | | | | | | | | | | | Section Reference | DMR Reference |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | CRaTER | DLRE | LAMP | LEND | LOLA | LROC | Mini-RF | KSC | CDDIS | MDPS | MOC/DMS | MOC/ITOS | NAIF/PDS | FDF | DSN | SCN | SDPS | SCN/GNSO | USN | SN | | |
| 32 | FDF-37 | Solar Conjunction File | FDF | | | | | | | | | | | ● | | | | | | | | | | Section 4.1.25 | DMR-52, DMR-685 |
| | | | MOC/DMS | | | | | | | | | | | | | | | | | | ● | | | | |
| 33 | FDF-38 | Target Thruster Vector File | FDF/Man | | | | | | | | | | | ● | | | | | | | | | | Section 4.1.26 | DMR-52, DMR-603 |
| 34 | FDF-39 | Laser Ranging Site View Period Predicts | FDF/OD | | | | | | | | | | | ● | | | | | | | | | | Section 4.1.27 | DMR-52, DMR-699 |
| | | | DMS | | | | | ● | | | | | | | | | | | | | | | | | |
| 35 | FDF-40 | Definitive GTDS Ephemeris | FDF/OD | | | | | | | | | | | ● | | | | | | | | | | Section 4.1.28 | DMR-52, DMR-700 |
| 36 | FDF-42 | FDF Time Coefficients File | FDF/OD | | | | | | | | | | | ● | | | | | | | | | | Section 4.1.29 | DMR-52, DMR-702 |
| 37 | FDF-44 | Trajectory Insertion Data | FDF/OD | | | | | | | | | | | ● | | | | | | | | | | Section 4.1.30 | DMR-52, DMR-706 |
| 38 | FDF-45 | LRO Operations Activity Request | FDF | | | | | | | | | | | ● | | | | | | | | | | Section 4.1.31 | DMR-51, DMR-52, DMR-218, DMR-77, DMR-573 |

| No. | ID | Product Name | Source | Destination(s) | | | | | | | | | | | | | | | | | | | | Section Reference | DMR Reference |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | CRaTER | DLRE | LAMP | LEND | LOLA | LROC | Mini-RF | KSC | CDDIS | MDPS | MOC/DMS | MOC/ITOS | NAIF/PDS | FDF | DSN | SCN | SDPS | SCN/GNSO | USN | SN | | |
| 39 | GNSO-1 | SCN Support Schedules | WOTIS | | | | | | | | | | | ● | | | | | | | | | | Section 4.2.1 | DMR-5, DMR-52, DMR-308, DMR-649 |
| | | | DMS | ● | ● | ● | ● | ● | ● | | | | | | | | ● | | | | | | | | |
| 40 | WS1-1 | WS1 Station Status Packets | WS1 | | | | | | | | | | | | ● | | | | | | | | | Section 4.2.7 | DMR-52, DMR-316, DMR-320, DMR-374 |
| 41 | WS1-2 | WS1 Weather Data | WS1 | | | | | | | | | | | ● | | | | | | | | | | Section 4.2.8 | DMR-52, DMR-574 |
| | | | MOC/DMS | | | | | ● | | | | | | | | | | | | | | | | | |
| 42 | WS1-3<br>WS1-4 | Ka-Band telemetry | WS1 | | | | | | | | | | | | | | | | | ● | | | | Section 4.2.9 | DMR-26, DMR-12, DMR-52, DMR-637, DMR-312, DMR-221 |
| 43 | WS1-5 | WS1 Raw Tracking Data | WS1 | | | | | | | | | | | ● | | | ● | | | | | | | Section 4.2.2 | DMR-5, DMR-4, DMR-52, DMR-322 |
| | | | MOC/DMS | | | | | ● | | | | | | | | | | | | | | | | | |
| 44 | WS1-6<br>WS1-7 | Real-time Orbiter telemetry | WS1 | | | | | | | | | | | | ● | | | | | | | | | Section 4.2.6 | DMR-26, DMR-28, DMR-12, DMR-52, DMR-617, DMR-311 |
| 45 | WS1-8 | Ka-Band RF Receiver Data | WS1 | | | | | | | | | | | ● | | | | | | | | | | Section 4.2.10 | DMR-5, DMR-52, |

| No. | ID | Product Name | Source | Destination(s) | | | | | | | | | | | | | | | | | | | | Section Reference | DMR Reference |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | CRaTER | DLRE | LAMP | LEND | LOLA | LROC | Mini-RF | KSC | CDDIS | MDPS | MOC/DMS | MOC/ITOS | NAIF/PDS | FDF | DSN | SCN | SDPS | SCN/GNSO | USN | SN | | |
| 46 | WS1-10 | Archived VC0 telemetry data | WS1 | | | | | | | | | | | ● | | | | | | | | | | Section 4.2.3 | DMR-5, DMR-13, DMR-52, DMR-575 |
| 47 | WS1-11 | Archived VC1 telemetry data | WS1 | | | | | | | | | | | ● | | | | | | | | | | Section 4.2.4 | DMR-5, DMR-13, DMR-52, DMR-575 |
| 48 | WS1-12<br>WS1-13 | Archived telemetry data File | WS1 | | | | | | | | | | | ● | | | | | | | | | | Section 4.2.5 | DMR-5, DMR-13, DMR-52, DMR-575 |
| 49 | WS1-14<br>WS1-16 | Raw Telemetry File Data | WS1/SDPS | | | | | | | | | | | ● | | | | | | | | | | Section 4.2.11 | DMR-52, DMR-227 |
| 50 | USN-1 | USN Station Status Packets | USN | | | | | | | | | | | | ● | | | | | | | | | Section 4.2.7 | DMR-52, DMR-334, DMR-374 |
| 51 | USN-2 | USN Weather Data | USN | | | | | | | | | | | ● | | | | | | | | | | Section 4.2.8 | DMR-5, DMR-52, DMR-574 |
| | | | MOC/DMS | | | | | ● | | | | | | | | | ● | | | | | | | | |
| 52 | USN-3 | Raw Tracking Data Files | USN | | | | | | | | | | | ● | | | ● | | | | | | | Section 4.2.2 | DMR-4, DMR-5, DMR-52, DMR-340 |
| | | | MOC/DMS | | | | | ● | | | | | | | | | | | | | | | | | |
| 53 | USN-4<br>USN-5 | Real-time Orbiter telemetry | USN | | | | | | | | | | | | ● | | | | | | | | | Section 4.2.6 | DMR-37, DMR-38, DMR-52, DMR-322 |

| No. | ID | Product Name | Source | Destination(s) | | | | | | | | | | | | | | | | | | | | Section Reference | DMR Reference |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | CRaTER | DLRE | LAMP | LEND | LOLA | LROC | Mini-RF | KSC | CDDIS | MDPS | MOC/DMS | MOC/ITOS | NAIF/PDS | FDF | DSN | SCN | SDPS | SCN/GNSO | USN | SN | | |
| 54 | USN-6 | Archived VC0 telemetry data | USN | | | | | | | | | | | ● | | | | | | | | | | Section 4.2.3 | DMR-5, DMR-13, DMR-52, DMR-575 |
| 55 | USN-7 | Archived VC1 telemetry data | USN | | | | | | | | | | | ● | | | | | | | | | | Section 4.2.4 | DMR-5, DMR-13, DMR-52, DMR-575 |
| 56 | KSC-1 KSC2 | Real-time Orbiter telemetry | KSC | | | | | | | | | | | | ● | | | | | | | | | Section 4.8.1 | DMR-51, DMR-52, DMR-204 |
| 57 | KSC-3 | Archived VC0 telemetry data | KSC | | | | | | | | | | | ● | | | | | | | | | | Section 4.8.2 | DMR-51, DMR-52, DMR-204 |
| 58 | KSC-4 | Archived VC1 telemetry data | KSC | | | | | | | | | | | ● | | | | | | | | | | Section 4.8.3 | DMR-51, DMR-52, DMR-204 |
| 59 | KSC-5 | Archived VC2 telemetry data | KSC | | | | | | | | | | | ● | | | | | | | | | | Section 4.8.4 | DMR-51, DMR-52, DMR-204 |
| 60 | KSC-6 | Archived VC3 telemetry data | KSC | | | | | | | | | | | ● | | | | | | | | | | Section 4.8.5 | DMR-51, DMR-52, DMR-204 |
| 61 | SN-1 | Real-time VC0 Orbiter Telemetry | SN | | | | | | | | | | | | ● | | | | | | | | | Section 4.2.6 | DMR-52, DMR-658 |

| No. | ID | Product Name | Source | Destination(s) | | | | | | | | | | | | | | | | | | | | Section Reference | DMR Reference |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | CRaTER | DLRE | LAMP | LEND | LOLA | LROC | Mini-RF | KSC | CDDIS | MDPS | MOC/DMS | MOC/ITOS | NAIF/PDS | FDF | DSN | SCN | SDPS | SCN/GNSO | USN | SN | | |
| 62 | LAMP-1 | LRO Operations Activity Request | LAMP | | | | | | | | | | | ● | | | | | | | | | | Section 4.3.1 | DMR-51, DMR-52, DMR-218, DMR-77, DMR-573 |
| 63 | LAMP-3 | LAMP Instrument FSW Loads | LAMP | | | | | | | | | | | ● | | | | | | | | | | Section 4.3.3 | DMR-52, DMR-573 |
| 64 | LV-1 | Launch Vehicle Post-Sep Vector | LV, via KSC Launch Support Team | | | | | | | | | | | | | | ● | | | | | | | Section 4.8.6 | DMR-557. DMR-655 |
| 65 | LEND-1 | LRO Operations Activity Request | LEND | | | | | | | | | | | ● | | | | | | | | | | Section 4.3.1 | DMR-51, DMR-52, DMR-218, DMR-77, DMR-573 |
| 66 | LOLA-1 | LRO Operations Activity Request | LOLA | | | | | | | | | | | ● | | | | | | | | | | Section 4.3.1 | DMR-51, DMR-52, DMR-218, DMR-77, DMR-573 |
| 67 | LOLA-2 | LOLA Gravity Model | LOLA | | | | | | | | | | | ● | | | | | | | | | | Section 4.3.4 | DMR-52 |
| | | | DMS | | | | | | | | | | | | | | ● | | | | | | | | |
| 68 | LOLA-3 | LOLA Instrument FSW Loads | LOLA | | | | | | | | | | | ● | | | | | | | | | | Section 4.3.3 | DMR-52, DMR-573 |

| No. | ID | Product Name | Source | Destination(s) | | | | | | | | | | | | | | | | | | | | Section Reference | DMR Reference |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | CRaTER | DLRE | LAMP | LEND | LOLA | LROC | Mini-RF | KSC | CDDIS | MDPS | MOC/DMS | MOC/ITOS | NAIF/PDS | FDF | DSN | SCN | SDPS | SCN/GNSO | USN | SN | | |
| 69 | LOLA-4 | LOLA Processed OD information | LOLA | | | | | | | | | | | ● | | | | | | | | | | Section 4.3.5 | DMR-52 |
| | | | DMS | | | | | | | | | | | | | | ● | | | | | | | | |
| 70 | LOLA-5 | LOLA Target Request | LOLA | | | | | | | | | | | ● | | | | | | | | | | Section 4.3.2 | DMR-52, DMR-77 |
| 71 | LOLA-6 | LOLA Processed LR Data | LOLA | | | | | | | | | | | ● | | | ● | | | | | | | Section 4.3.6 | DMR-51, DMR-52, |
| 72 | LOLA-7 | Lunar Laser Retro-Reflector Events | LOLA | | | | | | | | | | | ● | | | | | | | | | | Section 4.3.7 | DMR-51 |
| 73 | LR-1 | Laser Ranging Schedule | LR (via LOLA SOC) | | | | | | | | | | | ● | | | | | | | | | | Section 4.3.8 | DMR-52, DMR-649 |
| | | | DMS | | | | | | | | | | | | | | ● | | | | | | | | |
| 74 | LROC-1 | LRO Operations Activity Request | LROC | | | | | | | | | | | ● | | | | | | | | | | Section 4.3.1 | DMR-51, DMR-52, DMR-218, DMR-77, DMR-573 |
| 75 | LROC-2 | LROC Instrument Initialization Command Sequence | LROC | | | | | | | | | | | ● | | | | | | | | | | Section 4.3.9 | DMR-51, DMR-52, DMR-77 |

| No. | ID | Product Name | Source | Destination(s) | | | | | | | | | | | | | | | | | | | | Section Reference | DMR Reference |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | CRaTER | DLRE | LAMP | LEND | LOLA | LROC | Mini-RF | KSC | CDDIS | MDPS | MOC/DMS | MOC/ITOS | NAIF/PDS | FDF | DSN | SCN | SDPS | SCN/GNSO | USN | SN | | |
| 76 | LROC-3 | LROC Command Timeline | LROC | | | | | | | | | | | ● | | | | | | | | | | Section 4.3.10 | DMR-51, DMR-52, DMR-77 |
| 77 | LROC-4 | LROC Target Request | LROC | | | | | | | | | | | ● | | | | | | | | | | Section 4.3.2 | DMR-51, DMR-52, DMR-77 |
| 78 | MIRF-1 | LRO Operations Activity Request | Mini-RF | | | | | | | | | | | ● | | | | | | | | | | Section 4.3.1 | DMR-51, DMR-52, DMR-218, DMR-77, DMR-573 |
| 79 | MIRF-2 | Mini-RF Load Files | Mini-RF | | | | | | | | | | | ● | | | | | | | | | | Section 4.3.3 | DMR-51, DMR-52, DMR-573 |
| 80 | MIRF-3 | Mini-RF Command Timeline | Mini-RF | | | | | | | | | | | ● | | | | | | | | | | Section 4.3.11 | DMR-51, DMR-52, DMR-77 |
| 81 | MIRF-4 | Mini-RF Target Requests | Mini-RF | | | | | | | | | | | ● | | | | | | | | | | Section 4.3.2 | DMR-51, DMR-52, DMR-77 |
| 82 | MOC-2 | SPICE SCLK – Clock Correlation File | MOC | ● | ● | ● | ● | ● | ● | ● | | | | | | | ● | | | | | | | Section 4.5.2 | DMR-51. DMR-670 |

| No. | ID | Product Name | Source | Destination(s) | | | | | | | | | | | | | | | | | | | | Section Reference | DMR Reference |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | CRaTER | DLRE | LAMP | LEND | LOLA | LROC | Mini-RF | KSC | CDDIS | MDPS | MOC/DMS | MOC/ITOS | NAIF/PDS | FDF | DSN | SCN | SDPS | SCN/GNSO | USN | SN | | |
| 83 | MOC-3 | CRaTER - Spacecraft HK Data File | MOC/DMS | ● | | | | | | | | | | | | | | | | | | | | Section 4.5.9 | DMR-51, DMR-254 |
| 84 | MOC-4 | CRaTER HK Data Files | MOC/DMS | ● | | | | | | | | | | | | | | | | | | | | Section 4.5.10 | DMR-51, DMR-254, DMR-259 |
| 85 | MOC-5 | CRaTER Raw Measurement Data Files | MOC/DMS | ● | | | | | | | | | | | | | | | | | | | | Section 4.5.11 | DMR-51, DMR-254, DMR-259, DMR-261 |
| 86 | MOC-6 | CRaTER Real-time VC0 HK data | MOC/ITOS | ● | | | | | | | | | | | | | | | | | | | | Section 4.5.13 | DMR-51, DMR-392, DMR-255, DMR-256, DMR-257 |
| 87 | MOC-73 | Archived CRaTER VC0 Telemetry File | MOC/DMS | ● | | | | | | | | | | | | | | | | | | | | Section 4.5.14 | DMR-51 |
| 88 | MOC-7 | Daily Command Load Report | MOC/DMS | ● | ● | ● | ● | ● | ● | ● | | | | | | | | | | | | | | Section 4.5.1 | DMR-51 |
| 89 | MOC-62 | RTS Command Load Report | MOC/DMS | ● | ● | ● | ● | ● | ● | ● | | | | | | | | | | | | | | Section 4.5.16 | DMR-51 |

| No. | ID | Product Name | Source | Destination(s) | | | | | | | | | | | | | | | | | | | | Section Reference | DMR Reference |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | CRaTER | DLRE | LAMP | LEND | LOLA | LROC | Mini-RF | KSC | CDDIS | MDPS | MOC/DMS | MOC/ITOS | NAIF/PDS | FDF | DSN | SCN | SDPS | SCN/GNSO | USN | SN | | |
| 90 | MOC-8 | DLRE - Spacecraft HK Data File | MOC/DMS | | ● | | | | | | | | | | | | | | | | | | | Section 4.5.9 | DMR-51, DMR-254 |
| 91 | MOC-9 | DLRE HK Data Files | MOC/DMS | | ● | | | | | | | | | | | | | | | | | | | Section 4.5.10 | DMR-51, DMR-254, DMR-259 |
| 92 | MOC-10 | DLRE Raw Measurement Data Files | MOC/DMS | | ● | | | | | | | | | | | | | | | | | | | Section 4.5.11 | DMR-51, DMR-254, DMR-259, DMR-261 |
| 93 | MOC-11 | DLRE Real-time VC0 HK data | MOC/ITOS | | ● | | | | | | | | | | | | | | | | | | | Section 4.5.13 | DMR-51, DMR-392, DMR-255, DMR-256, DMR-257 |
| 94 | MOC-12 | LAMP - Spacecraft HK Data File | MOC/DMS | | | ● | | | | | | | | | | | | | | | | | | Section 4.5.9 | DMR-51, DMR-254 |
| 95 | MOC-13 | LAMP HK Data Files | MOC/DMS | | | ● | | | | | | | | | | | | | | | | | | Section 4.5.10 | DMR-51, DMR-254, DMR-259 |
| 96 | MOC-14 | LAMP Raw Measurement Data Files | MOC/DMS | | | ● | | | | | | | | | | | | | | | | | | Section 4.5.11 | DMR-51, DMR-254, DMR-259, DMR-261 |

| No. | ID | Product Name | Source | Destination(s) | | | | | | | | | | | | | | | | | | | | Section Reference | DMR Reference |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | CRaTER | DLRE | LAMP | LEND | LOLA | LROC | Mini-RF | KSC | CDDIS | MDPS | MOC/DMS | MOC/ITOS | NAIF/PDS | FDF | DSN | SCN | SDPS | SCN/GNSO | USN | SN | | |
| 97 | MOC-15 | LAMP Real-time VC0 HK data | MOC/ITOS | | | ● | | | | | | | | | | | | | | | | | | Section 4.5.13 | DMR-51, DMR-392, DMR-255 |
| 98 | MOC-16 | LEND - Spacecraft HK Data File | MOC/DMS | | | | ● | | | | | | | | | | | | | | | | | Section 4.5.9 | DMR-51, DMR-254 |
| 99 | MOC-17 | LEND HK Data Files | MOC/DMS | | | | ● | | | | | | | | | | | | | | | | | Section 4.5.10 | DMR-51, DMR-254, DMR-259 |
| 100 | MOC-18 | LEND Raw Measurement Data Files | MOC/DMS | | | | ● | | | | | | | | | | | | | | | | | Section 4.5.11 | DMR-51, DMR-254, DMR-259, DMR-261 |
| 101 | MOC-19 | LEND Real-time VC0 HK data | MOC/DMS | | | | ● | | | | | | | | | | | | | | | | | Section 4.5.13 | DMR-51, DMR-392, DMR-255 |
| 102 | MOC-20 | LOLA - Spacecraft HK Data File | MOC/DMS | | | | | ● | | | | | | | | | | | | | | | | Section 4.5.9 | DMR-51, DMR-254 |
| 103 | MOC-21 | LOLA HK Data Files | MOC/DMS | | | | | ● | | | | | | | | | | | | | | | | Section 4.5.10 | DMR-51, DMR-254, DMR-259 |
| 104 | MOC-22 | LOLA Raw Measurement Data Files | MOC/DMS | | | | | ● | | | | | | | | | | | | | | | | Section 4.5.11 | DMR-51, DMR-254, DMR-259, DMR-261 |

| No. | ID | Product Name | Source | Destination(s) | | | | | | | | | | | | | | | | | | | | Section Reference | DMR Reference |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | CRaTER | DLRE | LAMP | LEND | LOLA | LROC | Mini-RF | KSC | CDDIS | MDPS | MOC/DMS | MOC/ITOS | NAIF/PDS | FDF | DSN | SCN | SDPS | SCN/GNSO | USN | SN | | |
| 105 | MOC-23 | LOLA Real-time VC0 HK data | MOC/ITOS | | | | | ● | | | | | | | | | | | | | | | | Section 4.5.13 | DMR-51, DMR-392, DMR-255 |
| 106 | MOC-24 | LROC Real-time VC0 HK data | MOC/ITOS | | | | | | ● | | | | | | | | | | | | | | | Section 4.5.13 | DMR-51, DMR-392, DMR-255, DMR-256, DMR-257 |
| 107 | MOC-25 | LROC - Spacecraft HK Data File | MOC/DMS | | | | | | ● | | | | | | | | | | | | | | | Section 4.5.9 | DMR-51, DMR-254 |
| 108 | MOC-26 | LROC HK Data Files | MOC/DMS | | | | | | ● | | | | | | | | | | | | | | | Section 4.5.10 | DMR-51, DMR-254, DMR-259 |
| 109 | MOC-27 | LROC NAC Raw Measurement Data Files | MOC/DMS | | | | | | ● | | | | | | | | | | | | | | | Section 4.5.11 | DMR-51, DMR-254, DMR-259, DMR-261- |
| 110 | MOC-39 | LROC WAC Raw Measurement Data Files | MOC/DMS | | | | | | ● | | | | | | | | | | | | | | | Section 4.5.11 | DMR-51, DMR-254, DMR-259, DMR-261 |
| 111 | MOC-28 | Mini-RF - Spacecraft HK Data File | MOC/DMS | | | | | | | ● | | | | | | | | | | | | | | Section 4.5.9 | DMR-51, DMR-254 |

| No. | ID | Product Name | Source | Destination(s) | | | | | | | | | | | | | | | | | | | | Section Reference | DMR Reference |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | CRaTER | DLRE | LAMP | LEND | LOLA | LROC | Mini-RF | KSC | CDDIS | MDPS | MOC/DMS | MOC/ITOS | NAIF/PDS | FDF | DSN | SCN | SDPS | SCN/GNSO | USN | SN | | |
| 112 | MOC-29 | Mini-RF HK Data Files | MOC/DMS | | | | | | | ● | | | | | | | | | | | | | | Section 4.5.10 | DMR-51, DMR-254, DMR-259 |
| 113 | MOC-30 | Mini-RF Operations Opportunity | MOC | | | | | | | ● | | | | | | | | | | | | | | Section 4.5.15 | DMR-51 |
| 114 | MOC-31 | Mini-RF Raw Measurement Data Files | MOC/DMS | | | | | | | ● | | | | | | | | | | | | | | Section 4.5.11 | DMR-51, DMR-254, DMR-259, DMR-261 |
| 115 | MOC-32 | Mini-RF Real-time VC0 HK data | MOC/ITOS | | | | | | | ● | | | | | | | | | | | | | | Section 4.5.13 | DMR-51, DMR-392, DMR-255, DMR-256, DMR-257 |
| 116 | MOC-33 | SPICE Event Kernel | MOC/DMS | ● | ● | ● | ● | ● | ● | ● | | | | | | | | | | | | | | Section 4.5.3 | DMR-51. DMR-699 |
| 117 | MOC-34 MOC-36 | Real-time Orbiter Commands (WS1, USN and SN) | MOC/ITOS | | | | | | | | | | | | | | | | ● | | | ● | ● | Section 4.6.1 | DMR-51, DMR-30, DMR-40, DMR-319, DMR-337, DMR-640, DMR-663, DMR-300 |
| 118 | MOC-35 | DSN Real-Time orbiter commands | MOC/ITOS | | | | | | | | | | | | | | | ● | | | | | | Section 4.6.2 | DMR-51, DMR-347, DMR-458, DMR-459 |

| No. | ID | Product Name | Source | Destination(s) | | | | | | | | | | | | | | | | | | | | Section Reference | DMR Reference |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | CRaTER | DLRE | LAMP | LEND | LOLA | LROC | Mini-RF | KSC | CDDIS | MDPS | MOC/DMS | MOC/ITOS | NAIF/PDS | FDF | DSN | SCN | SDPS | SCN/GNSO | USN | SN | | |
| 119 | MOC-37 | Commands to KSC | MOC/ITOS | | | | | | | | ● | | | | | | | | | | | | | Section 4.9.2 | DMR-51 |
| 120 | MOC-38 | Telemetry to KSC | MOC/ITOS | | | | | | | | ● | | | | | | | | | | | | | Section 4.9.1 | DMR-51, DMR-392 |
| 121 | MOC-40 | SPICE FK – Frame Kernels | Multiple LRO Groups | | | | | | | | | | | ● | | | | | | | | | | Section 4.5.4 | DMR-51, DMR-621 |
| | | | | ● | ● | ● | ● | ● | ● | ● | | | | | | | ● | | | | | | | | |
| 122 | MOC-41 | SPICE Predicted CK (Predicted S/C Orientation) | AGS | | | | | | | | | | | ● | | | | | | | | | | Section 4.5.5 | DMR-51. DMR-619 |
| | | | MOC/DMS | ● | ● | ● | ● | ● | ● | ● | | | | | | | | | | | | | | | |
| 123 | MOC-42 | SPICE Definitive CK (Definitive S/C Orientation) | AGS | | | | | | | | | | | ● | | | | | | | | | | Section 4.5.6 | DMR-51, DMR-620 |
| | | | MOC/DMS | ● | ● | ● | ● | ● | ● | ● | | | | | | | ● | | | | | | | | |
| 124 | MOC-43 | SPICE Definitive HGA Orientation CK | AGS | | | | | | | | | | | ● | | | ● | | | | | | | Section 4.5.7 | DMR-51, DMR-616, DMR-259 |
| | | | MOC/DMS | ● | | ● | ● | ● | | | | | | | | | ● | | | | | | | | |
| 125 | MOC-44 | SPICE Definitive SA Orientation CK | AGS | | | | | | | | | | | ● | | | | | | | | | | Section 4.5.8 | DMR-51, DMR-616, DMR-259 |
| | | | MOC/DMS | ● | | ● | ● | ● | | | | | | | | | | | | | | | | | |

| No. | ID | Product Name | Source | Destination(s) | | | | | | | | | | | | | | | | | | | | Section Reference | DMR Reference |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | CRaTER | DLRE | LAMP | LEND | LOLA | LROC | Mini-RF | KSC | CDDIS | MDPS | MOC/DMS | MOC/ITOS | NAIF/PDS | FDF | DSN | SCN | SDPS | SCN/GNSO | USN | SN | | |
| 126 | MOC-46 | CRaTER HK Meta Summary Report | DMS | ● | | | | | | | | | | | | | | | | | | | | Section 4.5.12 | DMR-51, DMR-688, DMR-259 |
| 127 | MOC-47 | CRaTER Measurement Meta Summary Report | DMS | ● | | | | | | | | | | | | | | | | | | | | Section 4.5.12 | DMR-51, DMR-688, DMR-259 |
| 128 | MOC-48 | DLRE HK Meta Summary Report | DMS | | ● | | | | | | | | | | | | | | | | | | | Section 4.5.12 | DMR-51, DMR-688, DMR-259 |
| 129 | MOC-49 | DLRE Measurement Meta Summary Report | DMS | | ● | | | | | | | | | | | | | | | | | | | Section 4.5.12 | DMR-51, DMR-688, DMR-259 |
| 130 | MOC-50 | LAMP HK Meta Summary Report | DMS | | | ● | | | | | | | | | | | | | | | | | | Section 4.5.12 | DMR-51, DMR-688, DMR-259 |
| 131 | MOC-51 | LAMP Measurement Meta Summary Report | DMS | | | ● | | | | | | | | | | | | | | | | | | Section 4.5.12 | DMR-51, DMR-688, DMR-259 |
| 132 | MOC-52 | LEND HK Meta Summary Report | DMS | | | | ● | | | | | | | | | | | | | | | | | Section 4.5.12 | DMR-51, DMR-688, DMR-259 |

| No. | ID | Product Name | Source | Destination(s) | | | | | | | | | | | | | | | | | | | | Section Reference | DMR Reference |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | CRaTER | DLRE | LAMP | LEND | LOLA | LROC | Mini-RF | KSC | CDDIS | MDPS | MOC/DMS | MOC/ITOS | NAIF/PDS | FDF | DSN | SCN | SDPS | SCN/GNSO | USN | SN | | |
| 133 | MOC-53 | LEND Measurement Meta Summary Report | DMS | | | | ● | | | | | | | | | | | | | | | | | Section 4.5.12 | DMR-51, DMR-688, DMR-259 |
| 134 | MOC-54 | LOLA HK Meta Summary Report | DMS | | | | | ● | | | | | | | | | | | | | | | | Section 4.5.12 | DMR-51, DMR-688, DMR-259 |
| 135 | MOC-55 | LOLA Measurement Meta Summary Report | DMS | | | | | ● | | | | | | | | | | | | | | | | Section 4.5.12 | DMR-51, DMR-688, DMR-259 |
| 136 | MOC-56 | LROC HK Meta Summary Report | DMS | | | | | | ● | | | | | | | | | | | | | | | Section 4.5.12 | DMR-51, DMR-688, DMR-259 |
| 137 | MOC-57 | LROC NAC Meta Summary Report | DMS | | | | | | ● | | | | | | | | | | | | | | | Section 4.5.12 | DMR-51, DMR-688, DMR-259 |
| 138 | MOC-58 | LROC WAC Meta Summary Report | DMS | | | | | | ● | | | | | | | | | | | | | | | Section 4.5.12 | DMR-51, DMR-688, DMR-259 |
| 139 | MOC-59 | Mini-RF HK Meta Summary Report | DMS | | | | | | | ● | | | | | | | | | | | | | | Section 4.5.12 | DMR-51, DMR-688, DMR-259 |

| No. | ID | Product Name | Source | Destination(s) | | | | | | | | | | | | | | | | | | | | Section Reference | DMR Reference |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | CRaTER | DLRE | LAMP | LEND | LOLA | LROC | Mini-RF | KSC | CDDIS | MDPS | MOC/DMS | MOC/ITOS | NAIF/PDS | FDF | DSN | SCN | SDPS | SCN/GNSO | USN | SN | | |
| 140 | MOC-60 | Mini-RF Measurement Meta Summary Report | DMS | | | | | | | ● | | | | | | | | | | | | | | Section 4.5.12 | DMR-51, DMR-688, DMR-259 |
| 141 | MOC-63 | Propulsion System Data | DMS | | | | | | | | | | | | | | ● | | | | | | | Section 4.10.1 | DMR-51 |
| 142 | MOC-64 | Laser Ranging Go Flag | DMS | | | | | ● | | | | | | | | | | | | | | | | Section 4.11.1 | DMR-625 |
| 143 | MOC-65 | Definitive Spacecraft Body Frame Attitude File | AGS | | | | | | | | | | | ● | | | | | | | | | | Section 4.10.2 | DMR-51, DMR-703 |
| | | | DMS | | | | | | | | | | | | | | ● | | | | | | | | |
| 144 | MOC-66 | Spacecraft HGA Motion File | AGS | | | | | | | | | | | ● | | | | | | | | | | Section 4.10.3 | DMR-51, DMR-704 |
| | | | DMS | | | | | | | | | | | | | | ● | | | | | | | | |
| 145 | MOC-67 | Spacecraft Solar Array Motion File | AGS | | | | | | | | | | | ● | | | | | | | | | | Section 4.10.4 | DMR-51, DMR-705 |
| | | | DMS | | | | | | | | | | | | | | ● | | | | | | | | |
| 146 | MOC-68 | OBC Generated Attitude Data File | DMS | | | | | | | | | | | | | | ● | | | | | | | Section 4.10.5 | DMR-51 |

| No. | ID | Product Name | Source | Destination(s) | | | | | | | | | | | | | | | | | | | | Section Reference | DMR Reference |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | CRaTER | DLRE | LAMP | LEND | LOLA | LROC | Mini-RF | KSC | CDDIS | MDPS | MOC/DMS | MOC/ITOS | NAIF/PDS | FDF | DSN | SCN | SDPS | SCN/GNSO | USN | SN | | |
| 147 | MOC-69 | LRO Provided Separation Data | AGS | | | | | | | | | | | ● | | | | | | | | | | Section 4.9.3 | DMR-51, DMR-709 |
| | | | DMS | | | | | | | | ● | | | | | | | | | | | | | | |
| 148 | MOC-71 | Data Recorder Model Report | MOC | | | | | | ● | | | | | | | | | | | | | | | Section 4.5.17 | DMR-51 |
| 149 | MOC-72 | LRO Propulsion Data | MOC | | | | | | | | | | | | | | ● | | | | | | | Section 4.10.6 | DMR-51 |
| 150 | MOC-74 | Predictive LRO Spacecraft Body Attitude File | MOC/AGS | | | | | | | | | | | ● | | | | | | | | | | Section 4.10.7 | DMR-51 |
| | | | DMS | | | | | | | | | | | | | | ● | | | | | | | | |
| 151 | FSWM-1 | Orbiter FSW Load Files | FSWM | | | | | | | | | | | ● | | | | | | | | | | Section 4.4.1 | DMR-51, DMR-52, |
| 152 | NAIF-1 | SPICE Planetary SPK | JPL/NAIF | | | | | | | | | | | ● | | | | | | | | | | Section 4.7.1 | DMR-51, DMR-52, |
| | | | MOC/DMS | ● | ● | ● | ● | ● | ● | ● | | | | | | | | | | | | | | | |
| 153 | NAIF-2 | SPICE LSK (Leap Second Kernel) | JPL/NAIF | | | | | | | | | | | ● | | | | | | | | | | Section 4.7.2 | DMR-51, DMR-52, |
| | | | MOC/DMS | ● | ● | ● | ● | ● | ● | ● | | | | | | | | | | | | | | | |

| No. | ID | Product Name | Source | Destination(s) | | | | | | | | | | | | | | | | | | | | Section Reference | DMR Reference |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | CRaTER | DLRE | LAMP | LEND | LOLA | LROC | Mini-RF | KSC | CDDIS | MDPS | MOC/DMS | MOC/ITOS | NAIF/PDS | FDF | DSN | SCN | SDPS | SCN/GNSO | USN | SN | | |
| 154 | NAIF-3 | SPICE Generic PCK (Planetary Constants) | JPL/NAIF | | | | | | | | | | | ● | | | | | | | | | | Section 4.7.3 | DMR-51, DMR-52, |
| | | | MOC/DMS | ● | ● | ● | ● | ● | ● | ● | | | | | | | | | | | | | | | |
| 155 | NAIF-4 | SPICE High Precision Lunar Orientation PCK | JPL/NAIF | | | | | | | | | | | ● | | | | | | | | | | Section 4.7.4 | DMR-51, DMR-52, |
| | | | MOC/DMS | ● | ● | ● | ● | ● | ● | ● | | | | | | | | | | | | | | | |

# 4.0 LRO GROUND SYSTEM EXTERNAL INTERFACES AND PRODUCT

The following sections provide specific information regarding each product as listed in Table 3-1.

For each product, this ICD will provide the following details:

| Product Details | Detail Description |
|---|---|
| Time interval | Step size within the file, if applicable. Such as: data point every minute, every 10 minutes |
| File duration | Total time contained within the file or total number of days contained within the file |
| File or Data Generation Frequency | How often is the file generated; daily, weekly, per pass |
| Delivery method (real-time, SCP, FTP, etc) | Real-time TCP socket<br>Real-time UDP socket<br>File delivery with secure copy (SCP)<br>Standard File Transfer Protocol (FTP) |
| Data Volume | Total amount of data in either Kbytes, Mbytes, or GBytes) |
| Accuracy (if it applies) | Accurate to second, degrees, Km, etc (could be NA) |
| Other pertinent details | Provides additional details for the data product, if applicable; otherwise, set to NA |

The LRO MOC supports 2 standard delivery protocols to support data delivery to/from the MOC. The LRO MOC uses a standard TCP/IP socket connection to support the transfer of real-time telemetry or commands or other real-time status information.

The USN and SN stations initiate the socket connection with the MOC's telemetry and command system. The LRO MOC issues the socket connection to the various SOCs; the MOC's telemetry distribution element will retry these connections a configurable number of times in the event of any dropped sockets.

## 4.1 FLIGHT DYNAMICS FACILITY PRODUCTS

This section provides the details of the products that the Flight Dynamics Facility creates to support the LRO mission. FDF creates these products on a regular basis to provide data for:

- station acquisition data,
- science operations center planning purposes,
- attitude and maneuver planning
- general reports to the Mission Operations Team

For products destined to the MOC, FDF generates these products using a standard naming convention as defined by the following concepts of a file name and a file extension separated by the standard period (.):

<file name>.<file extension>; where

<file name> ➔ FDFnn_YYYYDDD_YYYYDDD_fnn; where

***Table 4-1 FDF File Naming Convention***

| | | |
|---|---|---|
| FDFnn | => | 5 ASCII characters in which the nn refers to the identifier listed as the LRO Ground System Product Matrix; for example<br>FDF03 = LRO Beta Angle Predict File<br>FDF14 = Lunar Orbit Terminator Crossing Predicts |
| Start Date of product YYYYDDD | => | 7 ASCII characters<br>YYYY => 4 ASCII characters for the year (2008 – 2013)<br>DDD => 3 ASCII characters for day of year designator (001 – 366); followed by the underscore (_) character |
| Stop Date of product YYYYDDD | => | 7 ASCII characters<br>YYYY => 4 ASCII characters for the year (2008 – 2013)<br>DDD => 3 ASCII characters for day of year designator (001 – 366); followed by the underscore (_) character |
| f | => | Flag to indicate if maneuvers are modeled or included within the product<br>B => Maneuvers are modeled. For definitive products, all maneuvers are modeled. For predictive products, at least one future maneuver is modeled.<br>N => No maneuvers are modeled. For predictive products, the propagation includes no spacecraft perturbations and represents the product as if no spacecraft maneuvers are performed within the time span of the product |
| nn | => | 2 ASCII Digits to represent the version number for the file. |

The initial creation of a file will be represented by version number 01; a subsequent version is 02, 03, etc. The YYYYDDD designation identifies the start date and the end date for which data are contained within the file. FDF generates the products to start at 0000Z on the start date and end at 0000Z on the end date so that there is always an overlap between products in the event that FDF was down and could not generate a new product until the previous had completely expired. FDF generates a product that has a start time of 0000Z for the start date and actually ends at 0000Z. In the example of a 10 day product (e.g., SCN Station Acquisition Data – FDF-6), the duration is 10 complete days, but the product includes 0000Z for the eleventh day.

For example, the name for the LRO Beta Angle Predict File, based on these concepts, is identified as FDF03_2009015_2009194_N01.txt. This assumes that the first data point represents a starting time of 0000Z on January 15, 2009 and an end date of July 14, 2009 at 0000Z and it was the first generation of the file and that no maneuvers were modeled.

<file extension> ➔ 3-4 ASCII characters representing the type of file; e.g.,
txt, for a text file
inp2 for the FDF generated SCN acquisition data product (version 2 of INP)

bsp, for a binary SPICE (SPK) file
bc, for a binary SPICE Attitude (CK) file
NOTE: this naming convention does not apply to the FDF generated INP Acquisition data product. For that specific product, FDF generates unique files names base on the 4-character station identifier, as noted in Section 4.1.1.

This naming convention is the standard, except where a different naming convention is noted that based upon other required mission concepts. These special cases will be explicitly called out in the corresponding sections.

This section of the ICD captures the FDF product creation and delivery schedule for the LRO mission from the beginning of commissioning orbit to the end of the nominal mission. The FDF-GS&O Operations Agreement (451-MOA-002960) documents the prelaunch, launch, and post launch products through the final Lunar Orbit Insertion maneuver. During this period of time, FDF will provide a subset of the nominal set of products needed to support LRO operations. Due to time constraints, these products do not have the same durations as specified below for the nominal mission.

### 4.1.1 (FDF-6) INP Station Acquisition Data

This product file contains acquisition information for the WS1, the SDO backup antenna, and the 2 USN owned ground station supporting the LRO telemetry and measurement data downlink or command uplink. FDF creates separate INP2 files that contain the station acquisition data for the specified station supporting the LRO mission.

When the WOTIS Scheduling Office receives the INP2 product, their systems automatically send the products to the corresponding WS1 or SDO backup antennas or to the USN sites.

#### 4.1.1.1 Product Details

| | |
|---|---|
| Time interval | Data samples provided at 1 minute increments |
| File duration | 10 days of station acquisition data starting at<br>0000Z Wednesday for nominal deliveries<br>Post-maneuver updates will start at 00:00 GMT on the current day |
| File or Data Generation Frequency | Weekly, on Wednesday of the week, by noon-time, Eastern<br>After maneuvers within best-effort available |
| Delivery method (real-time, SCP, FTP, etc) | FTP to WOTIS<br>scp to LRO MOC via the FD Communications Server; the backup uses the FDPC (MOC performs the scp pull)<br>WOTIS FTP-es the INP2 files to USN, WS1S, and STSS stations |
| Data Volume | Variable; approximately 500 -700 Kbytes based on number of views per station and duration for each station view for each of the INP2 data file |
| Accuracy (if it applies) | Data accuracy is within 800 meters over the 84 hour predicts;<br>Across maneuvers (orbit adjust or momentum unloads) accuracy is best available |
| Other pertinent details | Acquisition data are consistent with the predicted ephemeris data based upon the most recent tracking information |

#### 4.1.1.2 Format

FDF generates the INP2 product as an ASCII text file. The file contains the acquisition data for each contact for the station; FDF generates one file for each station that contains the acquisition data. The file will have 1:N lines of header information that identifies the file description information. This is followed by 1:N lines of station acquisition information. The standard fields and field description (for the 1:N lines of acquisition data) are listed in the following table. Data will be provided down to an identified station masking elevation angle.

***Table 4-2 FDF – SCN Acquisition Data Description***

| Field name | Field Characteristics |
|---|---|
| Strand name | 43 ASCII text characters representing the facility/station name to satellite/0059 (LRO). The station name is represented by the 4 ASCII text characters representing the unique station identifier. The field appears as follows:<br>Facility/NNNN to Satellite/0059/Sensor/Omni<br>Where NNNN represents the 4 character ASCII station name and 0059 is the 4-digit NASA SIC code for LRO.<br>NNNN = WS1S for LRO White Sands S-band Station<br>STSS for SDO S-Band backup Station<br>USPS for USN Dongara, Australia<br>USHS for USN South Point, Hawaii |
| Timetag information:<br>year<br>day of year and<br>time of day | YYYYDDD.HHMMSS (GMT) ; 14 ASCII digits with a period between the first 7 and last 6; where<br>YYYY => 4 ASCII digits of year (2008 – 2013)<br>DDD => 3 ASCII digits for day of year (1 – 366)<br>HHMMSS => 6 ASCII digits representing the hours, minutes, and seconds of day |
| Range | RRRRRR.ddddd (Km)<br>RRRRRR => 6 ASCII digits for whole range (0 – 999999)[Note 1]<br>ddddd => 5 ASCII digits for decimal portion of range (00000 – 99999) |
| Range rate | RR.dddddd (Km/s)<br>RR => 2 ASCII digits for whole range rate (0 – 99) [Note 1]<br>dddddd => 6 ASCII digits for decimal portion of range (000000 – 999999) |
| Azimuth angle | AAA.ddd (Degree)<br>AAA => 3 ASCII digits for whole angle measurement (0 – 360)<br>ddd => 3 ASCII digits for decimal portion of range (000 – 999) |
| Elevation angle | EEE.ddd (Degree)<br>EEE => 3 ASCII digits for whole angle measurement (0 – 90)<br>ddd =>3 ASCII digits for decimal portion of range (000 – 999) |
| Note 1 : Field is actually floating point and the value will vary in magnitude | |

A sample file name for the first generation of this data file has the following convention:

<File name>_<Start Date>_<Stop Date>_<Maneuver Model Flag><version number>.<file extension>

| | | | |
|---|---|---|---|
| where | File Name | = | [10 Characters], which includes an underscore character (_); the following field definitions are used to define the fields<br>Station Identifier =>5 total ASCII Characters<br>4 ASCII Characters used to represent the stations supporting the LRO mission; followed by a 1 character underscore; see Table 4-2 above for the list of the 4 character station IDs<br>Spacecraft Identifier = > 5 total ASCII Characters<br>4 ASCII Digits used to identify the spacecraft = 0059; followed by a 1 ASCII character (_) |
| | Start Date | = | [8 ASCII Digits] used to represent the start date associated with the first station acquisition; in the form of:<br>YYYYDDD; followed by a 1 character underscore |
| | Stop Date | = | [8 ASCII Digits] used to represent the start date associated with the first station acquisition; in the form of:<br>yyyyddd; followed by a 1 character underscore |
| | Maneuver Model Flag | = | [1 characters] One ASCII character that indicates whether maneuvers were modeled for this product<br>B => Maneuvers are modeled<br>N => No maneuvers are modeled |
| | version number | = | [2 characters] Two ASCII character version number. The initial version is 01, next is 02 … up to 99. |
| | file extension | = | [4characters]<br>inp2 to represent the second format version of the (Internet Predict) INP data product |

For example, a sample file name for the acquisition data (INP2 product version) corresponding to the WS1 Dual Ka/S Band station (for the 10 day duration of Thursday, January 15, 2009 at 0000Z through Sunday, January 25, 2009 at 0000Z would have the following file name convention:
WS1S_0059_2009015_2009022_N01.inp2

An INP-2 sample station acquisition data product is provided as a reference in Appendix B, Figure B.1-1.

### 4.1.2 (FDF-10) OEM Station Acquisition Data

For the USN collaborative sites, FDF generates an acquisition data product using a standard CCSDS format identified as an Orbital Ephemeris Message (OEM) Data Product. FDF generates this product based on an "earth-centered" reference frame.

When the WOTIS Scheduling Office receives the OEM product, their systems automatically send the products to the corresponding USN sites.

#### 4.1.2.1 Product Details

| | |
|---|---|
| Time interval | Data samples provided at 1 minute increments |
| File duration | 10 days of station acquisition data starting at 0000Z Wednesday for nominal deliveries<br>Post-maneuver updates will start at 00:00 GMT on the current day |
| File or Data Generation Frequency | Weekly, on Wednesday of the week, by noon-time, Eastern<br>After maneuvers within best-effort available |
| Delivery method (real-time, SCP, FTP, etc) | FDF FTP-es to WOTIS<br>WOTIS FTP-es the OEM file to USN<br>scp to LRO MOC via the FD Communications Server; the backup uses the FDPC (MOC performs the scp pull) |
| Data Volume | Approximately 1.5 MBytes for an OEM data file |
| Accuracy (if it applies) | Data accuracy is within 800 meters over the 84 hour predicts;<br>Across maneuvers (orbit adjust or momentum unloads) accuracy is best available |
| Other pertinent details | Acquisition data are consistent with the predicted ephemeris data based upon the most recent tracking information<br>EME2000 is the reference frame |

#### 4.1.2.2 Format

The OEM Data product format is defined within the CCSDS Blue Book *CCSDS 502.0-B-1, Orbit Data Messages, September 2004;* Section 4 of that document defines the specific details for the OEM format, content and structure. As such, no format definitions are listed within this document.

FDF will generate the OEM data product as an earth-centered vector. This file corresponds to the standard FDF-generated file name, so no additional details are required to document the file name concept.

A sample file name for the first generation of this data file has the following convention:

<File name>_<Maneuver Model Flag><version number>.<file extension>

A sample file name for the OEM acquisition data for the 10 day duration of Thursday, January 15, 2009 at 0000Z through Sunday, January 25, 2009 at 0000Z would have the following file name convention:
FDF10_2009015_2009025_N01.oem

An OEM sample station acquisition data product is provided as a reference in Appendix B, Figure B.1-2.

### 4.1.3 (FDF-5) DSN Predict-Grade SPK Data

The DSN "Predict-Grade" site acquisition data describes the FDF-generated information necessary to allow the DSN 34-meter subnet to acquire the LRO spacecraft; this is the SPICE data that DSN uses to schedule the 34-m subnet antennas to support LRO contacts. This is the standard file that DSN uses to support nominal LRO operational activities, which include any emergency or routine/backup operations and monthly maneuvers.

The FDF-GS&O Operations Agreement (451-MOA-002960) documents the prelaunch, launch, and post launch products through the final Lunar Orbit Insertion maneuver and identifies any products that FDF is required to deliver to DSN.

FDF generates the DSN SPICE SPK prediction data that the DSN stations use as pointing information to track LRO and ensure data acquisition.

#### 4.1.3.1 Product Details

| | |
|---|---|
| Time interval | Data samples provided at 1 minute increments |
| File duration | 10 days of station acquisition data starting on<br>at 0000Z Wednesday for nominal deliveries<br>Post-maneuver updates will start at 00:00 GMT on the current day |
| File or Data Generation Frequency | Weekly, on Wednesday of the week, by noon-time, Eastern<br>After maneuvers within best-effort available |
| Delivery method (real-time, SCP, FTP, etc) | FDF accesses the DSN Deep Space Mission System (DSMS) Service Preparation System (SPS) web- portal and posts the data file and associated meta data |
| Data Volume | Approx 6 Mbytes |
| Accuracy (if it applies) | Data accuracy is within 800 meters over the 84 hour predicts;<br>Across maneuvers (orbit adjust or momentum unloads) accuracy is best available |
| Other pertinent details | Acquisition data are consistent with the predicted ephemeris data based upon the most recent tracking information<br>DSN requires user authentication to access the SPS web site. |

#### 4.1.3.2 Format

The format is the predicted SPICE SPK Transfer Format file; this format is consistent with the information listed at the following URL:

https://spsweb.fltops.jpl.nasa.gov

The file name conforms to the standard DSN-generated file name specifications and not the FDF concept as originally noted above. The file naming convention is defined as follows:

<File name>.<file extension>;

There is a period (.) used as the standard separator between the file name and file extension. The file name confirms to the following convention:

<Spacecraft Designator>_<SPK type>_<Duration>_<Start Date>_<version #>; the underscore (_) character is used as the separator between the file name qualifiers.

The table below provides the definitions for the file name and file extension qualifiers:

| | | | |
|---|---|---|---|
| where | Spacecraft Designator | = | [3 ASCII Digits]; defaults to 085 for LRO Designation |
| | SPK Type | = | [8 ASCII Characters]; default to the following SPK type:<br>baseline |
| | Duration | = | [5 ASCII Characters/Digits] in the form of nnday; where<br>nn = the file duration qualifier (01 – 99), followed by 3 ASCII character "day" |
| | Start Date | = | [8 ASCII Digits] in the form of yyyymmdd; where<br>yyyy = 4 ASCII digits for start year (2008 – 2013)<br>mm – 2 ASCII digits for start month (01 – 12)<br>dd = 2 ASCII digits for start day (01 -31) |
| | Version # | = | [2 ASCII Digits]; 01 to 99 |
| | File Extension | = | 3 ASCII Characters]; defaults to xsp to represent the SPK Transfer Format Type |

.

For example, a sample file name for the SPICE file (for the 10 day duration during the nominal mission phase of Thursday, January 15, 2009 at 0000Z) would have the following file name convention:
085_baseline_10day_20090115_01.xsp

Another reference for SPICE SPK data formats is:

http://naif.jpl.nasa.gov/naif

The SPICE ID for LRO is 125 (octal) or -85 (decimal). The SPK file will be type 13 with order of interpolation equal to 3. Since this product is a binary file, no sample product is listed in Appendix B.

### 4.1.4 (FDF-41) DSN Long-Term Scheduling Grade SPK Data

To maintain DSN mission readiness, FDF will provide a long-term "Scheduling-Grade" SPK Product to assist DSN in load planning and analysis efforts. The DSN Long-Term Scheduling Grade SPK Product has 6-month duration with no implied accuracy after the first 28 days since FDF does not model any maneuvers after the first 28-days. FDF generates this file using a numerical integration with a more accurately known and representable force model for the first 28 days. After that 28-day period, FDF still generates the file using a numerical integration technique, except that the force model is not as accurate.

#### 4.1.4.1 Product Details

| | |
|---|---|
| Time interval | Data samples provided at 10 minute increments |
| File duration | 6 months days of station acquisition data starting at 0000Z Thursday for nominal deliveries |
| File or Data Generation Frequency | Monthly, on the first Wednesday of the week, by noon-time, Eastern<br>After maneuvers within best-effort available |
| Delivery method (real-time, SCP, FTP, etc) | FDF accesses the DSN Deep Space Mission System (DSMS) Service Preparation System (SPS) web- portal and posts the data file and associated meta data |
| Data Volume | Approx 11 MBytes |
| Accuracy (if it applies) | Same accuracy as for the FDF05 product within the first 28 days<br>No implied accuracy after the first 28 days |
| Other pertinent details | DSN requires user authentication to access the SPS web site. |

#### 4.1.4.2 Format

The format is the predicted SPICE SPK Transfer Format file; this format is consistent with the information listed at the following URL:

https://spsweb.fltops.jpl.nasa.gov

The file name conforms to the standard DSN-generated file name specifications and not the FDF concept as originally noted above. This file has the following conventions.

<File name>_<version number>.<file extension>

where File Name = [29 Characters], which includes the field delimiters of either an underscore character (_); the following field definitions are used to define the fields
File Qualifier => 13 ASCII characters
3 ASCII Digits (followed by underscore), followed by 9 ASCII characters
= 085_baseline for LRO baseline SPICE Transfer SPK
Duration => 6 ASCII Digits and Characters
= nnnday; where nnn = number of days within the file; followed by the underscore (_) character.
Start Date => 8 ASCII Digits/Characters in the form of:
YYYYDDD; 7ASCII Digits used to represent the start date associated with the first station acquisition; followed by a 1 character underscore (_) character

version number = [2 characters] Two ASCII character version number. The initial version is 01, next is 02 … up to 99.

file extension = [3characters] .xsp, for the SPICE transfer format.

For example, a sample file name for the SPICE file (for the 180 day duration of Thursday, January 15, 2009 at 0000Z) would have the following file name convention:
085_baseline_180day_YYYYDDD_01.xsp

This file is only the nominal trajectory and not the plus/minus 3-sigma

Another reference for SPICE SPK data formats is:

http://naif.jpl.nasa.gov/naif

The SPICE ID for LRO is 125 (octal) or -85 (decimal). The SPK file will be type 13 with order of interpolation equal to 3. Since this product is a binary file, no sample product is listed in Appendix B.

### 4.1.5 (FDF-7) Laser Ranging Site Prediction Data

The laser ranging site prediction data describes the FDF-generated information used by the laser ranging site; it provides detailed information to point the laser accurately to the spacecraft and to put the laser pulses in the LOLA earth range window. This information provides times, position vectors, and other necessary information to allow the laser ranging site to locate the LRO spacecraft and begin the laser ranging functions.

#### 4.1.5.1 Product Details

| | |
|---|---|
| Time interval | Receiver position vector data samples provided at 1 minute increments |
| File duration | 10 days of Laser Site Prediction data starting 0000Z of the current day for normal updates<br>Post-maneuver updates will start at 00:00 GMT on the current day |
| File or Data Generation Frequency | Daily, by noon-time, Eastern<br>After maneuvers within best-effort available |
| Delivery method (real-time, SCP, FTP, etc) | FDF delivers product via the FDPC (MOC performs the scp pull)<br>MOC scp pushes to the LOLA SOC; who then forwards the file to the CDDIS repository |
| Data Volume | Approximately 1.2 MBytes |
| Accuracy (if it applies) | Data accuracy is within 800 meters over the 84 hour predicts;<br>Across maneuvers (orbit adjust or momentum unloads) accuracy is best available |
| Other pertinent details | Acquisition data are consistent with the predicted ephemeris data based upon the most recent tracking information.<br>This predictive compares are not applicable across spacecraft maneuvers |

#### 4.1.5.2 Format

The laser ranging site acquisition data format provides the required information for a laser ranging site to be able to perform laser ranging activities to the LRO spacecraft. The LRO Laser Ranging Prediction information is the LRO position vector (in meters) at the signal receive time computed based on a transmission from the geocenter, rotated to the International Terrestrial Reference Frame (ITRF) at the signal transmit time, and timetagged at the signal transmit time. This record is repeated at 1 minute intervals. The format is the Consolidated Laser Prediction Format, Version 1.02. It consists of the following header and data record fields:

***Table 4-3 FDF – Laser Ranging Prediction Data Description***

| Field name | Field Characteristics |
|---|---|
| Header type 1 | Many of these fields are standard, such as the record type (H1), CPF, format version, year, month, day, hour of ephemeris production. The ephemeris source will be "FDF". The target name representing LRO is TBD from the laser group, although "LRO" is suggested. The notes field will contain comments. |
| Header type 2 | Many of these fields are standard, such as IDs. The SIC ID for LRO is "0059". The target type will be "TBD". The other IDs will be assigned at successful separation from the launch vehicle. |
| Header type 3 | Not supplied. |
| Header type 4 | Not supplied. |
| Header type 5 | Not supplied. |
| Header type 9 | End of header trailer, will be supplied. |
| Record type 10-1 | Receiver position vector (X, Y, Z) in meters at the signal receive time computed based on a transmission from the geocenter, rotated to the ITRF frame at the signal transmit time, and timetagged at the signal transmit time. This record is repeated at 1 minute intervals for the duration of the ephemeris prediction period. |
| Records type 99 | Ephemeris trailer record. |

This file does not conform to the FDF-standard file name conventions; it conforms to the CDDIS-identified standard file name concepts.
The following table identifies the convention used for this file:

<Sat-ID>_<File Type>_<Start Date>_<version number>.<file source>

where

| | | | |
|---|---|---|---|
| where | Sat-ID | = | [3 ASCII Characters], which identifies the spacecraft;<br>default to lro (all lowercase) |
| | File Type | = | File Format => 3 ASCII Characters<br>default to cpf (all lowercase) |
| | Start Date | = | [6 ASCII Digits]; in the form of YYMMDD; where<br>YY = 2 digits of year (08 – 13)<br>MM = 2 digits for the month (01 – 12)<br>DD = 2 digits for the day (01 – 31) |
| | version number | = | [4 ASCII Digits], in the form of nnnv, which identifies the ephemeris version number and the version within a day.<br>nnn = day of year + 500 to distinguish CPFs from TIVs in time bias and other messages. The .500. can be dropped when TIVs are discontinued. This field is three digits with zero leading fill and<br>v = one ASCII digit for version number, the initial version is 1 |
| | file source | = | [3characters] .fdf, that indicates that this is an FDF generated file. |

A sample file name (for the 10 day duration of Thursday, January 15, 2009 at 0000Z through Sunday, January 25, 2009 at 0000Z) and corresponding for the first generation of this data file is given as lro_cpf_090125_5251.fdf

A sample Laser Ranging Site Prediction Data file is provided as a reference in Appendix B, Figure B.1-3.

### 4.1.6 (FDF-8) Space Network Acquisition Data

This product file contains the LRO spacecraft acquisition data for the Space Network's TDRSS support during the launch and early orbit phase prior to ground station contacts.

#### 4.1.6.1 Product Details

| | |
|---|---|
| Time interval | Data samples provided at 1 minute increments |
| File duration | Approximately 24 hours of data for the launch day |
| File or Data Generation Frequency | Delivered L-3 days and for any launch delays over 1 day |
| Delivery method (real-time, SCP, FTP, etc) | FDF delivers product to the WSC TDRSS Scheduling Office |
| Data Volume | FDF delivers IIRVs as independent vectors and as such, the data volume aspect is NA |
| Accuracy (if it applies) | best available for launch predict |
| Other pertinent details | FDF will provide the SN Acquisition Data only for the L&EO mission phase or for pre-launch tests with SN<br>SN support will be less than several hours in duration |

.

#### 4.1.6.2 Format

The SN acquisition data are formatted as an Improved InterRange Vector (IIRV) file in accordance with the STDN 724.

This product is generated on an as-needed basis to support either the mission tests/rehearsals or for the L&EO mission phase. The product contains approximately 2 hour of acquisition data for the TDRSS contact to support the L&EO mission phase (though it is likely that 24 hours of acquisition data will be sent).

The IIRV character layout is shown for reference in the following table.

### *Table 4-4 FDF – IIRV TTY SN Acquisition Data Description*

| Line | Character | Explanation |
|---|---|---|
| 1 | ---- | Optional text message. |
| 2 | GIIRV<br>A<br><br><br><br>rrrr | Start of message (fixed).<br>A Alphabetic character indicating originator of message:<br>ASCII space = GSFC Z = WLP<br>E = ETR L = JPL, W = WTR J = JSC, P = PMR A = CSTC, K = KMR C = CNES<br>rrrr Destination routing indicator. Specifies the site for which the message was generated. If for more than one station, this field should contain "MANY." |
| 3 | V<br><br><br><br>S<br><br><br>1<br><br>C<br><br><br><br><br><br><br><br>Sic (4 chars)<br>bb<br>nnn<br><br>doy<br>hhmmsssss<br><br>ccc | Vector type:<br>1 = Free flight (routine on-orbit), 2 = Forced (special orbit update)<br>3 = Spare, 4 = Maneuver ignition, 5 = Maneuver cutoff<br>6 = Reentry, 7 = Powered flight, 8 = Stationary, 9 = Spare<br>S = Source of data:<br>1 = Nominal/planning, 2 = Real-time, 3 = Off-line, 4 = Off-line/mean<br>NOTE: Nominal/planning sets cannot be sent to White Sands Ground Terminal (WSGT) from the NCC.<br>1 Fixed one (1)<br>C = Coordinate system:<br>1 = Geocentric True-of-Date Rotating<br>2 = Geocentric mean of 1950.0 (B1950.0).<br>3 = Heliocentric B1950.0.<br>4 = Reserved for JPL use (non-GSFC).<br>5 = Reserved for JPL use (non-GSFC).<br>6 = Geocentric mean of 2000.0 (J2000.0).<br>7 = Heliocentric J2000.0.<br>sic (4 chars) SIC<br>bb Body number/VID (01-99).<br>nnn Counter incremented for each vector in a set of vector data on a per-station per-transmission basis.<br>doy Day of year (001 = January 1).<br>hhmmsssss Vector epoch in UTC with resolution to nearest millisecond. (The implied decimal point is three places from the right).<br><br>ccc Checksum of the decimal equivalent of the preceding characters on Line 3:<br>0 through 9 = face value.; Minus (-) = 1; ASCII Space = 0. |
| 4 | S<br>xxxxxxxxxx<br>yyyyyyyyyy<br>zzzzzzzzzz<br><br>ccc | s Sign character: ASCII Space = positive or Minus sign = negative<br>xxxxxxxxxxxx = X component of position (meters)<br>yyyyyyyyyyyy = Y component of position (meters)<br>zzzzzzzzzzzz = Z component of position (meters)<br><br>ccc Checksum of the decimal equivalent of the preceding characters on Line 4:<br>0 through 9 = face value.; Minus (-) = 1; ASCII Space = 0. |

| Line | Character | Explanation |
|---|---|---|
| 5 | S<br>xxxxxxxxxxx<br>yyyyyyyyyyy<br>zzzzzzzzzz<br><br><br><br><br>ccc | s Sign character (same as above)<br>xxxxxxxxxxxxx · = X-component of velocity<br>yyyyyyyyyyyy ·= Y-component of velocity<br>zzzzzzzzzzzz ·= Z-component of velocity<br>NOTE:<br>All velocity components are in meters/second with resolution to the nearest millimeter/second. The implied decimal point is three places from the right.<br><br>ccc Checksum of the decimal equivalent of the preceding characters on Line 5:<br>0 through 9 = face value.; Minus (-) = 1; ASCII Space = 0. |
| 6 | mmmmmmmmmmm<br><br>aaaaa<br><br>kkkk<br><br>S<br><br>rrrrrr<br><br>ccc | Mass of spacecraft in kilograms with resolution to 1/10 of a kilogram. The implied decimal point is one place from the right. Contains all zeros when not used.<br><br>Average spacecraft cross-sectional area in square meters with resolution to the nearest hundredth of a square meter. The implied decimal point is two places from the right. Contains all zeros when not used.<br><br>Dimensionless drag coefficient. The implied decimal point is two places from the right. Contains all zeros when not used.<br><br>Sign character for coefficient of solar reflectivity<br>ASCII Space = positive or Minus Sign = negative<br><br>Dimensionless Solar Reflectivity coefficient. The implied decimal point is six places from the right. Contains all zeros when not used.<br><br>Checksum of the decimal equivalent of the preceding characters on Line 6:<br>0 through 9 = face value.; Minus (-) = 1; ASCII Space = 0. |
| 7 | oooo | ITERM End of message (fixed)<br>Originator routing indicator |

FDF delivers the IIRVs as independent vectors to the Data Services Management Center (DSMC) at White Sands using conventional FDF transmission protocols and not in a file concept; as such, there is no file naming convention to document.

Appendix B, Figure B.1-4 provides a sample IIRV as a reference.

### 4.1.7 (FDF-9) Ground Station View Period Predicts File

The Ground Station View Period Predict file contains specific data associated with the High Gain antenna and the data associated with the omni antenna.

FDF uses the different station elevation mask information to identify different station views for the Ka-Band antenna as compared for the S-Band antenna. FDF uses a 20 degree station mask for the Ka-Band and a 5 degree minimum elevation mask for the S-band antenna.

FDF uses a DSN masking of six (6) degrees for a horizon mask. FDF will generate actual station masking files as they receive the masking data from each of the sites.

#### 4.1.7.1 Product Details

| | |
|---|---|
| Time interval | Data samples provided at 1 minute increments |
| File duration | 28 days starting at 0000 Hours on Thursday<br>Post-maneuver updates will start at 00:00 GMT on the current day |
| File or Data Generation Frequency | Delivered weekly, on Wednesday by noon-time Eastern<br>After maneuvers within best-effort available |
| Delivery method (real-time, SCP, FTP, etc) | FDF initiates ftp to the WOTIS to transfer file<br>scp to LRO MOC via the FD Communications Server; the backup uses the FDPC (MOC performs the scp pull) |
| Data Volume | Variable; approximately 500 -700 Kbytes based on number of views per station and duration for each station view |
| Accuracy (if it applies) | The file contents should have accuracy over the 84-hours prediction, of less than 800 m in along-track error. |
| Other pertinent details | Station elevation masking information is unique for each station<br>Contains both HGA and Omni views for each available station |

#### 4.1.7.2 Format

This file contains the data associated with view periods for all supporting ground stations used to provide LRO with Tracking, Telemetry, & Command (TT&C) support during the various mission phases. It consists of the station identifier and the view period information for that station based on a fixed minimum elevation angle of 5 degrees.

The general format of this file consists of the following information:

1:N Header lines that provide the Station Name and date that FDF generated the file, and header lines that provide the field description; the file then contains N lines of data for each station view period.

The N lines of data contain the following fields:

Start Time Stop Time Duration Start Pass # Max Elev. Degrees Maximum Elevation Time; where these fields are defined in the following table:

### *Table 4-5 FDF – Ground Station View Period Data Description*

| Field name | Field Characteristics |
|---|---|
| Station name | 42 – 43 ASCII text characters representing the unique station identifier, with the following format:<br>Facility-NNNN-To-Satellite-0059-Sensor-TTTT; where<br>NNNN = WS1S for LRO White Sands S-band Station<br>WS1K for White Sands Ka-Band Station<br>STSS for SDO backup<br>STSK for the SDO backup Ka-Band<br>USPS for USN Dongara<br>USHS for USN South Point, Hawaii<br>KU1S (or KU2S) for Kiruna, Sweden<br>WU1S (or WU2S) for Wilheim, Germany<br>DS24 for the DSN 34-m at Goldstone, Ca<br>DS27 for the High-Speed Beam Wave Guide site at Goldstone, Ca,<br>DS34 for the DSN-34m at Canberra, Australia<br>D34K for the DSN 34m Ka-Band site at Canberra, Australia<br>DS45 for the High-Efficiency site at Canberra, Australia<br>DS54 for the DSN 34-m at Madrid, Spain<br>DS65 for the High- Efficiency site at Madrid, Spain<br>and TTTT can either be referenced as:<br>Omni – for the S-Band Omni View<br>HGA – for the High Gain Antenna S- or Ka-Band View. |
| Start time information:<br>year<br>day of year and<br>time of day | YYYYDDD.HHMMSS, where<br>YYYY => 4 ASCII digits of year (2008 – 2013)<br>DDD => 3 ASCII digits for day of year (1 – 366), followed by a period (.)<br>HHMMSS => 6 ASCII digits for the hours, minutes, and seconds of day |
| Stop time information:<br>year<br>day of year and<br>time of day | YYYYDDD.HHMMSS, where<br>YYYY => 4 ASCII digits of year (2008 – 2013)<br>DDD => 3 ASCII digits for day of year (1 – 366), followed by a period (.)<br>HHMMSS => 6 ASCII digits for the hours, minutes, and seconds of day |
| Station View Duration (in seconds) | SSSSS.mmm (9 ASCII digits), where<br>SSSSS => 5 ASCII characters representing the whole seconds; followed by a period(.)<br>mmm => 3 ASCII characters for the milliseconds of station contact |
| Pass Number | 7 ASCII characters representing a monotonically increasing Orbit Number (1 to 9999999)<br>NOTE: This field is only valid after lunar insertion; this field should be ignored prior to LOI |
| Max elevation angle | EE.ddd<br>EE => 2 ASCII digits for whole angle measurement (0 – 90)<br>dd => 3 ASCII digits for decimal portion of range (000 – 999) |

| Field name | Field Characteristics |
|---|---|
| Time of Maximum Elevation | YYYYDDD.HHMMSS, where<br>YYYY => 4 ASCII digits of year (2008 – 2013)<br>DDD => 3 ASCII digits for day of year (1 – 366), followed by a period (.)<br>HHMMSS => 6 ASCII digits for the hours, minutes, and seconds of day |

There will be certain instances in which the FDF-generated view period product does not contain valid view period information for a specific station because of the orbital geometry. In that event, FDF uses a different format that discussed in Table 4-5. In this event, the FDF-generated information conforms to the following format, as noted in Table 4-6

***Table 4-6 FDF – Ground Station No View Period Data Description***

| Field name | Field Characteristics |
|---|---|
| Station name | 42 – 43 ASCII text characters representing the unique station identifier, with the following format:<br>Facility-NNNN-To-Satellite-0059-Sensor-TTTT; where<br>NNNN = WS1S for LRO White Sands S-band Station<br>WS1K for White Sands Ka-Band Station<br>STSS for SDO backup<br>STSK for the SDO backup Ka-Band<br>USPS for USN Dongara<br>USHS for USN South Point, Hawaii<br>KU1S (or KU2S) for Kiruna, Sweden<br>WU1S (or WU2S) for Wilheim, Germany<br>DS24 for the DSN 34-m at Goldstone, Ca<br>DS27 for the High-Speed Beam Wave Guide site at Goldstone, Ca,<br>DS34 for the DSN-34m at Canberra, Australia<br>D34K for the DSN 34m Ka-Band site at Canberra, Australia<br>DS45 for the High-Efficiency site at Canberra, Australia<br>DS54 for the DSN 34-m at Madrid, Spain<br>DS65 for the High- Efficiency site at Madrid, Spain<br>and TTTT can either be referenced as:<br>Omni – for the S-Band Omni View<br>HGA – for the High Gain Antenna S- or Ka-Band View. |
| No Data Found Descriptor | 3 lines (Carriage returns terminate each line); the first 2 lines are blank lines the Third line has 15 ASCII Characters to indicate<br><br>No Access Found |

A sample file name for the first generation of the View Period data file is given as FDF9_ 2009015_2009043_N01.txt.

A sample Ground Station View Period Predict Data file is provided as a reference in Appendix B, Figure B.1-5. This sample product shows both instances that indicate view period data and no view period data for a station.

### 4.1.8 (FDF-3) LRO Beta Angle Predict File

The LRO Beta Angle Predict File provides the angle information between the LRO lunar orbit plane and the sun with the following definition. When the sun is in the orbit plane, this results in a zero degree (0°) angle. If the sun and orbit plane are perpendicular to each other; then this results in a beta angle of ninety degrees (90°). In this specific instance, the LRO spacecraft is in continuous full sun.

#### 4.1.8.1 Product Details

| | |
|---|---|
| Time interval | Data samples provided at 6 hour increments |
| File duration | 6 months, starts on the Wednesday at 0000Z<br>Post-maneuver updates will start at 00:00 GMT on the current day |
| File or Data Generation Frequency | Monthly, on the first Wednesday of the month, by noon-time, Eastern<br>After maneuvers within best-effort available |
| Delivery method (real-time, SCP, FTP, etc) | scp to LRO MOC via the FD Communications Server; the backup uses the FDPC (MOC performs the scp pull)<br>MOC “scp” push to SOCs |
| Data Volume | Approx 24 Kbytes |
| Accuracy (if it applies) | Data accuracy is within 800 meters over the 84 hour predicts;<br>Across maneuvers (orbit adjust or momentum unloads) accuracy is best available. No implied accuracy after the first 28 day predict |
| Other pertinent details | This product is consistent with the predicted ephemeris data based upon the most recent tracking information<br>This file is generated using a 3-body after a 28 day interval |

FDF will generate this file for all post-LOI mission phases.

#### 4.1.8.2 Format

The LRO Beta Angle Predict file is an ASCII-formatted file in which the fields are space delimited; the number of spaces between each data field is variable. The file contains the time of the sample, the Beta angle information (given in degrees and hundredths of degree) and the sun quadrant information that provides information as to whether the angle is increasing or decreasing. A positive Beta Angle correlates to the spacecraft oriented to a positive orbit normal reference frame. FDF does not guarantee any inherent accuracy for this data product after the first 28 days since it does not model any other maneuvers. FDF performs a numerical integration within the first 28 days of the data product; after the first 28 days of the files, FDF uses a 3-body point mass to model the predictions;

The file contains the time, beta angle, and quadrant information; the following table provides a brief description of each field:

*Table 4-7 FDF – LRO Beta Angle Data Description*

| Field name | Field Characteristics |
|---|---|
| Time information:<br>year<br>day of year and<br>time of day | YYYYDDD.HHMMSS. (GMT) 14 total ASCII Characters with a period between the first 7 and last six; where<br>YYYY => 4 ASCII digits of year (2008 – 2013)<br>DDD => 3 ASCII digits for day of year (1 – 366)<br>HHMMSS => 6 ASCII digits (hours, minutes, and seconds of day) |
| Beta Angle | SBB.bb => (degrees) 6 total ASCII characters with a period between the first 3 and last 2<br>the first character is a sign value (positive or negative angles)<br>a Blank = Positive Orbit Normal reference<br>- = Negative Orbit Normal reference<br>the next 2 are the whole decimal degrees of the beta angle<br>last 2 are the decimal portion of the Beta angle |
| Quadrant | N => 1 ASCII character that identifies the quadrant information related to the Beta Angle definition. Allowable values are: 1 – 4 inclusive |

A sample file name for the first generation of this data file is given as FDF03_2009015_2009195_N01.txt

A sample LRO Beta Angle File data file is provided as a reference in Appendix B, Figure B.1-6.

### 4.1.9 (FDF-4) LRO Definitive Ephemeris File

The LRO Definitive Ephemeris file contains the LRO spacecraft's position and velocity information in an inertial, mean J2000 coordinate reference frame. The coordinate frame will be Earth-centered for pre-LOI mission phases and moon-centered for post-LOI mission phases.

#### 4.1.9.1 Product Details

| | |
|---|---|
| Time interval | Data samples provided at 1 minute increments |
| File duration | Previous 24 hours (day basis) from 0000Z to 0000Z |
| File or Data Generation Frequency | Delivered daily by noon-time, Eastern |
| Delivery method (real-time, SCP, FTP, etc) | scp to LRO MOC via the FD Communications Server; the backup uses the FDPC (MOC performs the scp pull) |
| Data Volume | Approx 1200 Kbytes |
| Accuracy (if it applies) | Accurate to 500 meters |
| Other pertinent details | Ephemeris data are consistent with the predicted ephemeris data based upon the most recent tracking information |

#### 4.1.9.2 Format

The Definitive Ephemeris file is an ASCII-formatted file in which the fields are space delimited; the number of spaces between each data field is variable. The file contains the time of the sample, the X,Y, Z position information (given in Kilometers, or Km) and the X, Y, and Z velocity components (given in Kilometers per second, or Km/sec). The file entries are generated at one minute increments. The following table provides a brief description of each field:

***Table 4-8 FDF – LRO Definitive Ephemeris Data Description***

| Field name | Field Characteristics |
|---|---|
| Time information:<br>year<br>day of year and<br>time of day | YYYYDDD.HHMMSS (GMT), 14 total ASCII Characters with a period between the first 7 and last six; where<br>YYYY => 4 ASCII digits of year (2008 – 2013)<br>DDD => 3 ASCII digits for day of year (1 – 366)<br>HHMMSS => 6 ASCII digits (hours, minutes, and seconds of day) |
| X-Position | SRRRRRR.rrrrrr (Km) => 14 ASCII characters including the period between the first 6 and last 6<br>first signed 6 are the whole portions of the X-component of LRO's position*<br>last 6 are the decimal portion of the X-component position |
| Y-Position | SRRRRRR.rrrrrr (Km) => 14 ASCII characters including the period between the first 6 and last 6<br>first signed 6 are the whole portions of the Y-component of LRO's position*<br>last 6 are the decimal portion of the Y-component position |
| Z-Position | SRRRRRR.rrrrrr (Km) => 14 ASCII characters including the period between the first 6 and last 6<br>first signed 6 are the whole portions of the Z-component of LRO's position*<br>last 6 are the decimal portion of the Z-component position |
| X-Velocity | SRR.rrrrrr (km/sec) => 10 ASCII characters including the period between the first 3 and last 6<br>first signed 6 are the whole portions of the X-component of the LRO's velocity*<br>last 6 are the decimal portion of the X-component velocity |
| Y-Velocity | SRR.rrrrrr (km/sec) => 10 ASCII characters including the period between the first 3 and last 6<br>first signed 2 are the whole portions of the Y-component of the LRO's velocity*<br>last 6 are the decimal portion of the Y-component velocity |
| Z-Velocity (Km/s) | SRR.rrrrrr (km/sec) => 10 ASCII characters including the period between the first 3 and last 6<br>first signed 2 are the whole portions of the Z-component of the LRO's velocity*<br>last 6 are the decimal portion of the Z-component velocity |
| * - Field is actually a floating value so the value will vary significantly over the course of the mission. | |

A sample file name for the first generation of this data file is given as FDF04_2009015_2009022_N01.txt

A sample LRO Definitive Ephemeris File data file is provided as a reference in Appendix B, Figure B.1-7.

### 4.1.10 (FDF-29) LRO Definitive SPICE SPK File

This file contains the SPICE "kernel" information for the definitive LRO spacecraft ephemeris data. This kernel file contains the definitive LRO spacecraft position and velocity information for the previous day based only on the received S-Band tracking data. This product will be Earth-centered J2000 and Moon-centered J2000 following LOI (or as needed).

#### 4.1.10.1 Product Details

| | |
|---|---|
| Time interval | Data samples provided at 1 minute increments |
| File duration | Previous 24 hours (day basis) from 0000Z to 0000Z |
| File or Data Generation Frequency | Delivered daily by noon-time, Eastern |
| Delivery method (real-time, SCP, FTP, etc) | scp to LRO MOC via the FD Communications Server; the backup uses the FDPC (MOC performs the scp pull)<br>MOC "scp" push to SOCs |
| Data Volume | Approx .08 Mbytes |
| Accuracy (if it applies) | Accurate to less than 500 meters |
| Other pertinent details | Pre-LOI product is Earth-centered J2000<br>Post LOI product is Moon-centered J2000 |

#### 4.1.10.2 Format

The Definitive Spice file is a binary SPICE file and will require the use of the SPICE Toolkit, which can be accessed from the Navigation and Ancillary Information Facility (NAIF) web site. This web site is located at the following URL: http://naif.jpl.nasa.gov/naif/index.html

For example, a sample file name for the first generation of this data file for the previous day of January 8, 2009 is fdf29_2009008_2009009_n01.bsp (binary SPICE format).

The SPICE ID for LRO will be -85, as assigned by JPL.

The SPK file will be type 13 and interpolation order 11; since this is a binary file, no sample product is provided in Appendix B.

### 4.1.11 (FDF-30) LRO Predictive SPICE SPK File

This file contains the SPICE "kernel" information for the predictive LRO spacecraft ephemeris data. This kernel file contains the LRO spacecraft positions and velocity information based upon the processed tracking data. This file will contain the LRO Predictive ephemeris data; FDF can model any upcoming LRO station keeping maneuvers that are to occur in within this 28 day time period.

#### 4.1.11.1 Product Details

| | |
|---|---|
| Time interval | Data samples provided at 1 minute increments |
| File duration | Contains 28 days starting on 0000Z of the current day for nominal deliveries<br>Pre-LOI phase only contains a time span for pre-LOI (approx 4-5 days)<br>Post-LOI phase contains the remainder of the 28 day duration<br>Post-maneuver updates will start at 00:00 GMT on the current day |
| File or Data Generation Frequency | Daily, by noon-time, Eastern<br>After maneuvers within best-effort available |
| Delivery method (real-time, SCP, FTP, etc) | scp to LRO MOC via the FD Communications Server; the backup uses the FDPC (MOC performs the scp pull)<br>MOC "scp" push to SOCs |
| Data Volume | Approx 2 Mbytes |
| Accuracy (if it applies) | Over the 84-hours prediction, of less than 800 m in along-track error. Across maneuvers (orbit adjust or momentum unloads) accuracy is best available |
| Other pertinent details | The SPICE ID for LRO is -85, as assigned by JPL.<br>The SPK file will be type 13 and interpolation order 11; |

#### 4.1.11.2 Format

This product will be Earth-centered J2000 and Moon-centered J2000 following LOI (or as needed). The Predictive Spice file is a binary SPICE file and will require the use of the SPICE Toolkit, which can be accessed from the Navigation and Ancillary Information Facility (NAIF) web site. This web site is located at the following URL: http://naif.jpl.nasa.gov/naif/index.html

The SPICE ID for LRO is 125 (octal) or -85 (decimal). The SPK file will be type 13 with order of interpolation equal to 3.

A sample file name for the first generation of this data file is given as FDF30_2009015_2009043_N01.bsp for a binary file.

Since this is a binary formatted file, no sample product will be shown in Appendix B.

### 4.1.12 (FDF-13) Lunar Orbit Ascending and Descending Node Predicts

This file contains the lunar-nodal crossing predicts associated when the LRO orbit either crosses the ascending node or the descending node.

#### 4.1.12.1 Product Details

| | |
|---|---|
| Time interval | Data samples provided at 1 minute increments |
| File duration | Next 7 days starting at 0000Z of the current day<br>Post-maneuver updates will start at 00:00 GMT on the current day |
| File or Data Generation Frequency | Daily, by noon-time, Eastern<br>After maneuvers within best-effort available |
| Delivery method (real-time, SCP, FTP, etc) | scp to LRO MOC via the FD Communications Server; the backup uses the FDPC (MOC performs the scp pull)<br>MOC "scp" push to SOCs |
| Data Volume | Approximately 9 KBytes |
| Accuracy (if it applies) | Data accuracy is within 800 meters over the 84 hour predicts; Across maneuvers (orbit adjust or momentum unloads) accuracy is best available |
| Other pertinent details | Only created for post-LOI mission phases |

#### 4.1.12.2 Format

This is a file that contains 1-week's worth of nodal crossing predicts. The file is an ASCII text file in which the fields are separated by standard white space characters. The file contains 1:n lines of file header information followed by the nodal crossing time, the nodal crossing type, and the corresponding lunar longitude, and the orbit number; these fields are separated by tabs. The following table provides a brief description of each field:

***Table 4-9 FDF – LRO Ascending Descending Node Data Description***

| Field name | Field Characteristics |
|---|---|
| timetag information:<br>year<br>day of year and<br>time of day | YYYYDDD.HHMMSS (GMT), where<br>YYYY => 4 ASCII digits of year (2008 – 2013)<br>DDD => 3 ASCII digits for day of year (1 – 366) preceding a period<br>HHMMSS => 6 ASCII digits representing hours, minutes and seconds of day |
| Node Crossing Type | 1 Character ASCII flag to indicate if the type of nodal crossing<br>A => Ascending Node Crossing Type<br>D => Descending Node Crossing Type |
| Lunar Longitude | AAA.dd (degrees, East Longitude)<br>AAA => 3 ASCII digits for whole angle measurement (0 – 360)<br>dd => 2 ASCII digits for decimal portion of longitude angle (00 – 99)<br>The lunar longitude is consistent with the DE421 coordinate system |
| Lunar Orbit | 5 ASCII Characters to represent a monotonically increasing orbit number from 1 .. 99999. Orbit number increments at ascending node crossing beginning at lunar insertion<br>NOTE1: The orbit number is only provided at the Ascending Node Crossing time |

| Field name | Field Characteristics |
|---|---|
| Lighting Condition | 3-5 ASCII Characters that identify the lighting conditions, such as<br>= Day – LRO is in a daylight (sun lit) condition<br>= Night – LRO is in a nighttime (not sun lit) condition |

A sample file name for the first generation of this data file is given as FDF13_2009015_2009022_N01.txt

FDF will generate this product on a daily basis or after a maneuver has occurred. The product will contain 7 days of data.

A sample LRO Ascending Descending Node data product is provided as a reference in Appendix B, Figure B.1-8.

### 4.1.13 (FDF-14) Lunar Orbit Terminator Crossing Predicts

This is a file that contains lunar terminator crossing predicts associated when the LRO spacecraft crosses the lunar terminator line.

#### 4.1.13.1 Product Details

| | |
|---|---|
| Time interval | Data samples provided at 1 minute increments |
| File duration | Next 7 days starting at 0000Z of the current day<br>Post-maneuver updates will start at 00:00 GMT on the current day |
| File or Data Generation Frequency | Daily, by noon-time, Eastern<br>After maneuvers within best-effort available |
| Delivery method (real-time, SCP, FTP, etc) | scp to LRO MOC via the FD Communications Server; the backup uses the FDPC (MOC performs the scp pull)<br>MOC “scp” push to SOCs |
| Data Volume | Approximately 7 KBytes |
| Accuracy (if it applies) | Data accuracy is within 800 meters over the 84 hour predicts; Across maneuvers (orbit adjust or momentum unloads) accuracy is best available |
| Other pertinent details | Only created for post-LOI mission phases |

.

#### 4.1.13.2 Format

This is a file that contains 1-week’s worth of lunar terminator crossing predicts. The file is an ASCII text file in which the fields are separated by standard white space characters. The file contains the actual terminator crossing time and the corresponding terminator type; the following table provides a brief description of each data field:

***Table 4-10 FDF – LRO Lunar Orbit Terminator Crossing Predicts Data Description***

| Field name | Field Characteristics |
|---|---|
| time information:<br>year<br>day of year and<br>time of day | YYYYDDD.HHMMSS (GMT), where<br>YYYY => 4 ASCII digits of year (2008 – 2013)<br>DDD => 3 ASCII digits for day of year (1 – 366) preceding a period<br>HHMMSS => 6 ASCII digits representing hours, minutes and seconds of day |
| Lunar Terminator Type | 1 Character ASCII flag to indicate if the type of terminator crossing<br>N => Into Lunar night (going from Lunar day into night)<br>D => Into Lunar day (going from Lunar night into day ) |

A sample file name for the first generation of this data file is given as FDF14_2009015_2009022_N01.txt.

FDF will generate this product on a daily basis or after a maneuver has occurred. The product will contain 7 days of data.

A sample LRO Lunar Terminator Crossing data product is provided as a reference in Appendix B, Figure B.1-9.

### 4.1.14 (FDF-15) Mission Eclipse Predicts

This file contains the predictive information associated when the LRO spacecraft is put into a shadow resulting from either a lunar or Earth caused eclipse.

#### 4.1.14.1 Product Details

| | |
|---|---|
| Time interval | Data samples provided at 1 minute increments |
| File duration | Next 90 days starting at 0000Z on the Wednesday delivery day<br>Post-maneuver updates will start at 00:00 GMT on the current day |
| File or Data Generation Frequency | Weekly on Wednesday, by noon-time, Eastern<br>After maneuvers within best-effort available |
| Delivery method (real-time, SCP, FTP, etc) | scp to LRO MOC via the FD Communications Server; the backup uses the FDPC (MOC performs the scp pull)<br>MOC “scp” push to SOCs |
| Data Volume | Approximately 470 KBytes |
| Accuracy (if it applies) | Data accuracy is within 800 meters over the 84 hour predicts;<br>Across maneuvers (orbit adjust or momentum unloads) accuracy is best available |
| Other pertinent details | 3-body propagation after 28 days |

#### 4.1.14.2 Format

FDF generates this file as an ASCII-formatted file in which the fields are separated by standard white space characters. The format for this file can consist of 1:N lines that identify the mission eclipses that result in both a partial eclipse (LRO is flying in the penumbra shadow) and a full eclipse (LRO is flying in the umbra shadow). The umbra is always a subset of the penumbra phase and as such the start/stop times and durations will be contained within the penumbra. The usual configuration is that a penumbra is followed immediately by an umbra then a penumbra as LRO enters, transits, and exits the eclipse. The file has the following field information: Start Time, Stop Time, Shadow Flag, Duration, and Occultation Flag, and Total Duration; these fields are defined in the following table:

***Table 4-11 FDF – LRO Mission Eclipse Data Description***

| Field name | Field Characteristics |
|---|---|
| Start time information:<br>year<br>day of year and<br>time of day | YYYYDDD.HHMMSS (GMT) where<br>YYYY => 4 ASCII digits of year (2008 – 2013)<br>DDD => 3 ASCII digits for day of year (1 – 366) preceding period.<br>HHMMSS => 6 ASCII digits representing hours, minutes, and seconds of day |
| Stop time information:<br>year<br>day of year and<br>time of day | YYYYDDD.HHMMSS (GMT) where<br>YYYY => 4 ASCII digits of year (2008 – 2013)<br>DDD => 3 ASCII digits for day of year (1 – 366) preceding period.<br>HHMMSS => 6 ASCII digits representing hours, minutes, and seconds of day |
| Current Condition | Penumbra or Umbra |
| Duration of Current Condition | SSSSS.MM (seconds)<br>SSSSS => 5 ASCII digits for whole portion of seconds (0 – 99999)<br>MM => 2 ASCII digits for decimal portion of seconds (00 – 99) |
| Occultation | Occulting Body<br>Earth or Moon |
| Total Duration | Total duration of penumbra and umbra on current orbit (seconds)<br>SSSSS.MM<br>SSSSS => 5 ASCII digits for whole portion of seconds (0 – 99999)<br>MM => 2 ASCII digits for decimal portion of seconds (00 – 99) |

A sample file name for the first generation of this data file is given as FDF15_2009015_2009104_N01.txt.

A sample LRO Mission Eclipse data product is provided as a reference in Appendix B, Figure B.1-10.

### 4.1.15 <u>(FDF-16) Lunar Ephemeris</u>

This file contains the Lunar Ephemeris, which is used to update the on-board attitude/orbit flight software tables used by the Attitude Control System (ACS) FSW.

#### 4.1.15.1 Product Details

| | |
|---|---|
| Time interval | Data samples provided at 10 minute increments |
| File duration | Next 10 days beginning the current day |
| File or Data Generation Frequency | Daily, by noon-time, Eastern |
| Delivery method (real-time, SCP, FTP, etc) | scp to LRO MOC via the FD Communications Server; the backup uses the FDPC (MOC performs the scp pull) |
| Data Volume | Approximately 177 KBytes |
| Accuracy (if it applies) | Lunar position data are accurate to 100 meters. |
| Other pertinent details | The lunar ephemeris vectors will be in the Earth Centered Inertial (ECI) reference frame for all mission phases |

#### 4.1.15.2 Format

The format for this file is an ASCII Formatted file in which the fields are separated by standard white space characters. The file contains multiple lines that provide the ephemeris information for the moon's position and velocity. The file consists of the following field: Time, X- Position, Y- Position, Z- Position, X-Velocity, Y- Velocity, and Z- Velocity; where the fields are defined in the following table

***Table 4-12 FDF – Lunar Ephemeris Data Description***

| Field name | Field Characteristics |
|---|---|
| Time information:<br>year<br>day of year and<br>time of day | YYYYDDD.HHMMSS (GMT), 14 total ASCII Characters with a period between the first 7 and last six; where<br>YYYY => 4 ASCII digits of year (2008 – 2013)<br>DDD => 3 ASCII digits for day of year (1 – 366)<br>HHMMSS => 6 ASCII digits (hours, minutes, and seconds of day) |
| X-Position | SRRRRRR.rrrrrr (Km) => 14 ASCII characters including the period between the first 6 and last 6<br>Sign plus the first 6 are the whole portions of the X-component of moon's position*<br>last 6 are the decimal portion of the X-component position |
| Y-Position | SRRRRRR.rrrrrr (Km) => 14 ASCII characters including the period between the first 6 and last 6<br>Sign plus the first 6 are the whole portions of the X-component of moon's position*<br>last 6 are the decimal portion of the Y-component position |
| Z-Position | SRRRRRR.rrrrrr (Km) => 14 ASCII characters including the period between the first 6 and last 6<br>Sign plus the first 6 are the whole portions of the X-component of moon's position*<br>last 6 are the decimal portion of the Z-component position |

| Field name | Field Characteristics |
|---|---|
| X-Velocity | SRR.rrrrrr (km/sec) => 10 ASCII characters including the period between the first 3 and last 6<br>first signed 6 are the whole portions of the X-component of the LRO's velocity*<br>last 6 are the decimal portion of the X-component velocity |
| Y-Velocity | SRR.rrrrrr (km/sec) => 10 ASCII characters including the period between the first 3 and last 6<br>first signed 2 are the whole portions of the Y-component of the LRO's velocity*<br>last 6 are the decimal portion of the Y-component velocity |
| Z-Velocity (Km/s) | SRR.rrrrrr (km/sec) => 10 ASCII characters including the period between the first 3 and last 6<br>first signed 2 are the whole portions of the Z-component of the LRO's velocity*<br>last 6 are the decimal portion of the Z-component velocity |
| * - Field is actually a floating value so the value will vary significantly over the course of the mission. | |

A sample file name for the first generation of this data file is given as FDF16_2009015_2009024_N01.txt.

A sample of the Lunar Ephemeris data product is provided as a reference in Appendix B, Figure B.1-11.

### 4.1.16 (FDF-23) Orbiter State Vector Table

The LRO State Vector Table provides the predicted set of OD state information for the LRO spacecraft for the upcoming referenced time period, nominally 1-weeks of predicted OD state information. These data are used by the on-board computer to update its attitude flight SW system.

#### 4.1.16.1 Product Details

| | |
|---|---|
| Time interval | Data samples provided at 10 minute increments |
| File duration | Next 10 days starting the current day<br>Post-maneuver updates will start at 00:00 GMT on the current day |
| File or Data Generation Frequency | Daily, by noon-time, Eastern<br>After maneuvers within best-effort available |
| Delivery method (real-time, SCP, FTP, etc) | scp to LRO MOC via the FD Communications Server; the backup uses the FDPC (MOC performs the scp pull) |
| Data Volume | Approximately 177 KBytes |
| Accuracy (if it applies) | Data accuracy is within 800 meters over the 84 hour predicts; Across maneuvers (orbit adjust or momentum unloads) accuracy is best available |
| Other pertinent details | The product must be Earth Centered Inertial for all mission phases |

### 4.1.16.2 Format

The file is an ASCII formatted file that provides the State Vector data file in which the fields are space delimited; the number of spaces between each data field is variable. The table is a multi-line file that contains both meta-data and state vector data. The meta-data corresponds to when the report was generated, the start and stop times and other information related to the state vector generation. The file contains a reference time, and x-, y-, and z-position data and the corresponding x-, y-, and z-velocity data. The LRO position information is given in Kilometers (or Km), the LRO velocity components given in Kilometers per second, or Km/sec). The file entries are time centered every 10 minutes. The following table provides a brief description of each field:

***Table 4-13 FDF – LRO State Vector Table Data Description***

| Field name | Field Characteristics |
|---|---|
| time information:<br>year<br>day of year and<br>time of day | YYYYDDD.HHMMSS (GMT) where<br>YYYY => 4 ASCII digits of year (2008 – 2013)<br>DDD => 3 ASCII digits for day of year (1 – 366) preceding period.<br>HHMMSS => 6 ASCII digits representing hours, minutes, and seconds of day |
| X-Position | SRRRRRR.rrrrrr (km) => 14 ASCII characters including the period<br>first signed 6 are the whole number of X-position vector information (0-999999) *<br>last 6 are the degree decimal of the X-position (000000- 999999) |
| Y-Position | SRRRRRR.rrrrrr (km) => 14 ASCII characters including the period<br>first signed 6 are the whole degrees of Y-position vector information (0-999999)*<br>last 6 are the degree decimal of the Y-position (000000- 999999) |
| Z-Position | SRRRRRR.rrrrrr (km) => 14 ASCII characters including the period<br>first signed 6 are the whole degrees of Z-position vector information (0-999999)*<br>last 6 are the degree decimal of the Z-Position (000000- 999999) |
| X-Velocity | SRRRRRR.rrrrrr (km/sec) => 10 ASCII characters including the period between the first 6 and last 6<br>first signed 6 are the whole portions of the X-component of the LRO's velocity*<br>last 6 are the decimal portion of the X-component velocity |
| Y-Velocity | SRRRRRR.rrrrrr (km/sec) => 10 ASCII characters including the period between the first 6 and last 3<br>first signed 6 are the whole portions of the Y-component of the LRO's velocity*<br>last 6 are the decimal portion of the Y-component velocity |
| Z-Velocity | SRRRRRR.rrrrrr (km/sec) => 10 ASCII characters including the period between the first 6 and last 3<br>first signed 6 are the whole portions of the Z-component of the LRO's velocity*<br>last 6 are the decimal portion of the Z-component velocity |
| * - Value is actually floating point and will vary in length due to mission phase | |

A sample file name for the first generation of this data file is given as FDF23_2009015_2009024_N01.txt

A sample LRO State Vector Table is provided as a reference in Appendix B, Figure B.1-19.

### 4.1.17 (FDF-17) Orbiter Thruster Maneuver Plans

This file contains the data information for the upcoming LRO maneuver related to the required start thruster firing time, the thruster sequence, initial attitude, stop thruster firing time. This MOC uses this file to create the commands that are uploaded to the spacecraft that identify the proposed maneuver configuration – duration, thruster setup, start/stop times, just to name some of the data required to define the LRO maneuver.

#### 4.1.17.1 Product Details

| | |
|---|---|
| Time interval | NA |
| File duration | NA; covers the time interval associated with the set of planned maneuvers |
| File or Data Generation Frequency | Varies based on type of maneuver; data generation frequency is listed in the FDF-GS&O Operations Agreement (451-MOA-002960) |
| Delivery method (real-time, SCP, FTP, etc) | scp to LRO MOC via the FD Communications Server; the backup uses the FDPC (MOC performs the scp pull) |
| Data Volume | Approximately 5 Kbyte |
| Accuracy (if it applies) | The data accuracy is best-estimated since this is a predicted maneuver plan |
| Other pertinent details | Product is only applicable for upcoming maneuver |

#### 4.1.17.2 Format

This product consists of one file detailing the parameters required to characterize any LRO thruster maneuver..

The file is a multi-line ASCII file that provides the maneuver metadata, which includes the file creation time and the start and stop of the maneuver, the anticipated pre- and post-burn fuel used and spacecraft mass, the planned delta-V, duration, and planned fuel mass, and the maneuver configuration. The header data also contains other file references, such as the Orbiter Ephemeris and thruster plan data files, that the FD maneuver team used to create this Maneuver Plan.

The following figure provides an example of the fields within this “header area”:

```
Maneuver Plan

Plan Date (UTCG): 2008 141 15:31:20  Burn Start (UTCG): 2009 037 19:48:46  Pre-burn fuel mass (kg):   267.343  official
Maneuver:         SK01b              Burn Stop (UTCG):  2009 037 19:50:46  Post-burn fuel mass (kg):  263.505 estimated
Planned dV (m/s): 6.699              Duration (s):      119.331            Fuel mass used (kg):         3.838 estimated
                                                                           Average SC Mass (kg):     1270.050 estimated
Notes:                          LRO MOC SIM09 SK01b Planning
Ephemeris File Name:
Thrust Vector File Name:

Maneuver Configuration:          Bank      1           2
                                   NT      OFF         OFF               Prop Mode: PressureReg
                                  ACS      OFF         Off-Pulsed    ACS Stop Mode: dV
```

***Figure 4-1 FDF Maneuver Plan Header Concept***

The file then provides 15 lines for each of the planned initial thruster data and the planned final thruster data. Because this is the maneuver plan, the repeating group associated with the initial thruster data and the final thruster data have the identical values for the records.

The following figure provides the details related to the initial thruster configuration and expected performance.

Initial Thruster Data:

| | Bank | Press (Pa) | Temp (degC) | Calculated Isp (sec) | Calculated Thrust (N) | Thrust Efficiency | Effective Thrust (N) | Duty Cycle (%) |
|---|---|---|---|---|---|---|---|---|
| NT1 | 1 | 1861584.5 | 25.0 | | | | | |
| NT2 | 2 | 1861584.5 | 25.0 | | | | | |
| NT3 | 1 | 1861584.5 | 25.0 | | | | | |
| NT4 | 2 | 1861584.5 | 25.0 | | | | | |
| AT1 | 1 | 1861584.5 | 25.0 | | | | | |
| AT2 | 2 | 1861584.5 | 25.0 | 231.441 | 13.409 | 1.000000 | 13.409 | 58.600 |
| AT3 | 1 | 1861584.5 | 25.0 | | | | | |
| AT4 | 2 | 1861584.5 | 25.0 | 231.441 | 18.787 | 1.000000 | 18.787 | 82.100 |
| AT5 | 1 | 1861584.5 | 25.0 | | | | | |
| AT6 | 2 | 1861584.5 | 25.0 | 238.702 | 25.307 | 1.000000 | 25.307 | 100.000 |
| AT7 | 1 | 1861584.5 | 25.0 | | | | | |
| AT8 | 2 | 1861584.5 | 25.0 | 231.441 | 16.270 | 1.000000 | 16.270 | 71.100 |

***Figure 4-2 FDF Maneuver Plan Initial Thruster Data Concept***

The same 15 lines are repeated to identify the final thruster data. As note above, since this is the "planned" maneuver data, the initial and final data records and values are identical.

Final Thruster Data:

| | Bank | Press (Pa) | Temp (degC) | Calculated Isp (sec) | Calculated Thrust (N) | Thrust Efficiency | Effective Thrust (N) | Duty Cycle (%) |
|---|---|---|---|---|---|---|---|---|
| NT1 | 1 | 1861584.5 | 25.0 | | | | | |
| NT2 | 2 | 1861584.5 | 25.0 | | | | | |
| NT3 | 1 | 1861584.5 | 25.0 | | | | | |
| NT4 | 2 | 1861584.5 | 25.0 | | | | | |
| AT1 | 1 | 1861584.5 | 25.0 | | | | | |
| AT2 | 2 | 1861584.5 | 25.0 | 231.441 | 13.409 | 1.000000 | 13.409 | 58.600 |
| AT3 | 1 | 1861584.5 | 25.0 | | | | | |
| AT4 | 2 | 1861584.5 | 25.0 | 231.441 | 18.787 | 1.000000 | 18.787 | 82.100 |
| AT5 | 1 | 1861584.5 | 25.0 | | | | | |
| AT6 | 2 | 1861584.5 | 25.0 | 238.702 | 25.307 | 1.000000 | 25.307 | 100.000 |
| AT7 | 1 | 1861584.5 | 25.0 | | | | | |
| AT8 | 2 | 1861584.5 | 25.0 | 231.441 | 16.270 | 1.000000 | 16.270 | 71.100 |

***Figure 4-3 FDF Maneuver Plan Final Thruster Data Concept***

Each group of data consists of these entries, as defined by the following table:

| Field name | Field Characteristics |
|---|---|
| Thruster Bank Data | 4 ASCII Characters/Digits (separated by blanks) in the form of<br>NT1 1 or NT2 2<br>ATn 1 or ATn 2; where n = 1 through 8 inclusive |
| Bank Data | 1 ASCII Digits to identify which thruster bank is used for this maneuver; values are either 1 or 2 |
| Pressure (Pa) | 13 ASCII Digits in the form of:<br>PPPP.pppppppp, which corresponds to the whole and decimal portion for the tank pressure |
| Temperature (C) | 11 ASCII Digits in the form of:<br>TT.tttttttt, which corresponds to the whole and decimal portion for the tank temperature |
| Calculated ISP (sec) | 12 ASCII Digits in the form of:<br>NNN.nnnnnnnn, which corresponds to the whole and decimal portion for the maneuver thruster impulse |
| Calculated Thrust (N) | 10-11 ASCII Digits in the form of:<br>NN.nnnnnnnn, which corresponds to the whole and decimal portion for the thrust for each thruster bank |
| Thrust Efficiency (unitless) | 10 ASCII Digits in the form of:<br>N.nnnnnnnn, which corresponds to the whole and decimal portion for the thrust for each thruster bank (100 percent = 1.0000000 |
| Effective Thrust (N) | 10-11 ASCII Digits in the form of:<br>NN.nnnnnnnn, which corresponds to the whole and decimal portion for the thrust for each thruster bank<br>For this product, both the calculated thrust and the effective thrust are equal since this is the anticipated results of the maneuver |
| Duty Cycle (%) | 10-12 ASCII Digits in the form of:<br>NNN.nnnnnnnn, which corresponds to the whole and decimal portion for the duty cycle required by each thruster (max value is 100.00000000) |

This file does not conform to the FDF-standard file name conventions. The following table identifies the convention used for this file:

<File Name Qualifier>_<Maneuver Type>_<Start Date>_<Stop Date>_<version number>.<file extension>

where File Name Qualifier = [5 Characters], for file designator character followed by underscore (_) character; e.g., FDF17_

| | | |
|---|---|---|
| Maneuver Type | = | [4-5 Characters] for the type of planned maneuver in the form of<br>MCCn – Mid-course correction maneuver #n or<br>LOIn – Lunar Orbit Insertion maneuver #n<br>MOIn – Mission Orbit Insertion maneuver #n<br>SKnna – Station keeping maneuver #nn [either "a" or "b" as each station keeping maneuver will consist of 2 parts], for example SK01a, SK01b,<br>Additionally, the "n" for the MCC, LOI, MOI can have the suffix of "E" to represent that this is an engineering pre-burn to test the thrusters prior to the official maneuver |
| Start Date | = | [8 characters] Eight ASCII digit for the start date in the form of<br>YYYYDDD; where<br>YYYY = 4 ASCII Digits for start year<br>DDD = 3 ASCII Digits for start day of year;<br>followed by the underscore (_) character |
| Stop Date | = | [8 characters] Eight ASCII digit for the stop date in the form of<br>YYYYDDD; where<br>YYYY = 4 ASCII Digits for stop year<br>DDD = 3 ASCII Digits for stop day of year;<br>followed by the underscore (_) character |
| version number | = | [2 characters] Two ASCII digits for version number. The initial version is 01, next is 02 … up to 99; followed by the period (.) |
| file extension or source | = | [3characters] .txt, that indicates that this is a textual file that FDF generated. |

A sample file name for the first generation of the Orbiter Thruster Maneuver Plan file that corresponds to the first Lunar Orbit Insertion maneuver is given as FDF17_LOI1_2008307_2008308_01.txt

A sample of the Orbiter Thruster Maneuver Plan product is provided as a reference in Appendix B, Figure B.1-12.

### 4.1.18 (FDF-19) Orbiter Post Maneuver Report

This file contains the data generated to show a comparison of the predicted and actual performance and provides a calculation of the fuel used and an estimate of the remaining fuel available. FDF generates this report after the completion of each thruster maneuver.

This report provides a reconstruction at how well the spacecraft executed the maneuver. However, FDF may not have all available/required tracking data needed to create orbit solutions or have all of the available maneuver-related telemetry when FDF creates this report.

### 4.1.18.1 Product Details

| | |
|---|---|
| Time interval | NA |
| File duration | NA |
| File or Data Generation Frequency | At the completion of each identified thruster maneuver within best available time; data generation frequency is listed in the FDF-GS&O Operations Agreement (451-MOA-002960) |
| Delivery method (real-time, SCP, FTP, etc) | scp to LRO MOC via the FD Communications Server; the backup uses the FDPC (MOC performs the scp pull)<br>MOC scp pushes the file to the LOLA SOC |
| Data Volume | Approximately 5 Kbyte |
| Accuracy (if it applies) | The data accuracy is best-estimated since this maneuver plan report may be generated without the complete set of required products or the most up-to-date products |
| Other pertinent details | Product is only applicable after maneuvers |

### 4.1.18.2 Format

The report is an ASCII formatted file in which the fields are space delimited; the number of spaces between each data field is variable. The report provides the thruster profile and compares the planned versus actual thruster information, the fuel used and the remaining on-board fuel, and the estimated and actual spacecraft mass following the thruster maneuver.

This file contains the exact same information as defined for the FDF-17 (Thruster Maneuver Plan) as listed in 4.1.17.2. However, for this data product, the report provides the actual spacecraft and thruster data associated with the completion of the maneuver as well as the original, planned maneuver spacecraft and thruster maneuver data.

Since the data format is identical to the FDF-17 product, the format is not repeated.

This file does not conform to the FDF-standard file name conventions. The following table identifies the convention used for this file:

<File Name Qualifier>_<Maneuver Type>_<Start Date>_<Stop Date>_<version number>.<file extension>

| | | | |
|---|---|---|---|
| where | File Name Qualifier | = | [5 Characters], for file designator character followed by underscore (_) character; e.g., FDF19_ |

| | | |
|---|---|---|
| Maneuver Type | = | [4-5 Characters] for the type of planned maneuver in the form of<br>MCCn – Mid-course correction maneuver #n<br>LOIn – Lunar Orbit Insertion maneuver #n<br>MOIn – Mission Orbit Insertion maneuver #n<br>SKnna – Station keeping maneuver #nn [either “a“ or “b” as each station keeping maneuver will consist of 2 parts], for example SK01a, SK01b,<br>Additionally, the “n” for the MCC, LOI, MOI can have the suffix of “E” to represent that this is an engineering pre-burn to test the thrusters prior to the official maneuver |
| Start Date | = | [8 characters] Eight ASCII digit for the start date in the form of<br>YYYYDDD; where<br>YYYY = 4 ASCII Digits for start year<br>DDD = 3 ASCII Digits for start day of year;<br>followed by the underscore (_) character |
| Stop Date | = | [8 characters] Eight ASCII digit for the stop date in the form of<br>YYYYDDD; where<br>YYYY = 4 ASCII Digits for stop year<br>DDD = 3 ASCII Digits for stop day of year;<br>followed by the underscore (_) character |
| version number | = | [2 characters] Two ASCII digits for version number. The initial version is 01, next is 02 … up to 99; followed by the period (.) |
| file extension or source | = | [3characters] .txt, that indicates that this is a textual file that FDF generated. |

A sample file name for the first generation of the Orbiter Post-Maneuver Report file that corresponds to a Lunar Orbit Insertion maneuver is given as FDF19_LOI1_2008307_2008308_01.txt

A sample of the Orbiter Post Maneuver Report product is provided as a reference in Appendix B, Figure B.1-13.

#### 4.1.19 (FDF-18) Post Separation Report

This report provides a comparison of the launch separation vector that the launch vehicle support team reports against the launch separation vector that FDF calculates based on the updated launch information.

The report compares the time-slipped nominal separation vector (or if available the FDF-determined separation vector from inertial guidance telemetry or radar data) versus the EELV-vendor supplied actual separation vector.

#### 4.1.19.1 Product Details

| | |
|---|---|
| Time interval | NA |
| File duration | NA |
| File or Data Generation Frequency | Best effort immediately following the launch vehicle separation<br>With nominal (within 3 sigma separation), report is created within 1 hour |
| Delivery method (real-time, SCP, FTP, etc) | scp to LRO MOC via the FD Communications Server; the backup uses the FDPC (MOC performs the scp pull) |
| Data Volume | Approximately 1 KBytes |
| Accuracy (if it applies) | The accuracy will be to the best available from the data |
| Other pertinent details | Product is only applicable after Orbiter separation from launch vehicle |

#### 4.1.19.2 Format

The report is an ASCII formatted file in which the fields are space delimited; the number of spaces between each data field is variable. The report fields provide the comparison between the reported launch vehicle separation vector and the FDF-calculated launch vehicle separation vector (updated to reflect the actual launch epoch). The report is a multi-line file, which contains the two original vectors (and their magnitudes) and then the position and velocity magnitudes of the differences. This information is identified in the following table:

***Table 4-14 FDF – LRO Post Separation Report Data Description Information***

| Report Section | Data Fields |
|---|---|
| Section 1 | Epoch and Vectors of Actual Separation State<br>X (km) Y (km) Z (km) DX (km/sec) DY (km/sec) DZ (km/sec)<br>SMA (km) ECC INC (deg) RAAN (deg) AP (deg) TA (deg) |
| Section 2 | Epoch and Vectors of Nominal Separation State<br>X (km) Y (km) Z (km) DX (km/sec) DY (km/sec) DZ (km/sec)<br>SMA (km) ECC INC (deg) RAAN (deg) AP (deg) TA (deg) |
| Section 3 | Comparison fields<br>Date/Time Range 1 (km) Range 2 (km) Radial (km) Cross-track (km)<br>Along-Track (km)<br>Total Delta-R (km) True Anomaly (deg) |
| Section 4 | Summary of Comparisons<br>Minimum Position Differences by Component and Total<br>Maximum Position Differences by Component and Total<br>Minimum Velocity Differences by Component and Total<br>Maximum Velocity Differences by Component and Total<br>Position RMS by Component and Total<br>Velocity RMS by Component and Total |

A sample file name for the first generation of this data file (for a launch date of 28 October 2008) is given as FDF18_2008302_2008302_B01.txt

A sample of the Post Separation Report product is provided as a reference in Appendix B, Figure B.1-15.

### 4.1.20 <u>(FDF-20) Predicted LRO Ephemeris File</u>

This file contains predictive LRO ephemeris data for the spacecraft position and velocity information centered at one minute increments. The file is generated in an inertial, mean Earth-Centered J2000 coordinate reference frame. This file is only used internally by the MOC-AGS element

#### 4.1.20.1 Product Details

| | |
|---|---|
| Time interval | Data samples provided at 1 minute increments |
| File duration | Next 10 days starting on the current day<br>Post-maneuver updates will start at 00:00 GMT on the current day |
| File or Data Generation Frequency | Daily, by noon-time, Eastern<br>After maneuvers within best-effort available |
| Delivery method (real-time, SCP, FTP, etc) | scp to LRO MOC via the FD Communications Server; the backup uses the FDPC (MOC performs the scp pull) |
| Data Volume | Approx 1.7 Mbytes |

| | |
|---|---|
| Accuracy (if it applies) | accuracy over the 84-hours prediction, of less than 800 m in along-track error. Across maneuvers (orbit adjust or momentum unloads) accuracy is best available |
| Other pertinent details | Product is always Earth-centered J2000 and only used by AGS element |

#### 4.1.20.2 Format

The Predictive LRO Ephemeris file is an ASCII-formatted file in which the fields are space delimited; the number of spaces between each data field is variable. The file contains the time of the sample, the X,Y, Z position information (given in Kilometers, or Km) and the X, Y, and Z velocity components (given in Kilometers per second, or Km/sec). The file entries are generated at five minute increments. The following table provides a brief description of each field:

***Table 4-15 FDF – LRO Predictive Ephemeris Data Description Information***

| Field name | Field Characteristics |
|---|---|
| time information:<br>year<br>day of year and<br>time of day | YYYYDDD.HHMMSS (GMT) where<br>YYYY => 4 ASCII digits of year (2008 – 2013)<br>DDD => 3 ASCII digits for day of year (1 – 366) preceding period.<br>HHMMSS => 6 ASCII digits representing hours, minutes, and seconds of day |
| X-Position | SRRRRRR.rrrrrr (km) => 14 ASCII characters including the period<br>Signed first 6 whole portions of the X-component of LRO's position*<br>last 6 are the decimal portion of the X-component position |
| Y-Position | SRRRRRR.rrrrrr (km) => 14 ASCII characters including the period<br>Signed first 6 are the whole portions of the Y-component of the LRO's position*<br>last 6 are the decimal portion of the Y-component position |
| Z-Position | SRRRRRR.rrrrrr (km) => 14 ASCII characters including the period<br>Signed first 6 are the whole portions of the Z-component of the LRO's position*<br>last 6 are the decimal portion of the Z-component position |
| X-Velocity | SRRRRRR.rrrrrr (km/sec) => 14 ASCII characters including the period<br>Signed first 6 are the whole portions of the X-component of the LRO's velocity*<br>last 6 are the decimal portion of the X-component velocity |
| Y-Velocity | SRRRRRR.rrrrrr (km/sec) => 14 ASCII characters including the period<br>Signed first 6 are the whole portions of the Y-component of the LRO's velocity *<br>last 3 are the decimal portion of the Y-component velocity |
| Z-Velocity | SRRRRRR.rrrrrr (km/sec) => 14 ASCII characters including the period<br>Signed first 6 are the whole portions of the Z-component of the LRO's velocity*<br>last 6 are the decimal portion of the Z-component velocity |
| * - Signed whole number is floating point and could be from 1 to 7 characters for LRO | |

A sample file name for the first generation of this data file is given as FDF20_2009015_2009022_N01.txt

A sample Predictive LRO Ephemeris File data file is provided as a reference in Appendix B, Figure B.1-16.

### 4.1.21 (FDF-21) Predicted Lunar Ground Track File

This file contains the predictive LRO ground track against the lunar surface. The Predicted Lunar Ground Track provided this information in the principal axis (PA) reference frame.

#### 4.1.21.1 Product Details

| | |
|---|---|
| Time interval | Data samples provided at 1 minute increments |
| File duration | Next 7 days starting on the current day<br>Post-maneuver updates will start at 00:00 GMT on the current day |
| File or Data Generation Frequency | Daily, by noon-time, Eastern<br>After maneuvers within best-effort available |
| Delivery method (real-time, SCP, FTP, etc) | scp to LRO MOC via the FD Communications Server; the backup uses the FDPC (MOC performs the scp pull)<br>MOC “scp” push to SOCs |
| Data Volume | Approx 887 Kbytes |
| Accuracy (if it applies) | Data accuracy is within 800 meters over the 84 hour predicts; Across maneuvers (orbit adjust or momentum unloads) accuracy is best available |
| Other pertinent details | Generated for post-LOI mission phases only |

#### 4.1.21.2 Format

The Predictive Lunar Ground Track file is an ASCII-formatted file in which the fields are separated by spaces. The file contains the time of the sample, the lunar Longitude and Latitude position, the LRO altitude, and ground track velocity every 60 seconds. The longitude and latitude information is based on the DE421 reference frame. The LRO altitude is given in Kilometers (Km), the LRO ground track velocity magnitude given in Kilometers per second, (Km/sec). The file entries are generated at one minute increments. The following table provides a brief description of each field:

***Table 4-16 FDF – LRO Predicted Ephemeris Data Description Information***

| Field name | Field Characteristics |
|---|---|
| Time information:<br>year<br>day of year and<br>time of day | YYYYDDD.HHMMSS (GMT) where<br>YYYY => 4 ASCII digits of year (2008 – 2013)<br>DDD => 3 ASCII digits for day of year (1 – 366) preceding period.<br>HHMMSS => 6 ASCII digits representing hours, minutes, and seconds of day |
| Lunar Longitude | RRR.rrr (degrees) => 7 ASCII characters including the period between the first 3 and last 3<br>first 3 are the whole degrees of Longitude East (0- 360)<br>last 3 are the degree decimal of Longitude (000- 999) |
| Lunar Latitude | SRR.rrr (degrees) => 6 ASCII characters including the period between the first 3 and last 3<br>first character is the sign (blank = Northern Lats; - = Southern Lats)<br>next 2 are the whole degrees of Latitude (0- 90)<br>last 3 are the degree decimal of Latitude (000- 999) |
| LRO Altitude | RRR.rrr (km) => 7 ASCII characters including the period between the first 3 and last 3<br>first 3 are the whole portions of the LRO's altitude in floating point (expected values for LRO are 000 – 999 km)<br>last 3 are the decimal portion of the LRO's altitude (in hundredths of Km, 000 – 999) |
| Ground Track-Velocity Magnitude | SRRRRRR.rrr (km/sec) => 10 ASCII characters including the period between the first 6 and last 3<br>first 6 are the whole portions of the X-component of the LRO's velocity (floating point value, expected value for LRO is single digit)<br>last 3 are the decimal portion of the X-component velocity |

A sample file name for the first generation of this data file is given as FDF21_2009015_2009022_N01.txt

A sample LRO Predictive Lunar Ground Track File is provided as a reference in Appendix B, Figure B.1-17.

### 4.1.22 <u>(FDF-22) Definitive Lunar Ground Track File</u>

This file contains the definitive LRO ground track against the lunar surface based on the most recent definitive ephemeris. The Definitive Lunar Ground Track file provides this information in the PA reference frame.

#### 4.1.22.1 Product Details

| | |
|---|---|
| Time interval | Data samples provided at 1 minute increments |
| File duration | Previous 24 hours 0000Z previous day to 0000Z current day |
| File or Data Generation Frequency | Daily, by noon-time, Eastern<br>After maneuvers within best-effort available |
| Delivery method (real-time, SCP, FTP, etc) | scp to LRO MOC via the FD Communications Server; the backup uses the FDPC (MOC performs the scp pull)<br>MOC "scp" push to SOCs |
| Data Volume | Approx 127 Kbytes |
| Accuracy (if it applies) | Data accuracy is within 500 meters over the def product timespan |
| Other pertinent details | Generated for post-LOI mission phases only |

#### 4.1.22.2 Format

The Definitive Lunar Ground Track file is an ASCII-formatted file in which the fields are separated by standard white space characters. The file contains the time of the sample, the lunar Longitude and Latitude position, the LRO altitude, and ground track velocity every 60 seconds. The longitude and latitude information is based on the DE421 reference frame. The LRO altitude is given in Kilometers (Km), the LRO ground track velocity magnitude given in Kilometers per second, (Km/sec). The file entries are generated at one minute increments. The following table provides a brief description of each field:

***Table 4-17 FDF – LRO Definitive Lunar Ground Track Description Information***

| Field name | Field Characteristics |
|---|---|
| time information:<br>year<br>day of year and<br>time of day | YYYYDDD.HHMMSS (GMT) where<br>YYYY => 4 ASCII digits of year (2008 – 2013)<br>DDD => 3 ASCII digits for day of year (1 – 366) preceding period.<br>HHMMSS => 6 ASCII digits representing hours, minutes, and seconds of day |
| Lunar Longitude | RRR.rrr (degrees) => 7 ASCII characters including the period between the first 3 and last 3<br>first 3 are the whole degrees of Longitude East (0- 360)<br>last 3 are the degree decimal of Longitude (000- 999) |
| Lunar Latitude | SRR.rrr (degrees) => 7 ASCII characters including the period between the first 3 and last 3<br>first character is the sign (blank = Northern Lats; - = Southern Lats)<br>next 2 are the whole degrees of Latitude (0- 90)<br>last 3 are the degree decimal of Latitude (000- 999) |

| | |
|---|---|
| LRO Altitude | RRR.rrr (km) => 7 ASCII characters including the period between the first 3 and last 3<br>first 3 are the whole portions of the LRO's altitude in floating point (in Km, 000 – 999)<br>last 3 are the decimal portion of the LRO's altitude (in hundredths of Km, 000 – 999) |
| Ground Track Velocity Magnitude | SRRRRRR.rrr (km/sec) => 11 ASCII characters including the period between the first 6 and last 3<br>first signed 6 are the whole portions of the X-component of the LRO's velocity in floating point (value will typically be 1.6)<br>last 3 are the decimal portion of the X-component velocity |

A sample file name for the first generation of this data file is given as FDF22_2009014_2009015_N01.txt

A sample Definitive Lunar Ground Track File is provided as a reference in Appendix B, Figure B.1-18.

#### 4.1.23 (FDF-25) Thruster Calibration Data

This is a report that includes updated parameters for the thruster calibration based on all available information received about past maneuvers. This is an informational report that provides the Post-Maneuver Calibration. It provides the final assessment of how well the maneuver was executed and it uses best pre-maneuver and post-maneuver orbit solutions, and telemetry (pressures, duty cycles, & attitude) to determine a thrust scale factor that can be used to plan future maneuvers (as long as they use the same thruster set NT x AT).

##### 4.1.23.1 Product Details

| | |
|---|---|
| Time interval | NA |
| File duration | NA |
| File or Data Generation Frequency | At the completion of each identified thruster maneuver; data generation frequency is listed in the FDF-GS&O Operations Agreement (451-MOA-002960) |
| Delivery method (real-time, SCP, FTP, etc) | scp to LRO MOC via the FD Communications Server; the backup uses the FDPC (MOC performs the scp pull) |
| Data Volume | Approximately 5 Kbyte |
| Accuracy (if it applies) | NA |
| Other pertinent details | NA |

### 4.1.23.2 Format

This file contains identical types of information as defined for the FDF-17 (Thruster Maneuver Plan) and the FDF-19 (Orbiter Post Maneuver Report) and follows the similar format as noted for those products. The format and content are listed in Section 4.1.17.2.

However, for this data product, the report provides the actual spacecraft and thruster data associated with the completion of the maneuver as well as the original, planned maneuver spacecraft and thruster maneuver data. Since the data format is identical to the FDF-17 product, the format is not repeated.

This file does not conform to the FDF-standard file name conventions. The following table identifies the convention used for this file:

<File Name Qualifier>_<Maneuver Type>_<Start Date>_<Stop Date>_<version number>.<file extension>

| | | | |
|---|---|---|---|
| where | File Name Qualifier | = | [5 Characters], for file designator character followed by underscore (_) character; e.g., FDF25_ |
| | Maneuver Type | = | [4-5 Characters] for the type of planned maneuver in the form of<br>MCCn – Mid-course correction maneuver #n<br>LOIn – Lunar Orbit Insertion maneuver #n<br>MOIn – Mission Orbit Insertion maneuver #n<br>SKnna – Station keeping maneuver #nn [either "a" or "b" as each station keeping maneuver will consist of 2 parts], for example SK01a, SK01b,<br>Additionally, the "n" for the MCC, LOI, MOI can have the suffix of "E" to represent that this is an engineering pre-burn to test the thrusters prior to the official maneuver |
| | Start Date | = | [8 characters] Eight ASCII digit for the start date in the form of<br>YYYYDDD; where<br>YYYY = 4 ASCII Digits for start year<br>DDD = 3 ASCII Digits for start day of year;<br>followed by the underscore (_) character |
| | Stop Date | = | [8 characters] Eight ASCII digit for the stop date in the form of<br>YYYYDDD; where<br>YYYY = 4 ASCII Digits for stop year<br>DDD = 3 ASCII Digits for stop day of year;<br>followed by the underscore (_) character |
| | version number | = | [2 characters] Two ASCII digits for version number. The initial version is 01, next is 02 … up to 99; followed by the period (.) |
| | file extension or source | = | [3characters] .txt, that indicates that this is a textual file that FDF generated. |

A sample file name for the first generation of the Thruster Calibration Data file that corresponds to the first Mission Orbit Insertion maneuver is given as FDF25_MOI1_2009015_2009016_01.txt

A sample Thruster Calibration Data File is provided as a reference in Appendix B, Figure B.1-20

#### 4.1.24 (FDF-36) FDF Reprocessed SPICE Definitive Ephemeris Data SPK

The FDF Reprocessed SPICE Definitive ephemeris data SPK file provides the LRO ephemeris based upon a DE421 reference frame. FDF creates this product using the LRO OD reprocessing results which will include both laser tracking measurements and LOLA OD and Improved gravity model products.

This reprocessed SPICE transfer format SPK file is based upon both S-band and laser tracking. Since FDF generates a 55-hour solution arcs for the LRO orbit determination (with 7-hr overlap periods), ephemeris data will be generated in 48-hr non-contiguous segments. This product will only be generated in post-processing using the laser data, not for day-to-day navigation support of the mission. The MOC sends this product to the NAIF/PDS for permanent archival.

This product is based on a Moon-centered J2000 based on the ME reference frame.

#### 4.1.24.1 Product Details

| | |
|---|---|
| Time interval | Data samples provided at 1 minute increments |
| File duration | Weekly files |
| File or Data Generation Frequency | Generated twice during the mission after it receives the LOLA Improved Gravity Model, which occurs twice during the mission.<br>FDF generates the files approximately 2 months after receipt of the LOLA Improved Gravity Model |
| Delivery method (real-time, SCP, FTP, etc) | scp to LRO MOC via the FD Communications Server; the backup uses the FDPC (MOC performs the scp pull)<br>MOC “scp” push to SOCs |
| Data Volume | Approximately .5 MBytes |
| Accuracy (if it applies) | Data accuracy is within 500 meters over the definitive product timespan |
| Other pertinent details | Only generated for post-LOI mission phases |

#### 4.1.24.2 Format

The FDF Reprocessed SPICE Definitive SPK file is a binary formatted file generated by the SPICE Toolset. The SPICE ID for LRO is -85, as assigned by JPL. The format of this file is consistent with the other FDF-generated SPK files for ephemeris data.

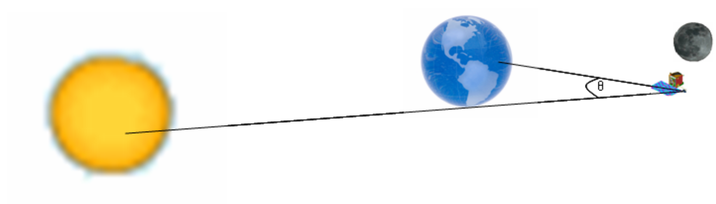
A sample file name for the first generation of this data file is given as fdf36_2009015_2009022_n01.bsp for a binary file. The product will include all definitive portions of the mission since LOI. SPK file will be type 13 and interpolation order 11; since this is a binary formatted file, no sample product will be shown in Appendix B.

### 4.1.25 (FDF-37) FDF Solar Conjunction File

The Solar conjunction File contains the periods whenever the sun, Orbiter and earth align such that the sun will cause radio frequency interference. In these instances, there will be solar Radio Frequency interference (RFI) that affects the scheduled station contact. The following table provides a quick reference to the Solar Conjunction Type and the corresponding geometry. Figure 4-1 provides the geometry for the two solar conjunction types.

| SC Type | Affected Communication | Geometry |
|---|---|---|
| Type 1 | Uplink | Sun position "inline with the earth to Orbiter vector"<br>Reported when angle between facility and SUN is less than 3° (three degrees) |
| Type 2 | Downlink | Sun position "inline with the orbiter to earth vector"<br>Reported when angle between LRO and SUN is less than facility defined angle for each station |

Solar Conjunction – Type 1 (Uplink RFI)




Solar Conjunction – Type 2 (Downlink RFI)

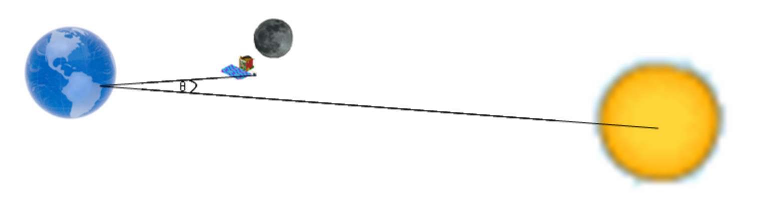



*Figure 4-4 Solar Conjunction Geometry Examples*

The solar conjunction predictions will contain all upcoming conjunctions on both the uplink and the downlink within the product span. For many of the deliveries, no solar conjunctions may be present during the product span. If there are no times of solar conjunction, the file will only contain the initial file header information (date generation information and header line).

#### 4.1.25.1 Product Details

| | |
|---|---|
| Time interval | Data samples provided at 1 minute increments |
| File duration | next 28 days starting at 0000Z on the current generation day<br>Post-maneuver updates will start at 00:00 GMT on the current day |
| File or Data Generation Frequency | Weekly, on Wednesday, by noon-time, Eastern<br>After maneuvers within best-effort available |
| Delivery method (real-time, SCP, FTP, etc) | scp to LRO MOC via the FD Communications Server; the backup uses the FDPC (MOC performs the scp pull) |
| Data Volume | Approx 10 Kbytes; variable based on whether there are any Solar Conjunctions for the requested time period |
| Accuracy (if it applies) | Data accuracy is within 800 meters over the 84 hour predicts; Across maneuvers (orbit adjust or momentum unloads) accuracy is best available |
| Other pertinent details | Only generated for post-LOI mission phases<br>if there are no periods of solar RFI, the file only contains the base header information for each station |

#### 4.1.25.2 Format

The solar Conjunction File is an ASCII text formatted file in which the fields are separated by a variable number of blanks. The solar conjunction file will contain the start time, stop time and a flag to indicate what type of solar conjunction (e.g., Type 1 or Type 2 as an example). The file contains 3-4 lines of header details that identify the file generation information and the file contents. There are 3-4 more lines that provide the format details for the following data fields. After these lines, the file consists of 1:N lines of solar conjunction information.

The following table provides a description of the fields within the file.

***Table 4-18 FDF – Solar Conjunction Data Description***

| Field name | Field Characteristics |
|---|---|
| Station name | 4 ASCII text characters representing the unique station identifier, with the following format:<br>NNNN ; where<br>NNNN = WS1S for LRO White Sands S-band Station<br>WS1K for White Sands Ka-Band Station<br>STSS for SDO backup<br>STSK for the SDO backup Ka-Band<br>USPS for USN Dongara<br>USHS for USN South Point, Hawaii<br>KU1S (or KU2S) for Kiruna, Sweden<br>WU1S (or WU2S) for Wilheim, Germany<br>DS24 for the DSN 34-m at Goldstone, Ca<br>DS27 for the High-Speed Beam Wave Guide site at Goldstone, Ca<br>DS34 for the DSN-34m at Canberra, Australia<br>D34K for the DSN 34m Ka-Band site at Canberra, Australia<br>DS45 for the High-Efficiency site at Canberra, Australia<br>DS54 for the DSN 34-m at Madrid, Spain<br>DS65 for the High- Efficiency site at Madrid, Spain |
| Start Time information:<br>year<br>day of year and<br>time of day | YYYYDDD.HHMMSS (GMT), 14 total ASCII Characters with a period between the first 7 and last six; where<br>YYYY => 4 ASCII digits of year (2008 – 2013)<br>DDD => 3 ASCII digits for day of year (1 – 366)<br>HHMMSS => 6 ASCII digits (hours, minutes, and seconds of day) |
| Stop Time information:<br>year<br>day of year and<br>time of day | YYYYDDD.HHMMSS (GMT), 14 total ASCII Characters with a period between the first 7 and last six; where<br>YYYY => 4 ASCII digits of year (2008 – 2013)<br>DDD => 3 ASCII digits for day of year (1 – 366)<br>HHMMSS => 6 ASCII digits (hours, minutes, and seconds of day) |
| Duration (seconds) | [9 ASCII Digits] SSSSS.mmm; separated by the period (.) character<br>SSSSS = 5 ASCII digits for whole number of seconds in the duration<br>mmm = 3 ASCII digits for the millisecond portion of the duration |
| Solar Interference | [6 or 8} ASCII Characters; where<br>6 ASCII Characters identified with Uplink or<br>8 ASCII Characters identified with Downlink |
| Solar Conjunct Type | 1 ASCII Digit<br>n; where n = 1 or 2 depending on the solar conjunction geometry<br>1 = Uplink, 2 = Downlink |

A sample file name for the first generation of this data file is given as FDF37_2009015_2009043_N01.txt

A sample of the Solar Conjunction product is provided as a reference in Appendix B, Figure B.1-21.

### 4.1.26 (FDF-38) Target Thruster Vector File

The Target Thruster Vector File includes the specified thrust vector data for the upcoming maneuver. FDF generates the Target Thruster Vector File in support of creating an attitude slew plan used during LRO maneuver execution

#### 4.1.26.1 Product Details

| | |
|---|---|
| Time interval | NA |
| File duration | Only applicable for the upcoming maneuver |
| File or Data Generation Frequency | Varies based on type of maneuver; data generation frequency is listed in the FDF-GS&O Operations Agreement (451-MOA-002960) |
| Delivery method (real-time, SCP, FTP, etc) | scp to LRO MOC via the FD Communications Server; the backup uses the FDPC (MOC performs the scp pull) |
| Data Volume | Variable based on maneuver support; can be up to approximately 330 Kbytes |
| Accuracy (if it applies) | NA |
| Other pertinent details | NA |

#### 4.1.26.2 Format

The Target Thruster Vector File is an ASCII formatted file that provides the direction of the spacecraft Body-X axis (essentially the thrust axis) during the maneuver. The report is a multi-line file containing the four columns of space-delimited data. The first column has time in the format of YYYYDOY.HHMMSS. The next 3 columns provide the LRO Body axis vector in Earth-centered, J2000 coordinates; the second column provides J2000 X component of the Body X-axis vector, the third column is the J2000 Y component of the Body X-axis vector, the fourth column is the J2000 Z component of the Body X-axis vector.

This file does not contain any header information; the data are listed at whole second intervals. The following table provides the field designations.

| Field name | Field Characteristics |
|---|---|
| Time | 14 ASCII Characters/Digits in the form of:<br>YYYYDOY.HHMMSS; where<br>YYYY = 4 ASCII Digits for the year designation for the data<br>DOY = 3 ASCII Digits for the day of year designator<br>HHMMSS = 6 ASCII digits for the hours, minutes seconds for the data<br>NOTE: The YYYDOY and HHMMSS are separated by the period (.) character |
| LRO Body-X axis vector in Earth-centered, J2000 coordinates (X component of the Body X-axis vector) | 12 ASCII digits and characters to represent the Signed unit vector; in the form of: (s)0.nnnnnnnnn; where:<br>(s) = 1 ASCII character; either a blank (represents a positive value or -, which indicates a negative value<br>0.nnnnnnnnn = 11 ASCII Digits and characters; 1 digit before the decimal place and 9 digits after the decimal place |
| LRO Body-X axis vector in Earth-centered, J2000 coordinates (Y component of the Body X-axis vector) | 12 ASCII digits and characters to represent the Signed unit vector; in the form of: (s)0.nnnnnnnnn; where:<br>(s) = 1 ASCII character; either a blank (represents a positive value or -, which indicates a negative value<br>0.nnnnnnnnn = 11 ASCII Digits and characters; 1 digit before the decimal place and 9 digits after the decimal place |
| LRO Body-X axis vector in Earth-centered, J2000 coordinates (Z component of the Body X-axis vector) | 12 ASCII digits and characters to represent the Signed unit vector; in the form of: (s)0.nnnnnnnnn; where:<br>(s) = 1 ASCII character; either a blank (represents a positive value or -, which indicates a negative value<br>0.nnnnnnnnn = 11 ASCII Digits and characters; 1 digit before the decimal place and 9 digits after the decimal place |

This file does not conform to the FDF-standard file name conventions. The following table identifies the convention used for this file:

<File Name Qualifier>_<Maneuver Type>_<Start Date>_<Stop Date>_<version number>.<file extension>

where File Name Qualifier = [5 Characters], for file designator character followed by underscore (_) character; e.g., FDF38_

| | | |
|---|---|---|
| Maneuver Type | = | [4-5 Characters] for the type of planned maneuver in the form of<br>MCCn – Mid-course correction maneuver #n or<br>LOIn – Lunar Orbit Insertion maneuver #n<br>MOIn – Mission Orbit Insertion maneuver #n<br>SKnna – Station keeping maneuver #nn [either "a" or "b" as each station keeping maneuver will consist of 2 parts], for example SK01a, SK01b,<br>Additionally, the "n" for the MCC, LOI, MOI can have the suffix of "E" to represent that this is an engineering pre-burn to test the thrusters prior to the official maneuver |
| Start Date | = | [8 characters] Eight ASCII digit for the start date in the form of<br>YYYYDDD; where<br>YYYY = 4 ASCII Digits for start year<br>DDD = 3 ASCII Digits for start day of year;<br>followed by the underscore (_) character |
| Stop Date | = | [8 characters] Eight ASCII digit for the stop date in the form of<br>YYYYDDD; where<br>YYYY = 4 ASCII Digits for stop year<br>DDD = 3 ASCII Digits for stop day of year;<br>followed by the underscore (_) character |
| version number | = | [2 characters] Two ASCII digits for version number. The initial version is 01, next is 02 … up to 99; followed by the period (.) |
| file extension or source | = | [3characters] .txt, that indicates that this is a textual file that FDF generated. |

A sample file name for the first generation of this data file is given as FDF38_LOIE_2008333_2008334_01.txt

A sample Target Thruster Vector File is provided as a reference in Appendix B, Figure B.1-22.

### 4.1.27 (FDF-39) Laser Ranging Site View Period Predicts

The Laser Ranging Site View Period Predict file contains specific view periods for the various laser ranging sites that will support the LRO mission. FDF uses a standard laser-ranging station elevation mask of 10 degrees, to identify the different laser ranging station view periods.

#### 4.1.27.1 Product Details

| | |
|---|---|
| Time interval | Data samples provided at 1 minute increments |
| File duration | 28 days starting at 0000 Hours on current generation day (Wednesday)<br>Post-maneuver updates will start at 00:00 GMT on the current day |
| File or Data Generation Frequency | Delivered weekly, on Wednesday by noon-time Eastern<br>After maneuvers within best-effort available |
| Delivery method (real-time, SCP, FTP, etc) | scp to LRO MOC via the FD Communications Server; the backup uses the FDPC (MOC performs the scp pull))<br>LRO MOC scp pushes the file to the LOLA SOC, which then scp-pushes the data product to the CDDIS for eventual use in laser ranging support |
| Data Volume | Approximately 100 Kbytes |
| Accuracy (if it applies) | The file contents should have accuracy over the 84-hours prediction, of less than 800 m in along-track<br>Across maneuvers (orbit adjust or momentum unloads) accuracy is best available |
| Other pertinent details | Station elevation masking information is unique for each station<br>Contains HGA views for each available laser ranging site |

#### 4.1.27.2 Format

This file contains the data associated with view periods for all supporting laser ranging ground sites that support the LRO mission. The general format of this file consists of the following information:

1:N Header lines that provide the Station Name and date that FDF generated the file, and header lines that provide the field description; the file then contains N lines of data for each station view period.

The N lines of data contain the following fields:

Start Time Stop Time Duration Start Pass # Max Elev. Degrees Maximum Elevation Time; where these fields are defined in the following table:

### *Table 4-19 FDF – Laser Ranging View Period Data Description*

| Field name | Field Characteristics |
|---|---|
| Station name | 43 ASCII text characters representing the unique station identifier, with the following format:<br>Facility-NNNN-To-Satellite-0059-Sensor-HGA; where<br>NNNN = GO1L, SLR2000 at Greenbelt, MD (previously GGAO)<br>MDOL, McDonald Observatory at Ft. Davis, TX<br>MONL, Monument Peak, California<br>MATM, Matera Laser Ranging Observatory, Matera, Italy<br>ZIML, Zimmerwald, Switzerland<br>STL3, Mount Stromlo at Canberra, Australia<br>HERL, Herstmonceaux, England<br>GRSM, Grasse, France<br>WETL, Wettzel, Germany<br>HARL, Hartebeesthoek, South Africa (MOBLAS-6)<br>YARL, Yarragadee, Dongara, Australia (MOBLAS-5)<br>KOGC, Koganei, Tokyo, Japan |
| Start time information:<br>year<br>day of year and<br>time of day | YYYYDDD.HHMMSS, where<br>YYYY => 4 ASCII digits of year (2008 – 2013)<br>DDD => 3 ASCII digits for day of year (1 – 366), followed by a period (.)<br>HHMMSS => 6 ASCII digits for the hours, minutes, and seconds of day |
| Stop time information:<br>year<br>day of year and<br>time of day | YYYYDDD.HHMMSS, where<br>YYYY => 4 ASCII digits of year (2008 – 2013)<br>DDD => 3 ASCII digits for day of year (1 – 366), followed by a period (.)<br>HHMMSS => 6 ASCII digits for the hours, minutes, and seconds of day |
| Station View Duration (in seconds) | SSSSS.mmm (9 ASCII digits), where<br>SSSSS => 5 ASCII characters representing the whole seconds; followed by a period(.)<br>mmm => 3 ASCII characters for the milliseconds of station contact |
| Pass Number | 7 ASCII characters representing a monotonically increasing Orbit Number (1 to 9999999)<br>NOTE: This field is only valid after lunar insertion; this field should be ignored prior to LOI |
| Max elevation angle | EE.ddd<br>EE => 2 ASCII digits for whole angle measurement (0 – 90)<br>dd d=> 3 ASCII digits for decimal portion of elevation angle (000 – 999) |
| Time of Maximum Elevation | YYYYDDD.HHMMSS, where<br>YYYY => 4 ASCII digits of year (2008 – 2013)<br>DDD => 3 ASCII digits for day of year (1 – 366), followed by a period (.)<br>HHMMSS => 6 ASCII digits for the hours, minutes, and seconds of day |

This file follows the standard FDF file naming convention; a sample file name for the first generation of the laser Ranging View Period data file is given as FDF39_2009015_2009043_N01.txt.

A sample Laser Ranging View Period Predict Data file is provided as a reference in Appendix B, Figure B.1-23.

### 4.1.28 (FDF-40) Definitive Goddard Trajectory Determination System (GTDS) Ephemeris File

This file contains definitive GTDS-formatted LRO ephemeris data for the spacecraft position and velocity information earth-centered data. FDF generates this file for the MOC/AGS use only; no other systems should use this data file.

#### 4.1.28.1 Product Details

| | |
|---|---|
| Time interval | Data samples provided at 1 minute increments |
| File duration | Continually appended until predefined limit reached (at approximately 200 Mbytes for file size) |
| File or Data Generation Frequency | Daily, by noon-time |
| Delivery method (real-time, SCP, FTP, etc) | scp to LRO MOC via the FD Communications Server; the backup uses the FDPC (MOC performs the scp pull) |
| Data Volume | Not to exceed 200 Mbytes |
| Accuracy (if it applies) | accuracy is approximately 500 m RSS total |
| Other pertinent details | Data format is consistent with Code 500 GTDS format |

#### 4.1.28.2 Format

The Definitive LRO GTDS Ephemeris file is an EBCDIC/binary formatted file that is consistent with the standard Code 500 formatted ephemeris data files; the file is identified as a big-Endian format. The FDF Product Guide provides the file data contents and format; therefore this document will not redefine these parameters.

FDF continually concatenates data onto the end of this file and it will continue to grow in file size. When the file reaches to approximately 200 MByte file size limit, FDF create a new file that contains a 2-3 day overlap and starts adding data to the file.
This file does not conform to the FDF-standard file name conventions. The following table identifies the convention used for this file:

<File Name Qualifier>_<Start Date>_<version number>.<file extension>

where File Name Qualifier = [5 Characters], for file designator character followed by underscore (_) character; e.g., FDF40_

| | | |
|---|---|---|
| Start Date | = | [8 characters] Eight ASCII digit for the start date in the form of YYYYDDD; where<br>YYYY = 4 ASCII Digits for start year<br>DDD = 3 ASCII Digits for start day of year;<br>followed by the underscore (_) character |
| version number | = | [2 characters] Two ASCII digits for version number. The initial version is 01, next is 02 … up to 99, followed by the period (.) |
| file extension or source | = | [3characters] .txt, that indicates that this is a textual file that FDF generated. |

A sample file name for the first generation of the Definitive GTDS data file is given as FDF40_2008320_01.bin

Since this file contains data in a binary/EBCDIC form, there is no sample product listed in Appendix B.

### 4.1.29 (FDF-42) FDF Time Coefficient File

The FDF Time coefficient file contains the lunar/planetary coefficients and time coefficients; such as the leap-seconds; time offsets between UTC and UT1 reference times and polar motion data (x, and y positional data) updates.

#### 4.1.29.1 Product Details

| | |
|---|---|
| Time interval | One entry for each day |
| File duration | File is updated on a daily basis and could contains up to approximately 20 years of data from both a historical (time) and predicted (polar motion)<br>contains up to the limit of the data span |
| File or Data Generation Frequency | Daily; by noon-time |
| Delivery method (real-time, SCP, FTP, etc) | scp to LRO MOC via the FD Communications Server; the backup uses the FDPC (MOC performs the scp pull) |
| Data Volume | Approx 1 MByte |
| Accuracy (if it applies) | Data are accurate based on the retrieved data from United States Naval Observatory (USNO) |
| Other pertinent details | NA |

#### 4.1.29.2 Format

The data format for this file is a binary data file.  The data consists of the predicted polar motion and historical time offsets.  This file following the standard file name conventions as listed previous with the minor exception that the maneuver flag is removed from the file name since this file never implies or has any maneuver concepts involved with the internal data.

For example, the first file version generated on January 25, 2009 is:

FDF42_2009025_00.bin; since this file is a binary formatted file, no sample product is listed in Appendix B.

### 4.1.30 (FDF-44) Trajectory Insertion Data

FDF provides the trajectory insertion data as a file to the MOC for inclusion with orbital elements that the MOC eventually transfers back to the United Launch Alliance (ULA)

#### 4.1.30.1 Product Details

| | |
|---|---|
| Time interval | data are time stamped at the separation epoch |
| File duration | NA; file is generated once post-launch |
| File or Data Generation Frequency | FDF generates product once within 3-4 days of launch |
| Delivery method (real-time, SCP, FTP, etc) | scp to LRO MOC via the FD Communications Server; the backup uses the FDPC (MOC performs the scp pull) |
| Data Volume | Approx 100 bytes |
| Accuracy (if it applies) | accuracy is 500 m RSS total |
| Other pertinent details | NA |

#### 4.1.30.2 Format

FDF provides the derived instantaneous trajectory insertion data as specified in the following table; these data will represent the most accurate orbit data available for an epoch propagated back to LRO separation and prior to any LRO impulsive maneuver. The FD generated file contains 2-3 lines of header information that identifies the file creation meta-data information; each of the header lines are preceded with the hash (#) symbol in the first column to denote a comment line. The file then contains the following data lines for the True equinox of date and the Orbital parameters as defined by the Keplerian orbital information as defined within this table.

***Table 4-20 FDF – Trajectory Insertion Data Description***

| Field name | Field Characteristics |
|---|---|
| Date of launch vehicle separation) | 8 ASCII digits that represent the True equinox of date; with the following format: MMDDYYYY = |
| Time of launch vehicle separation | 6 ASCII digits that represent the True equinox of date; with the following format HHMMSS |
| Semi-major Axis (Km) | Floating point value, format: nnnnnnnn.nnnnnn |
| Eccentricity (Unitless) | Floating point value; format 0.nnnnnnnnnn |
| Inclination (Degrees) | Floating point value: format: nnn.nnnnnn; not zero padded |
| Right Ascension of Ascending Node (Degrees) | Floating point value: format: nnn.nnnnnn; not zero padded |
| Argument of perigee (Degrees) | Floating point value: format: nnn.nnnnnn; not zero padded |
| True Anomaly (Degrees) | Floating point value: format: nnn.nnnnnn; not zero padded |

The file following the standard FDF-generated file name convention previous listed with the exception that the file name does not require any maneuver flag as part of the file name. A sample file name is identified as:
FDF44_2008302_2008302_00.txt. Appendix B, Figure B.1-24 provides a sample of the file content.

#### 4.1.31 (FDF-45) LRO Operations Activity Request

This is the LRO Operations Activity Request, which FDF can use to identify routine requests of standard activities, such as commands, guidance, navigation, and control procedure activation, ground support, or any other features that FDF and the LRO MOC have identified as possible routine operations that have been thoroughly checked and validated during the spacecraft integrations and test phase.

FDF generates the LRO Operations Activity Request and forwards the inputs to the LRO MOC. The MOT merges any this Activity Requests with command input for the spacecraft and orbiter health and safety commands and any specific maneuver commands based on mission profile support phases.

If the activity requests contains any commands, the commands in the file must be defined in the LRO Telemetry and Command Handbook – Database (431-HDBK-000053). If the command contains submnemonics, they must be specified with the command.

#### 4.1.31.1 Product Details

| | |
|---|---|
| Time interval | NA |
| File duration | NA |
| File or Data Generation Frequency | File delivered 48 hours prior to the requested activity, assuming the activity currently exists. Otherwise best effort based on time required to generate new procedures or test new instrument commands.<br>Additional time required if FDF delivers via backup protocol |
| Delivery method (real-time, SCP, FTP, etc) | scp to LRO MOC via the FD Communications Server;<br>the backup uses the FDPC (MOC performs the scp pull) |
| Data Volume | Variable; based on contents, but nominally less that 1KBytes |
| Accuracy (if it applies) | NA |
| Other pertinent details | NOTE: The time interval will be relaxed if the request is based on an Orbiter anomaly |

#### 4.1.31.2 Format

The Activity Request File is intended to capture all information necessary to execute the activity described. All fields identified are required, if a field is not required enter “NA”, this includes the initial submission of an activity request number field. The following sections describe each field. A linefeed character terminates each field and a blank line should separate each field. The following table identifies the file contents and provides additional information on the data entered for each field

***Table 4-21 LRO Operations Activity Request Definitions***

| Field name | Field Characteristics |
|---|---|
| OAR Request Date | Date when the requestor submitted the OAR to the MOC; in yyyy-mm-dd format; where<br>yyyy = 4 digit year designation (2008 – 2013)<br>mm = 2 digit month designator (01 – 12), with leading zeros<br>dd = 2 digit day of month designator (01 – 31) with leading zeros<br>**The OAR requestor is required to enter this field**. |
| OAR Approved Date | Date when the MOT approves the OAR to the MOC; in yyyy-mm-dd format; where<br>yyyy = 4 digit year designation (2008 – 2013)<br>mm = 2 digit month designator (01 – 12), with leading zeros<br>dd = 2 digit day of month designator (01 -32) with leading zeros<br>**The OAR requestor should enter NA for this field.** |

| Field name | Field Characteristics |
|---|---|
| OAR Planned Execution Date | This field will contain the MOT identified expected date when the OAR is expected to execute; in yyyy-mm-dd format; where<br>yyyy = 4 digit year designation (2008 – 2013)<br>mm = 2 digit month designator (01 – 12), with leading zeros<br>dd = 2 digit day of month designator (01 -32) with leading zeros<br>**The OAR requestor should enter NA for this field.** |
| OAR Status | This field contains the indication as to whether the MOT has accepted/rejected the OAR; the MOT completes this field<br>**The OAR requestor should enter NA for this field.** |
| OAR Status Detail | This field contains the explanation if the MOT "rejects" OAR; otherwise, the MOT enters an NA<br>**The OAR requestor should enter NA for this field.** |
| OAR Name | This field contains the name of the activity that the SOC is requesting.<br>The field is a short description of the activity. When possible, this field should identify an existing LRO Flight Procedure Document.<br>**The OAR requestor is required to enter this field**. |
| OAR Number | This field is intended for tracking purposes.<br>The MOT assigns the OAR number when received. The MOT will assign numbers for both approved and unapproved OARs.<br>**The OAR requestor should enter NA for this field.** |
| OAR Requested By | Name of person making the request. The LRO Operations Agreement with each organization will identify the individuals, a primary and backup.<br>The MOT will only act on requests submitted by those individuals identified in the approved LRO Operations Agreement<br>**The OAR requestor is required to enter this field.** |
| OAR Requestor Phone Number | The OAR Requestor must provide a telephone number in this field.<br>As the MOT reviews and implements the request, the MOT will contact the requestor at the telephone number provided to answer any questions regarding the request.<br>**The OAR requestor is required to enter this field.** |
| OAR Requestor Email Address | The Requestor must provide an email address in this field.<br>The MOT will send an email to this address and all email addresses on record for this requesting organization, which verifies MOT receipt of the OAR. The MOT will send another email when the OAR is approved or rejected<br>**The OAR requestor is required to enter this field.** |
| OAR Request Org | The Requesting organization indicates the affiliation of the person requesting the change<br>**The OAR requestor is required to enter this field.** |

| Field name | Field Characteristics |
|---|---|
| OAR Type | The activity type field gives an indication to the MOT as to which area is affected by the request. One of the following types:<br>GROUND OPERATION – activity will affect only ground assets; e.g., requesting the MOT to generate a specific product<br>INSTRUMENT OPERATION – activity will affect the instrument; e.g., sending a command, updating a FSW Table, downlinking a specific memory location<br>SPACECRAFT OPERATION – activity will affect the spacecraft; e.g., sending specific commands, updating C&DH flight software or changing a table onboard the spacecraft<br>**The OAR requestor is required to enter this field.**<br>**NOTE: FDF-generated OARs should NEVER use INSTRUMENT OPERATION as a type** |
| OAR Execution Window | This field identifies the window for when the FDF requests execution of the requested activity.<br>**The OAR requestor can supply one of the following valid inputs:**<br>**NA**<br>**NET** yyyy-mm-dd;<br>**NLT** yyyy-mm-dd where<br>yyyy = 4 digit year designation (2008 – 2013)<br>mm = 2 digit month designator (01 – 12), with leading zeros<br>dd = 2 digit day of month designator (01 -31) with leading zeros<br>**NOTE:** The MOT will schedule the request at the next available opportunity if the requestor enters an 'NA' in this field. |
| OAR Constraints | 1:N lines of free form text describing constraints for executing activity, e.g. Only during eclipse<br>The activity constraints field identifies to the MOT limitations on when the activity may be executed. In most instances, flight procedure documents will identify constraints related to the operation.<br>If additional constraints are required, they should be included in this field.<br>**The OAR requestor can either supply NA or enter a valid constraint data into this field.** |
| OAR Sequence | This field specifies the activity to be executed.<br>The MOT will execute the activity according to the instructions provided. Instructions can be as simple as execute Flight Procedure XYZ at next available ground station contact. When the Flight Procedure already exists and is approved for operational use, the MOT will execute the procedure at the time specified. When it is necessary to execute the activity at a specific time, the Requestor should identify absolute times in the format of YYYY-DOY-HH:MM:SS for each step in the activity where applicable. All absolute times in this field shall be represented in Coordinated Universal Time (UTC).<br>**The OAR requestor is required to enter this field**. |

A sample LRO Operations Activity Request is provided in Appendix B, Figure B.3-1.

The following file-naming convention is used for the OAR files transmitted between FDF and the LRO MOC. The filename consists of up to 22 characters; it also contains a three -character file extension name. There is an underscore (_) between the first four fields and a period (.) between the last two fields. The form of the filename is as follows:

<FILENAMEDESIGNATOR>_YYYY_DOY_NN.<file extension>

| | | | |
|---|---|---|---|
| where | File name designator | = | [10 ASCII characters]; defaults to LROFDF_OAR for FDF Ops Activity request |
| | Date | = | YYYY_DOY; where<br>YYYY = 4ASCII digits for year<br>DOY – 3 ASCII digits for day or year<br>NOTE: Date field identifies when FDF generated request |
| | Version | = | NN; where nn= 2 ASCII Digits to reflect the version number within a day; first version = 01; this allows for multiple files in the same day |
| | file extension | = | [3 characters] Standard file extension for all text input files<br>txt to indicate that the file is text information |

A sample FDF-generated LRO Activity Request file name is:
LROFDF_OAR_YYYY_DOY_NN.txt.

## 4.2 STATION PRODUCTS AND DESCRIPTIONS

The following sections provide the details on the interface products generated by the various ground stations used to support the LRO mission. The following several products are derived by or created by various groups that fall under the general category of the Space Communications Network. They provide specific information required by the LRO mission and are used either in support of the Mission Operations Center or by various entities within the LRO mission.

DSN is used for early mission launch critical supports activities and for any mission maneuver; DSN provides regularly scheduled proficiency supports. Outside of these supports, DSN is used solely to provide an emergency, or contingency, supports in the event that the commercial S-band stations are down.

The Space Network (SN) Tracking and Data Relay Satellites (TDRS) system supports the LRO mission; its support is limited for the several hours immediately after launch.

The following sections identify the interfaces sent by the LRO MOC to the various ground stations supporting the LRO mission. Nominally, these interfaces are used to transmit command from the LRO MOC to the corresponding station. The command structure that the LRO MOC uses is dependant upon the station that is scheduled to be the interface for sending commands to the LRO spacecraft. The following conventions are used by the LRO MOC to support the interface with each of the corresponding stations:

- SMEX/LEOT Header is used for transferring telemetry from either the WS1, SN or USN stations to the LRO MOC

- The Data Storage System (DSS) provides the interface from the HDR to the Station Data Processing System for the transfer of high-speed VC2 and VC3 telemetry VCDUs. The DSS will forward only VCDUs with frame sync, the DSS does not provide any additional headers or trailers.
- Space Link Extension (SLE) telemetry structure for interfacing with DSN stations

The SMEX/LEOT Telemetry header is 10 bytes long and has the following data structure as identified in Figure 4-5; Table 4-22 provides a reference definition for the fields contained within the SMEX/LEOT Telemetry Header.

The ground station will decommutate the Channel Access Data Units (CADU) received from the spacecraft and perform Reed Solomon decoding for eventual delivery of the Virtual Channel Data Unit (VCDU) to the MOC. The SMEX/LEO-T Telemetry header is a 10 byte header attached to every VCDU that is forwarded in real-time to the MOC's T&C system. The details for the CADU & VCDU definition are documented in the T&C Formats Handbook. In the figure below, the fields are represented in bits, not bytes.

| SMEX/LEOT Telemetry Header | | | | | | | | | | | | | | | | | | VCDU w/ Frame Sync (1788 bytes) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Version # (2) | Frame Length (14) | RS Enable Flag (1) | RS Error Flag (1) | CRC Enable Flag (1) | CRC Pass/ Fail (1) | MCS Enable Flag (1) | MCS # Error (1) | Data Inversion Flag (2) | Frame Sync Mode Flag (2) | Data Forward /reverse flag (1) | Data Class (5) | Earth Received Time Flag (1) | Earth Received Time Julian Day (14) | Earth Received Time Secs MSB (1) | Earth Received Time Secs (16) | Earth Received Time Msecs (10) | Fill/ Spare (6) | |

***Figure 4-5 SMEX/LEOT Telemetry Header***

***Table 4-22 SMEX/LEOT Field Definitions and Expected Values***

| Field Name | Size (bits) | LRO Value | Nominal Values |
|---|---|---|---|
| Version | 2 | '01' | Value = 01, frame data |
| Message Length | 14 | 1798 decimal | for LRO = 1798 bytes (includes frame synch and SMEX/LEOT Header) |
| Reed-Solomon Enable Flag | 1 | '1' | Value = 0, RS not enabled;<br>1, RS enabled<br>Will be 1 for LRO |
| Reed-Solomon Error Flag | 1 | variable | Value = 0, no RS errors<br>1, RS errors |
| CRC Enable Flag | 1 | '1' | Value = 0, CRC not enabled;<br>1, CRC enabled |
| CRC Pass/Fail | 1 | variable | Value = 0, pass;<br>1, fail |
| Master channel sequence (MCS) checking enabled flag | 1 | '0' | Value = 0, MCS not enabled;<br>1, MCS enabled<br>Not applicable for LRO |
| MCS number error | 1 | '0' | Value = 0, number increased monotonically;<br>1, number increased by 2 or more;<br>Not applicable for LRO |

| Field Name | Size (bits) | LRO Value | Nominal Values |
|---|---|---|---|
| Data inversion flags | 2 | variable | Value = 00, data true;<br>01, data inverted;<br>02, data inverted and corrected |
| Frame sync mode flags | 2 | variable | Value = 00, search frame;<br>01, check frame;<br>02, lock frame;<br>03, flywheel frame |
| Data forward/reverse flag | 1 | variable | Value = 0, data forward;<br>1, data reversed |
| Data Class | 5 | '01' or '02' | Value = 01, spacecraft telemetry<br>02, spacecraft command (will be used to identify the station status packet)<br>03, tracking data (N/A for LRO) |
| Earth received time of data (PB-5 format): flag bit | 1 | '0' | 1 PB5 flag bit; value = 0 |
| Earth received time of data (PB-5 format): truncated Julian day | 14 | variable | 2-15 Truncated Julian day; 14 bits; truncate the most significant decimal digits, retaining only the four least significant decimal digits ranging from 0000 to 9999. The current Julian day epoch begins on is Jan 01, 2001 |
| Earth received time of data (PB-5 format): seconds of day | 1 | variable | 16 Seconds of day; 17 bits; most significant bit |
| Earth received time of data (PB-5 format): seconds of day | 16 | variable | 1-16 Seconds of day; 17 bits total; remaining 16 bits from word 3, bit 16, above. Value is variable; range is 0 to 86,399; binary unsigned integer |
| Earth received time of data (PB-5 format): milliseconds of a second | 10 | variable | 1-10 Milliseconds of a second; value is variable; range is 0 to 999; binary unsigned integer |
| Fill / spare | 6 | 0 | 16 Fill/spare |

### 4.2.1 (GNSO-1) SCN Support Schedules

This is a schedule file that contains 1 week of station contacts that support LRO; this support schedule includes WS1, USN, and DSN and SN contacts when required. This support schedule is the version that the Mission Planning System ingests as part of its timeline generation function.

When the LRO MOC receives the WOTIS-generated Operational schedules from the GNSO, it will transfer the product via the scp protocol to FDF Product Center and to the LOLA SOC for eventual transfer to the CDDIS for use by the laser ranging facilities. The MOC merely acts as a conduit to pass on this information to the CCDIS and FDF and does not modify this Operational schedule.

The Station support schedule is three separate files that are created to cover various Monday – Sunday weekly activity schedules. The basic concepts for the mission schedule identifies three working versions that are used to identify the over all station support schedules for future weeks as noted here:

- Strawman Schedule – generated and delivered to the LRO MOC approximately 28 days prior to the start of that week's operational supports and planned scheduled station contacts
- Forecast Schedule – generated and delivered to the LRO MOC approximately 2 weeks prior to the start of that week's operational supports and planned scheduled station contacts
- Operational Schedule – generated and delivered to the LRO MOC on the Thursday prior to the start of the operational scheduled events; this schedule is conflict free.

In the event the MOC requires changes to the schedule, the MOC will create a schedule file in the same format as described here and send the update request back to WOTIS. The MOC will revise the file name and change the first character in the filename changed to a 'U'. The MOC will make changes to the file as required, which for example, may include changing the TR code or a start and stop time.

#### 4.2.1.1 Product Details

| | |
|---|---|
| Time interval | NA |
| File duration | Standard Strawman, Forecast, and Operational schedules are 7 days,<br>GNSO can create any file duration for LRO MOC requested schedule updates |
| File or Data Generation Frequency | Weekly |
| Delivery method (real-time, SCP, FTP, etc) | scp to LRO MOC<br>MOC "scp" pushes to FDF (via the FD Communications Server; the backup uses the FDPC) and all SOCs, except for Mini-RF |
| Data Volume | Variable; based on number of identified station contacts for the week in question |
| Accuracy (if it applies) | Contact times are accurate to 1 second; based on data from FDF View Period File |
| Other pertinent details | NA |

#### 4.2.1.2 Format

The Station Support Schedule file is an ASCII-formatted file and consists of the station name, start time, stop time, duration, and configuration identified for the requested station support; the following table provides a brief description of each field: The support activity codes, as initially defined within **Error! Reference source not found.**, are only used to identify a preliminary set of TR codes. The LRO operations team and WOTIS scheduling personnel will coordinate the actual codes and how the codes reference Ka-band and S-band Station contacts.

### *Table 4-23 SCN Station Support Schedule Field Definitions*

| Field name | Field Characteristics |
|---|---|
| Support Activity Tag | Up to 15 ASCII Characters, assigned by WOTIS to uniquely identify each specific station contact |
| Station Name | 4 ASCII Characters that uniquely identify the station, ; in the form of:<br>NNNN; where the 4 character NNNN is one of the station designators:<br>WS1S for LRO White Sands S-band Station<br>WS1K for White Sands Ka-Band Station<br>STSS for SDO backup<br>STSK for the SDO backup Ka-Band<br>USPS for USN Dongara<br>USHS for USN South Point, Hawaii<br>KU1S (or KU2S) for Kiruna, Sweden<br>WU1S (or WU2S) for Wilheim, Germany<br>DS24 for the DSN 34-m at Goldstone, Ca<br>DS34 for the DSN-34m at Canberra, Australia<br>D34K for the DSN 34m Ka-Band site at Canberra, Australia<br>DS54 for the DSN 34-m at Madrid, Spain<br>DS27 for the High-Speed Beam Wave Guide site at Goldstone, Ca,<br>DS45 for the High-Efficiency site at Canberra, Australia<br>DS65 for the High- Efficiency site at Madrid, Spain |
| Start time:<br>year<br>day of year and<br>time of day | YYYYDDDHHMMSS, where<br>YYYY => 4 ASCII digits of year (2008 – 2013)<br>DDD => 3 ASCII digits for day of year (1 – 366)<br>HHMMSS => 6 ASCII digits for the hours, minutes, and seconds of day |
| Stop time:<br>year<br>day of year and<br>time of day | YYYYDDDHHMMSS, where<br>YYYY => 4 ASCII digits of year (2008 – 2013)<br>DDD => 3 ASCII digits for day of year (1 – 366)<br>HHMMSS => 6 ASCII digits for the hours, minutes, and seconds of day |
| Support Activity Code | 3-4 ASCII Character that identifies the station configuration used to support the LRO station contact; allowable values are: TR1 – TR99;<br>The actual LRO TR codes are listed in the **Error! Reference source not found.** |
| Orbit Number | 1-5 ASCII Characters representing a monotonically increasing orbit counter; this field is only valid after the first lunar orbit insertion maneuver. |
| Band | 2 ASCII Characters representing the support contact type; where<br>S1 = S-band Support<br>K1= Ka-Band Support |

A sample Station Support Schedule file is identified with the following naming conventions:

<S><Mission ID><Year/Date Information><Schedule Duration><Schedule Type>.ext; where

S => 1 Character Schedule Type Identifier
= s to indicate this is a schedule file from WOTIS
= u to indicate a MOC request to update the schedule

| | | |
|---|---|---|
| Mission ID | => | 3 characters to identify the mission<br>= lro |
| Year/Date Information | => | 7 characters in the form of YYYYDDD, where<br>YYYY – start year designator (2008 – 2013)<br>DDD – start day of year (Monday) for the first station contact in the schedule file |
| Schedule Duration | => | 3 characters d07, d14, where<br>last 2 characters represent the number of days (duration) of the file; nominally set for 7 days |
| Schedule Type | => | 1 character to identify the specific schedule<br>o = operational<br>f = Forecast<br>s = Strawman |
| Extension | => | 9 characters<br>xxxxxxxxx, nominally represents the DOYHHMMSS of the file creation; this is used to uniquely identify the file |

A sample file name for the Support Schedule is defined as follows:

slroYYYYDOYd07o.xxxxxxxxx – sample file name for the Operational schedule
slroYYYYDOYd07f.xxxxxxxxx – sample file name for the Forecast schedule
slroYYYYDOYd14s.xxxxxxxxx - sample file name for the Strawman schedule
NOTE: Because of MOC internal processing requirements, this file name construct is translated to all upper case characters, where appropriate. All downstream users (all SOCs and FDF) receive the file name in an upper case format as noted here:
SLROYYYYDOYd07O.xxxxxxxxx
A sample Station Support Schedule file is provided as a reference in Appendix B, Figure B.2-1.

### 4.2.2 (WS1-5) (USN-3) Station Raw Tracking Data

The Station Raw Tracking Data provides the LRO Flight Dynamics Facility with the data required to support tracking of the orbiter and generation of orbit and mission products. These data are also transferred to the LRO MOC for eventual distribution to the LOLA SOC.

Each ground station (WS1 and the USN stations) that supports tracking for the LRO mission will create the data in a format identified as the Universal Tracking Data Format (UTDF) as defined in the STDN Tracking and Acquisition Handbook (STDN-724, 1990).

#### 4.2.2.1 Product Details

| | |
|---|---|
| Time interval | Doppler data every 5 seconds;<br>Range data, if available, at same 5 second data interval |
| File duration | 5 minutes |
| File or Data Generation Frequency | Every station tracking support |
| Delivery method (real-time, SCP, FTP, etc) | WS1 and USN "scp" the data files to the LRO MOC (Stations scp "push")<br>WS1 and USN stations FTP the files to the FDF Comm Server<br>LRO MOC scp pushes the file to the LOLA SOC |
| Data Volume | 75 bytes of data – every 5 seconds – for 5 minutes |
| Accuracy (if it applies) | Best Effort given station contact geometry conditions |
| Other pertinent details | NA |

#### 4.2.2.2 Format

This data will be consistent with STDN-724; WS1 can provide the tracking data either as a real-time data source to FDF or as a post-pass file to both FDF and to the LRO MOC. However, the ICD identifies that WS1 should provide LRO tracking data via the file delivery method.

USN always provides the data via a post-pass file transfer.

The tracking data are in a binary form; one datum contains seventy-five (75) bytes of information as identified in the *Tracking and Acquisition Handbook*. The following table provides the fields and field definitions for the station tracking data. FDF does not reference the data contained within byte 45 or byte 47. Since FDF does not use these two fields, the stations should default these two values to represent the closest antenna size used to support the LRO missions.

### *Table 4-24 WS1 Raw Tracking Data File Field Definitions*

| Byte | Format | Description |
|---|---|---|
| 1 | 0D(16) | Fixed |
| 2 | 0A(16) | Fixed |
| 3 | 01(16) | Fixed |
| 4-5 | ASCII | Tracking Data Router<br>4141=AA=GSFC<br>4444=DD=GSFC |
| 6 | Binary | Last two digits of current year |
| 7-8 | Binary | Satellite Identification Code (SIC) |
| 9-10 | Binary | Vehicle Identification (VID) |
| 11-14 | Binary | Seconds of year |
| 15-18 | Binary | Microseconds of second |
| *Note: For bytes 19-22/23-36, convert angle data to decimal form. Angle data are given in fractions of a circle. To express raw angle in degrees, multiply decimal angle by 8.381903173 x $10^{-8}$ (360 degrees divided by 232)* | | |
| 19-22 | FOC | Angle 1: X or az |
| 23-26 | FOC | Angle 2; Y or el (angle 2 byte/bit format is the same as for bytes 19-22.) |
| 27-32 | Binary | RTLT in 1/256 nsec (MSB = 524288 ns; LSB = 0.00390625 ns) |
| 33-38 | Binary | Bias Doppler, counts of: 240 MHz +1000 fd1 LSB - 1 count |
| 39-40 | Binary | AGC (an integer * (-150/8192) AGC-50=dBm) |
| 41-44 | Binary | Transmit frequency information in 10's of Hz |

| Byte | Format | Description |
|---|---|---|
| 45 | Discrete | MSD = antenna size (xmit) as follows:<br>0(16) = less than 1 m<br>1(16) = 3.9 m<br>2(16) = 4.3 m<br>3(16) = 9 m<br>4(16) = 12 m<br>5(16) = 26 m<br>6(16) = TDRSS ground antenna<br>7(16) = 6 m<br>8(16) = 7.3 m<br>9(16) through Feet = spares<br>LSD = antenna geometry (xmit) as follows:<br>0(16) = az-el<br>1(16) = X-Y (+X-south)<br>2(16) = X-Y (+X-east)<br>3(16) = RA-DEC<br>4(16) = HR-DEC<br>5(16) through F(16) = spares |
| 46 | Binary | Pad ID (xmit) |
| 47 | Discrete | Antenna size (rcv) – (see byte 45) |
| 48 | Binary | Pad ID (rcv) |
| 49-50 | Discrete | Mode-system unique<br>(refer to Table 2) |
| 51 | Discrete | Data Validity<br>Bit 8 = (MSB) sidelobe (1-sidelobe)<br>7 = destruct R (1 = destruct)<br>6 = refraction correction to R, R (1corrected)<br>5 = refraction correction to angles (1 =corrected)<br>4 = angle data correction (1 =corrected)<br>3 = angle valid (1=valid)<br>2 = R° valid (1=valid)<br>1 = (LSB) R valid (1=valid) |
| 52 | Discrete | MSD = frequency band, as follows:<br>1(16) = VHF<br>2(16) = UHF<br>3(16) = S-band<br>4(16) = C-band<br>5(16) = X-band<br>6(16) = Ku-band<br>7(16) = visible<br>8(16) through F(16) = spares |

| Byte | Format | Description |
|---|---|---|
| | | LSD = data transmission type, as follows:<br>0(16) = test<br>1(16) = spare<br>2(16) = simulated<br>3(16) = resubmit<br>4(16) = RT (real time)<br>5(16) = PB (playback)<br>6(16) through F(16) = spares |
| 53-54 | Discrete | MSD - tracker type Byte 53, bits 8 thru 5:<br>0(16) = C-band pulse track<br>1(16) = SRE (S-band and VHF) or RER<br>2(16) = X-Y angles only (data acquisition antenna)<br>3(16) = spare<br>4(16) = SGLS (AFSCN S-band trackers)<br>5(16) = spare<br>6(16) = TDRSS<br>7(16) through F(16) = spares |
| | | Byte 54, bit 4:<br>1 = last frame of data |
| | | Byte 53, bits 3 thru 1 and eight bits of byte 54:<br>11 bits for transmission rate (positive indicates the binary seconds between samples up to a maximum of 1023; negative indicates the two's complement of the number of samples per second). |
| 55-72 | Spare | |
| 73 | 04(16) | Fixed |
| 74 | 04(16) | Fixed |
| 75 | 04(16) | Fixed |

WS1 stores these UTDF data records into a file based on the 5-minute duration and then forwards the file to both the FDF and LRO MOC facility. Similarly, the USN station provides the same support capabilities and delivery concepts for transferring the data to the LRO MOC and to FDF.

A UTDF Tracking data file is identified with the following naming conventions:

<File Qualifier>_<Spacecraft Designations>_<Receiver PADID>_<Date Information>.<ext>; where

File Qualifier => 6 ASCII characters to identify the type of UTDF data
= LSUTDF (indicates low-speed UTDF data)

| | | |
|---|---|---|
| Spacecraft Designations | => | 6 ASCII Digits (SSSSVV) to identify the spacecraft designation, where<br>SSSS = Spacecraft ID (0059 for LRO)<br>VV = Vehicle ID (01 for LRO) |
| Receiver PADID | => | 3ASCII Digits to identify the station receive PAD identifier<br>188 for the White Sands station<br>189 for the SDO Backup station<br>103 for USPS for USN Dongara<br>105 for USHS for USN South Point, Hawaii<br>126 for KU1S (or KU2S) for Kiruna, Sweden<br>128 for WU1S (or WU2S) for Wilheim, Germany |
| Date Information | => | 11 ASCII digits, separated by the underscore (_) Character, in the form of YYYY_DDD_HHMM; where<br>YYYY = 4 ASCII digits for year (2008 -2013)<br>DDD = 3 ASCII digits for day of year (001 – 366)<br>HHMM = 4 ASCII digits (24 Hour time qualifier) to represent the hours and minutes of when the station closed the file |
| File Extension | => | 3 ASCII Characters;<br>default to trk |

A sample file name for the first WS1 generated low-speed UTDF tracking data file that corresponds to a file that the station closed at 0957GMT on 25 January 2009 is defined as follows: LSUTDF_005901_188_2009_025_0957.trk

The station tracking data file is a binary formatted file and as such, no sample is provided in Appendix B.

#### 4.2.3 (WS1-10) (USN-6) Archived VC0 Telemetry Data

This interface consists of the downlinked data that are stored in a file format at a station upon receipt of the real-time spacecraft housekeeping telemetry. These data are stored with the fill data (VC63) removed. These files are stored at the ground station using their local storage functionality. The stations store the files for up to seventy-two (72) hours in the event of a possible retransmission to the LRO MOC upon request by the LRO operations team; this would normally be considered within a contingency support concept.

#### 4.2.3.1 Product Details

| | |
|---|---|
| Time interval | Variable based on Orbiter VC0 Data collection filters and per APID |
| File duration | Based on station contact interval<br>WS1 file duration limited to 60 minutes |
| File or Data Generation Frequency | Per station contact;<br>WS1 create 1:N files per station contact<br>USN creates 1 file per station contact |
| Delivery method (real-time, SCP, FTP, etc) | MOC scp pulls from the WS1 station<br>USN scp pushes the files to the MOC upon MOC request |
| Data Volume | Variable; based on APIDs and downlink rate |
| Accuracy (if it applies) | NA; based on data mnemonics for specified APIDs |
| Other pertinent details | WS1/USN sites archive data for 72 hour retention |

#### 4.2.3.2 Format

The Archived VC0 Telemetry Data are stored with the VC63 (fill data) removed. The station archives the VC0 data stream (the downlinked VCDUs) using the station generated SMEX/LEOT Header.

A sample Archived VC0 Telemetry Data File is a binary file of the downlinked telemetry data; as such, no sample product is listed in Appendix B.

When, or if requested, by the LRO MOT, the station would transfer the archived VC0 Telemetry file back to the LRO MOC facility using the secure copy mechanism. The archive files that WS1 creates are based on configurable time duration; this configurable duration is set for the LRO mission at 60 minutes. However, the LRO Mission Operations Support Plan (MOSP), 431-PLAN-000050, will finalize the details of this file size duration and identify any instances when and how the MOT could request a different file size limit.

The archive files that the USN stations create are not configurable based on a time duration; USN creates one archive file that corresponds to the complete station contact interval.

An Archived VC0 telemetry file name is identified with the following naming conventions:

<SID>_<SIC>_<Data Source>_<Scheduled AOS Time>_<File Number>.vc0; where

SID => 3-4 ASCII Characters for the station ID
WS1 for White Sands
USPS for USN Dongara, Australia
USHS for USN South Point, Hawaii
KU1S (or KU2S) for Kiruna, Sweden
WU1S (or WU2S) for Wilheim, Germany

| | | |
|---|---|---|
| SIC | => | 4 ASCII Digits to identify the spacecraft ID<br>= 0059 |
| Data Source | => | 4 ASCII characters for the source of the data<br>= rcp1 or rcp2 (from WS1)<br>= REC1 for USN stations |
| Schedule AOS time | => | 13 ASCII characters in the form of YYYYDOY_HHMMSS, where<br>YYYY – start year designator (2008 – 2013)<br>DDD – start day of year (0 – 366)<br>HHMMSS – Hours, Minutes and seconds of AOS |
| File Number | => | 4 ASCII digit number to indicate the sequence of the file in the segmented series of files for a particular pass<br>= (0001 - 9999)<br>NOTE: Does not apply for USN stations and is not used in the file name conventions |
| extension | => | 4 ASCII characters, vcnn; where<br>nn = 00, (used to represent the Virtual Channel 0) |

For example, for an LRO pass captured at the WS1 station that began on DOY 223 at 12:15:07 in the year 2008, where the data was received from High data-rate receiver #1, and the segment time is set to 3600 seconds (as is expected for LRO), the filename would be:

WS1_0059_rcp1_2008223121507_0001.vc00

If there were multiple files associated with one pass, the files would be named as follows:
WS1_0059_rcp1_2008223121507_0001.vc00
WS1_0059_rcp1_2008223121507_0002.vc00
WS1_0059_rcp1_2008223121507_0003.vc00
WS1_0059_rcp1_2008223121507_0004.vc00

For an LRO VC0 Archive file captured at the Dongara station that began on DOY 223 at 21:12:50 in the year 2008, the file name would be identified as:
USPS_0059_REC1_2008223211250.vc00

### 4.2.4 (WS1-11) (USN-7) Archived VC1 Telemetry Data

This interface consists of the downlinked VC1 data that are stored in a file format at a station upon receipt of the spacecraft housekeeping telemetry. These data are stored with the fill data (VC63) removed. These files are stored at the ground station using their local storage functionality. The files are stored for up to seventy-two (72) hours in the event of a possible retransmission to the LRO MOC upon request by the LRO operations team; this would normally be considered within a contingency support concept.

#### 4.2.4.1 Product Details

| | |
|---|---|
| Time interval | Variable based on Orbiter VC1 Data collection filters and per APID |
| File duration | Based on station contact interval<br>WS1 file duration limited to 60 minutes |
| File or Data Generation Frequency | Per station contact |
| Delivery method (real-time, SCP, FTP, etc) | MOC scp pulls from the WS1 station<br>USN scp pushes the files to the MOC upon MOC request |
| Data Volume | Variable; based on APIDs and downlink rate |
| Accuracy (if it applies) | NA; based on data mnemonics for specified APIDs |
| Other pertinent details | WS1/USN sites archive data for 72 hour retention |

#### 4.2.4.2 Format

The Archived VC1 Telemetry Data File is stored with the VC63 (fill data) removed. The station archives the VC1 data stream (the downlinked VCDUs) using the station generated SMEX/LEOT Header. The archive files that WS1 creates are based on configurable time duration; this configurable duration is set for the LRO mission at 60 minutes. However, the LRO MOSP, 431-PLAN-000050, will finalize the details of this file size duration and identify any instances when and how the MOT could request a different file size limit.

A sample Archived VC1 Telemetry Data File is a binary file of the downlinked telemetry data; as such, no sample product is listed in Appendix B.

An Archived VC1 telemetry file name is identified with the following naming conventions:

<SID>_<SIC>_<Data Source>_<Scheduled AOS Time>_<File Number>.vc1; where

SID => 3-4 ASCII Characters for the station ID
WS1S for White Sands
USPS for USN Dongara, Australia
USHS for USN South Point, Hawaii
KU1S (or KU2S) for Kiruna, Sweden
WU1S (or WU2S) for Wilheim, Germany

SIC => 4 ASCII Digits to identify the spacecraft ID
= 0059

Data Source => 4 ASCII characters the source of the data as provided by the MCS
= rcp1 or rcp2 (from WS1)
= RECn, where n=1,2 for USN stations

| | | |
|---|---|---|
| Schedule AOS time | => | 13 ASCII characters in the form of YYYYDOYHHMMSS, where<br>YYYY – start year designator (2008 – 2013)<br>DDD – start day of year (0 – 366)<br>HHMMSS – Hours, Minutes and seconds of AOS |
| File Number | => | 4 ASCII digit number to indicate the sequence of the file in the segmented series of files for a particular pass<br>= (0001 - 9999)<br>NOTE: Does not be applicable for USN archived data files and is not used in the file name conventions |
| extension | => | 4 ASCII characters, vcnn; where<br>nn = 01, (to represent the Virtual Channel 1) |

For example, for an LRO pass that began on DOY 223 at 12:15:07 in the year 2008, where the data was received from High data-rate receiver #2, and the segment time is set to 3600 seconds (as is expected for LRO), the archived VC01 filename would be:

WS1S_0059_rcp2_2008223121507_0001.vc01

If there were multiple files associated with one pass, the files would be named as follows:
WS1S_0059_rcp2_2008223121507_0001.vc01
WS1S_0059_rcp2_2008223121507_0002.vc01
WS1S_0059_rcp2_2008223121507_0003.vc01
WS1S_0059_rcp2_2008223121507_0004.vc01

For an LRO VC1 Archive file captured at the Dongara station that began on DOY 223 at 21:12:50 in the year 2008,, the file name would be identified as:
USPS_0059_REC1_2008223211250.vc01

### 4.2.5 (WS1-12) (WS1-13) Archived Telemetry Data File

This interface consists of the downlinked data that are stored in a file format at a station upon receipt of any telemetry that is downlinked in either VC2 or VC3. These data are stored with the fill data (VC63) removed. These files are stored at the ground station using their local storage functionality; this storage takes place before the data are routed to the LRO SDPS. The files are stored for up to seventy-two (72) hours in the event of a possible retransmission to the LRO MOC upon request by the LRO operations team; this would normally be considered within a contingency support concept.

#### 4.2.5.1 Details

| | |
|---|---|
| Time interval | Variable based on specified Data collection filters and per APID for any data downlinked via VC2 or VC3 |
| File duration | Based on station contact interval<br>WS1 file duration limited to 60 minutes |
| File or Data Generation Frequency | 1:N files per station contact |
| Delivery method (real-time, SCP, FTP, etc) | MOC scp pulls the data from the WS1 Data Storage System |
| Data Volume | Variable; based on APIDs and downlink rate |
| Accuracy (if it applies) | NA; based on data mnemonics for specified APIDs |
| Other pertinent details | WS1 archive data for 72 hour retention |

#### 4.2.5.2 Format

The Archived Telemetry Data File is stored with the VC63 (fill data) removed. The station archives the data stream (the downlinked VCDUs) with attached frame sync. Only good quality frames are recorded and all R-S check symbols are removed. The archive files that WS1 creates are based on configurable time duration; this configurable duration is set for the LRO mission at 60 minutes. However, the LRO MOSP, 431-PLAN-000050, will finalize the details of this file size duration and identify any instances when and how the MOT could request a different file size limit.

A sample Archived Telemetry Data File is a binary file of the downlinked telemetry data; as such, no sample product is listed in Appendix B.

An Archived telemetry data file name is identified with the following naming conventions:

<SID>_<SIC>_<Data Source>_<Scheduled AOS Time>_<File Number>.vcn; where

SID => 4 ASCII Characters for the station ID
= WS1S for White Sands

SIC => 4 ASCII Digits to identify the spacecraft ID
= 0059

Data Source => 4 ASCII characters the source of the data as provided by the MCS
= HDR1 or HDR2

| | | |
|---|---|---|
| Schedule AOS time | => | 13 ASCII characters in the form of YYYYDOYHHMMSS, where<br>YYYY – start year designator (2008 – 2013)<br>DDD – start day of year (0 – 366)<br>HHMMSS – Hours, Minutes and seconds of AOS |
| File Number | => | 4 ASCII digit number to indicate the sequence of the file in the segmented series of files for a particular pass<br>= (0001 - 9999) |
| extension | => | 4 ASCII characters, vcnn; where<br>nn = 00, 01, 02, or 03 (to represent the virtual Channel ID) |

For example, for an LRO pass that began on DOY 223 at 12:15:07 in the year 2008 and where VC2 data are received from High data-rate receiver #1, and the segment time is set to 3600 seconds (as is expected for LRO), the filename would be:

WS1S_0059_HDR1_2008223121507_0001.vc02

If there were multiple files associated with one pass, the files would be named as follows:
WS1S_0059_HDR1_2008223121507_0001.vc02
WS1S_0059_HDR1_2008223121507_0002.vc02
WS1S_0059_HDR1_2008223121507_0003.vc02
WS1S_0059_HDR1_2008223121507_0004.vc02
An Archived VC3 telemetry data file is not shown as an example since it follows a similar file name concept.

### 4.2.6 (WS1-6) (WS1-7) (USN-4) (USN-5) (SN-1) Real-time Orbiter Telemetry Data

This is the real-time data stream that is sent from the stations to the LRO MOC during a real-time station contact; the data stream consists of the Virtual Channel Data Units (VCDUs) that the Orbiter downlinks during this support. The real-time data are Reed-Solomon decoded by the station prior to the transfer to the LRO MOC. This interface applies for both the real-time VC0 and the VC1 data that are downlinked during the station contact.

#### 4.2.6.1 Product Details

| | |
|---|---|
| Time interval | Variable based on Orbiter VC0 or VC1 Data collection filters and per APID |
| File duration | NA |
| File or Data Generation Frequency | NA |
| Delivery method (real-time, SCP, FTP, etc) | Real-time TCP socket connection<br>MOC-ITOS issues connection requests to SN, DSN, and WS1<br>USN stations issue connection requests to MOC-ITOS |

| | |
|---|---|
| Data Volume | Variable; based on APIDs and downlink rate |
| Accuracy (if it applies) | NA; based on data mnemonics for specified APIDs<br>RF link is operating at nominal conditions as per the RF ICD |
| Other pertinent details | The station performs R-S decoding and only ships VC0 data that passes the R-S decoding; the station will not send any data that fails the R-S decoding. |

#### 4.2.6.2 Format

The real-time data product for the virtual channel (VC) format is defined in the LRO Telemetry and Command Formats Handbook (LRO-HDBK-000052). The station inserts the VCDUs into a structure that has a SMEX/LEOT header.

This interface is the real-time VC telemetry stream that contains the downlinked telemetry in the VCDUs; this is a stream of binary data and as such, will not be represented in the Appendix B.

### 4.2.7 <u>(WS1-1) (USN-1) Station Status Packets</u>

This interface consists of status packets, which contain the general station status information, the downlink performance related to data quality, data statistics, RF status, and uplink time. This information is sent in a CCSDS fixed data packets; each station is assigned a unique APID to provide this station status packet data.

#### 4.2.7.1 Product Details

| | |
|---|---|
| Time interval | Every 1 second for all WS1 and USN sites |
| File duration | NA |
| File or Data Generation Frequency | Status Packet delivered Every 1 second as noted above |
| Delivery method (real-time, SCP, FTP, etc) | Real-time TCP socket connection from station to the prime MOC-ITOS |
| Data Volume | 88 bytes per status packet for the USN Station Status Packets<br>236 bytes for WS1 Station Status packets |
| Accuracy (if it applies) | NA; based on data mnemonics for specified APIDs |
| Other pertinent details | NA |

#### 4.2.7.2 Format

The Station Status Packets contains the real-time quality and monitoring statistics for the telemetry and command functions. The data statistics are contained within a standard CCSDS packet and defined as a standard APID so that the LRO T&C system (ITOS) can decommutated the packet and display the monitor information.

These station status packets are formatted within the standard CCSDS primary packet header (6 bytes) and secondary packet header (6 bytes). These CCSDS primary and secondary packet headers are defined within the CCSDS Blue Book; they will not be re-referenced here.

These data quality statistics are reset before the next station contact. The station status packets are identified by APIDs in the LRO Telemetry and Command Handbook - Database (431-HDBK-000053) and are binary data packets; as such, no sample product is provided in Appendix B.

The USN ICD 1A00846, USN to LRO ICD, is the governing document for the content of the USN stations status packets. The WS1 ICD (453-ICD-GN/WS1) is the governing document for the WS1 Station Status packet definition.

### 4.2.8 (WS1-2) (USN-2) Weather Data

This file contains the weather information per pass, such as the temperature, barometric pressure, and relative humidity, and wind speed collect during the WS1 or USN station contact.

#### 4.2.8.1 Product Details

| | |
|---|---|
| Time interval | Data sampled every 5 minutes |
| File duration | Based on station contact times |
| File or Data Generation Frequency | Every station contact |
| Delivery method (real-time, SCP, FTP, etc) | scp post pass from supporting station to LRO MOC<br>MOC scp pushes the data to the LOLA SOC |
| Data Volume | ~ 5 Kbytes per file |
| Accuracy (if it applies) | Temperature accurate to tenths of a degree Celsius<br>Pressure accurate to tenths of a millibar of pressure<br>Relative humidity accurate to the tenths of a percentage point<br>Wind speed accurate to the nearest whole value in Kilometers per hour |
| Other pertinent details | NA |

#### 4.2.8.2 Format

The Weather data are an ASCII formatted, space-delimited, information sent in a file format. It consists of multiple lines in which the first line contains start date (YYYYMMDD), Day of Year (DDD), and station identifier information and then there are 1:N repeating lines that provide the following information:
Time reference, temperature, Pressure, Relative Humidity, and Wind Speed

The following table defines the format of the weather file product:

### *Table 4-25 Station Weather Data Field Definitions*

| Field name | Field Characteristics |
|---|---|
| **First Line of File** | |
| Date/Day of Year/Station Identifier | 17 ASCII Characters with the following format:<br>YYYYMMDD DDD NNNN; where:<br>YYYYMMDD, defined as<br>YYYY => 4 ASCII digits of year (2008 – 2013)<br>MM => 2 ASCII digits for the month (01 – 12)<br>DD => 2 ASCII digits for the day (01 – 31)<br>DDD => 3 ASCII digits for day of year (1 – 366)<br>NNNN => 4 ASCII Characters for the Station Identifier (e.g.,<br>WS1S for White Sands 1 Ka/S-Band Station<br>USPS = USN Dongara<br>USHS for USN Hawaii<br>KI3S for Kiruna, Sweden<br>WG1S for Wilheim, Germany |
| **Repeating Lines (1:N) of File** | |
| Time Reference (UTC Formatted) | => 5 ASCII characters with the following format:<br>HH:MM; where<br>HH => 2 ASCII digits for hours (01- 23)<br>MM => 2 ASCII digits for minutes (00- 59) |
| temperature (in Degrees Celsius)) | 5 ASCII characters;<br>First ASCII Character is the sign indicator of the temperature; where<br>BLANK = positive temperature<br>- = Negative temperature<br>Next 2 ASCII Character represent the whole temperature value (0 -99)<br>Next character is the decimal point separator (.)<br>Last 1 Character is the tenths of a degree temperature (0 – 9) |
| Barometric Pressure (in millibars of Mercury) | 6 ASCII characters;<br>4 ASCII Character represent the whole value of pressure (0000 -1200); with leading zeros, if necessary<br>Next character is the decimal point separator (.)<br>Last 1 Character is the tenths of the pressure (0 – 9) |
| Relative humidity (%) | 5 ASCII characters with the following definition<br>3 ASCII Character represent the whole value of relative humidity (000 -100); with leading zeros, if necessary<br>Next character is the decimal point separator (.)<br>Last 1 Character is the tenths of a percentage of the relative humidity (0 – 9) |
| Wind Speed (Km/Hr) | 2 ASCII Digits represent the whole value of wind speed (00 - 99) |
| Note1: In the field definition above, all fields are a fixed number of characters; leading zeroes (or blanks) should be used where appropriate. An ASCII space is inserted between each of the defined fields for the repeating line elements.<br>NOTE2: For condition where there may be invalid weather data or no weather data for any particular sample period, the option is to skip the entry for that sample period. | |

The file name has the following naming convention:
<Station ID>_<Station AOS Contact Time>.wea

Station ID => 4 ASCII Characters for the station ID
WS1S = White Sands
USPS = USN Dongara
USHS = USN Hawaii
KI3S = Kiruna, Sweden
WG1S = Wilheim, Germany; followed by the underscore (_) character

Schedule AOS time => 12 ASCII Digits in the form of YYYYDOY_HHMM, where
YYYY – start year designator (2008 – 2013)
DDD – start day of year (0 – 366)
HHMM – Hours and Minutes of AOS
HH = (00 – 23)
MM = (00 – 59)
Note: There is an underscore (_) separator between the DDD and the HH fields

extension => 3 ASCII characters,
wea (to represent this is a weather file); file extension is represented as lower-case letters

For example, the file name for the weather product from White Sands has the following file sample:
WS1S_2009040_0824.wea.

A sample Weather Data file is provided as a reference in Appendix B, Figure B.2-2.

#### 4.2.9 (WS1-3) (WS1-4) Ka-Band Telemetry

This interface is the real-time data stream consisting of either the VC2 or VC3 VCDUs, which the WS1 high-rate data receiver (HDR) transfers through the Data Storage System to the LRO Station Data Processing System. This product consists of VCDUs with frame sync mark and are transferred from the DSS to the DPS via a socket connection.

#### 4.2.9.1 Product Details

| | |
|---|---|
| Time interval | Variable based on Instrument VC2 or VC3 Data collection filters |
| File duration | NA |
| File or Data Generation Frequency | VC2 and VC3 VCDUs delivered as received from Orbiter during ground station contact |
| Delivery method (real-time, SCP, FTP, etc) | Real-time socket from station High Rate Data Receiver to LRO Station DPS element |
| Data Volume | Variable |
| Accuracy (if it applies) | NA |
| Other pertinent details | The WS1 Data Storage System filters any data that fails the Reed-Solomon decoding checks; The station DPS only receives good quality data. |

#### 4.2.9.2 Format

The Ka-Band Telemetry Data are a composite of VCDUs received at the station and transmitted to the SDPS element. The VCDUs are composed of specific APIDs for each science instrument. The VCDU formats the underlying APIDs are defined in the LRO Telemetry and Command Handbook – Database (431-HDBK-000053); these products are binary data packets and are not shown as a sample product in Appendix B.

### 4.2.10 (WS1-8) Ka-Band RF Receiver Data

The Ka-Band RF Receiver Data are the RF Strength data from Ka-Band receiver that will be used for HGA calibration.

#### 4.2.10.1 Product Details

| | |
|---|---|
| Time interval | Data samples provided at 1 Hz frequency during WS1 Ka Band station contact |
| File duration | Variable, based on Ka-band contact (20 – 60) minutes |
| File or Data Generation Frequency | Every WS1 station contact during the HGA Cal phase<br>Nominally during Orbiter commissioning; might be 1-2 times during normal operations, if required |
| Delivery method (real-time, SCP, FTP, etc) | scp to LRO MOC at the completion of the station contact |
| Data Volume | Variable based on station contact duration; approx 200 Kbytes for a 20 minute duration contact |
| Accuracy (if it applies) | Receiver strength accuracy is identified by the intrinsic 32-bit floating point value that provides the receiver strength<br>Timetag accurate to 0.1 second |
| Other pertinent details | NA |

### 4.2.10.2 Format

The Ka-Band RF Receiver Data File is an ASCII formatted file in which commas separate the fields within the file. The file contains multiple data records, which is formatted as an ITOS-like sequential print file.

The 1:N lines of data records have the following details as identified in the following table. .

***Table 4-26 WS1 Ka-Band Receiver Data Field Definitions***

| Field name | Field Characteristics |
|---|---|
| APID | [5 ASCII Digits]; defaults to 00000 |
| Separator | [1 ASCII Character]; a comma character to separate the APID from the time tag field |
| Date, Time Field | [24 ASCII digits and characters to identify the UTC time stamp for the data; formatted as:<br>YYYY-DOY-HH:MM:SS.mmmuuu;<br>[8 ASCII digits/characters for the year and day of year; the 2 fields are separated by the hyphen (-) character<br>[15 ASCII Digits/Characters] to identify the hours, minutes seconds, and milliseconds and microseconds for the time stamp; fields are separated by the colon (:) or period (.) designators |
| Separator | [1 ASCII Character]; a comma character to separate the time tag field from the first mnemonic |
| Mnemonic Name for KA-Band Receiver Strength | [11 ASCII Characters] Default to GSHDRIFLVL1 |
| Separator | [1 ASCII Character]; a comma character to separate the first mnemonic from the first blank field |
| Blank Field | [3 ASCII Characters] default to 3 ASCII spaces |
| Separator | [1 ASCII Character]; a comma character to separate the first blank field first from the mnemonic data value |
| Mnemonic Value for Ka-Band Receiver Strength | [13 – 14 ASCII Digits/characters] representation of the Ka-Band Receiver data; encoded in a representation, between -128 to 127 dBm; in the form of: -nnn.mmmmmmmmm to nnn.mmmmmmmmm; includes the leading minus sign for negative values and a blank for positive values (See Note 1) |
| Separator | [1 ASCII Character]; a comma character follows the last field in the data record |
| Note 1: value is accurate only to approximately 6 decimal digits of precision. | |

A sample Ka-Band RF Receiver Data file is provided as a reference in Appendix B, Figure B.2-3. The sample file naming format is identified as Follows:

<Station Name>_<Data Source>_<Station AOS>.<karf>, where:

Station Name => 4 ASCII Characters for the station name followed by an underscore;
= WS1S to denote the White Sands station; followed by the underscore (_) character

Data Source => 4 ASCII characters the source of the data as provided by the MCS
= HDR1 or HDR2 for the White Sands stations; followed by the underscore (_) character

Scheduled AOS Time => YYYYDOYHHMM; followed by a period; where
YYYY is the 4 digit year representation (2008 – 2013)
DOY is the 3 digit representation for day of year (1 – 366)
HHMM is the 4 digit scheduled AOS time for that specific station contact (24 Hour time reference; e.g., 0000 to 2359)

extension => 4 ASCII characters
karf; used to represent this file represents Ka-band RF receiver status data; the file extension is represented in lower case letters

For example, for an LRO pass that began on DOY 333 at 12:15:07 in the year 2008, where the White Sands' High Data-Rate receiver #2 provided the source of the data, the filename would be identified with the following naming convention:

WS1S_HDR2_20083331215.karf

#### 4.2.11 (WS1-14) (WS1-16) Raw Telemetry File Data

This interface consists of the data downlinked using either the VC2 or VC3 channel that are stored in a file format at a station upon receipt of the corresponding instrument telemetry. These data are stored with the fill data (VC63) removed. These files are the transmitted products between the SDPS, located at the WS1 station, and the LRO MOC. These files are the raw data files as they existed on board the spacecraft.

#### 4.2.11.1 Product Details

| | |
|---|---|
| Time interval | Variable based on VC2/VC3 Data collection filters and per APID from any file that the MOT commanded down using VC2/VC3 |
| File duration | Variable, based on 1MByte, 1 hour, or instrument commanded limits |
| File or Data Generation Frequency | Every WS1 KaBand Station contact |
| Delivery method (real-time, SCP, FTP, etc) | scp to LRO MOC |
| Data Volume | Variable; based on file durations as defined above |
| Accuracy (if it applies) | NA, based on specific data product and mnemonic values as defined in T&C Handbook |
| Other pertinent details | NA |

#### 4.2.11.2 Format

The Raw Telemetry File Data is formatted to contain a series of Virtual Channel Data Units (VCDUs) for that specific VC. The VCDU format and the file naming conventions are defined in the LRO Telemetry and Command Formats Handbook (LRO-HDBK-000052).

This file contains the selected APIDs downlinked via the VC2/VC3 channel. This file contains the data in a binary format; as such, no sample product is provided as a reference in Appendix B.

### 4.2.12 (DSN-1) DSN Tracking Data

The DSN Tracking Data File provides the LRO Flight Dynamics Facility with the data required to support tracking of the orbiter and generation of orbit and mission products.

#### 4.2.12.1 Product Details

| | |
|---|---|
| Time interval | Data (Range point) collected every 40 seconds |
| File duration | NA |
| File or Data Generation Frequency | Every DSN station contact |
| Delivery method (real-time, SCP, FTP, etc) | Near Real-time socket using UDP/IP protocols to FDF (SFDU format) via Closed IONet |
| Data Volume | Variable |
| Accuracy (if it applies) | Based on TRK-2-34 format |
| Other pertinent details | DSN, which supports LRO through the 34 meter subnet, will provide this data such that it is consistent with the TRK-2-34 format. |

#### 4.2.12.2 Format

This data will be consistent with DSN formatted tracking data as identified via the TRK-2-34 format. The data product is a binary file and as such, no sample product is provided in Appendix B.

### 4.2.13 (DSN-2) (DSN-3) Real-time Telemetry Data

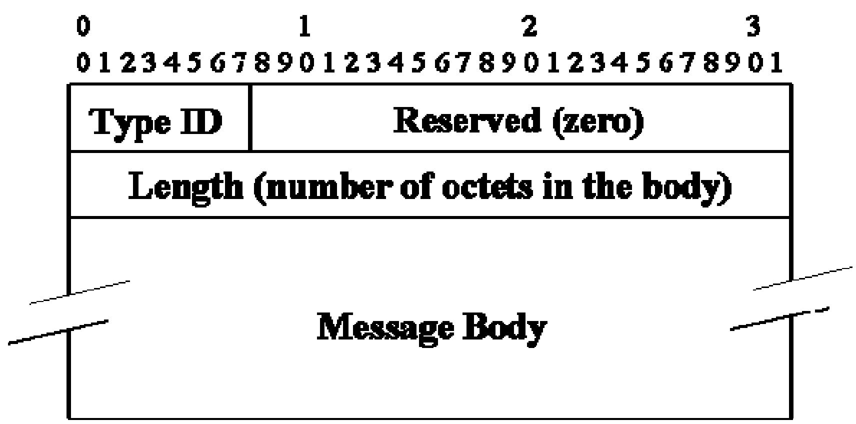
The real-time data consists of the orbiter housekeeping telemetry data packets that the spacecraft downloads to the DSN station in real-time. This interface consists of the downlinked packet data that are transferred with the fill data (VC63) removed.

The SLE service uses three types of messages using a common format for exchange of data over an established TCP connection:

- An SLE PDU message for transfer of SLE PDUs;
- A context message to transmit initialization parameters;
- A heartbeat message periodically used to probe an idle TCP connection.

The following figure identifies the SLE structure for the telemetry interfaces with the LRO MOC.

***Figure 4-6 Common SLE Format Header Structure***




The following table identifies the fields used within this figure:

***Table 4-27 SLE Telemetry Header Structure Definitions***

| Field | Representation |
|---|---|
| Type ID | 8 bits that identify the SLE Message PDU type<br>=1 represents an SLE PDU Message<br>=2 represents a Context Message<br>=3 represents a Heartbeat Message |
| Reserved | 24 bits, reserved and set to all zeros (0) |
| Length (octets) | 32 bits that provide the message body length; represented as a binary unsigned integer value |
| Message Body | 1:N 32 bit octets of PDU message data |

The MOC issues a "Return Channel Frames (RCF)" to request a selective return of either VC0 or VC1; the MOC would issue 2 RCFs Service Binds to request DSN to return VC0 and VC1 as two separate connections.

The LRO MOC will request the "*online timely*" option for the VC0 data transfer from DSN. The "*online timely*" description implies that the currency of the data is more important than its completeness.

The LRO MOC will request the "*online complete*" option for the VC1 transfers from DSN. The "*online complete*" implies that the completeness of the data is more important than its currency.

LRO and DSN have negotiated all other bind options for the service instance identifier, such as IP addresses, port numbers, destination and host machines. The LRO and DSN operations teams control these values; the DSN Operations team fully tests the service instances before entering them into the operational environment.

The LRO MOC will first issue a bind request using the type ID =2; the message body will contain the heartbeat interval and dead factor and described within the DSN telecommand document, *DSN 820-013 0163-Telecomm Interface Document.* That document identifies the information that the MOC would use to instantiate the SLE connection with DSN. After a successful RCF SLE Bind connection and an associated RCF Start request, the LRO MOC will wait for DSN to send the SLE PDU messages.

#### 4.2.13.1 Product Details

| | |
|---|---|
| Time interval | Variable based on VC0 or VC1 Data collection filters and per APID |
| File duration | NA |
| File or Data Generation Frequency | Every DSN station contact<br>SLE using either the Return all Frames (RAF) or Return Channel Frames (RCF) option |
| Delivery method (real-time, SCP, FTP, etc) | Real-time socket to LRO MOC from JPL telemetry recorder<br>Near real-time as the data are received |
| Data Volume | Variable |
| Accuracy (if it applies) | NA |
| Other pertinent details | SLE formatted data stream. |

#### 4.2.13.2 Format

The Real-time VC0 Telemetry Data are formatted to contain a series of Virtual Channel Data Units (VCDUs) for VC0. The VCDU format is defined in the LRO Telemetry and Command Formats Handbook (LRO-HDBK-000052).

Since this is a stream of real-time packets, which are sent in a binary format consistent with the LRO Telemetry and Command Formats Handbook (LRO-HDBK-000052), and via the CCSDS SLE interface. There are no sample products listed in Appendix B; the user may reference DSN 820-013 0163-Telecomm interface document for additional details.

### 4.2.14 (DSN-5) (DSN-6) Archived Telemetry Data

Nominally, DSN delivers both the VC0 and VC1 data to the LRO MOC in near real-time. The DSN station also stores the downlinked data for up to 72 hours in the event that the LRO MOT requests a retransmission of the data; this would normally be considered within a contingency support concept.

This interface consists of the downlinked data that are stored in a file format at the DSN upon receipt of the real-time spacecraft housekeeping telemetry. These data are stored with the fill data (VC63) removed.

This interface is for a contingency request to retransmit specified data after the original station contact. The MOT would request a post-pass transfer of data from the DSN's storage facility. This request is treated as another "real-time" connection to transfer a specified set of APIDs. The MOC would request a RCF Service Bind option (for a specified channel) and would identify a specified time interval. This offline transfer assumes that DSN provides a complete set of data in the post-pass transfer.

#### 4.2.14.1 Product Details

| | |
|---|---|
| Time interval | Variable based on VC0 or VC1 Data collection filters and per APID |
| File duration | NA |
| File or Data Generation Frequency | Can be accessed for every DSN station contact |
| Delivery method (real-time, SCP, FTP, etc) | As requested by MOC (Post-pass) using Real-time socket to LRO MOC<br>SLE using Return Channel Frames (RCF) option |
| Data Volume | Variable |
| Accuracy (if it applies) | NA |
| Other pertinent details | SLE formatted data stream. From the archived file |

#### 4.2.14.2 Format

The Archived Telemetry Data File is stored at JPL's storage facility as it is received from the station with VC63 (fill data) removed. The format of this data contains VCDU formatted APIDs and is defined in the LRO Telemetry and Command Formats Handbook (LRO-HDBK-000052).

A sample Archived Telemetry Data File is a binary file of the downlinked telemetry data; as such, no sample product is listed in Appendix B; the user may reference DSN 820-013 0163-Telecomm interface document for additional details.

DSN returns the Archived telemetry data via a socket connection to the LRO MOC as an off-line data transfer; this transfer is similar in nature to the real-time data delivery, except that it occurs post-pass and the LRO MOC's initiating telemetry and command system might not be the prime telemetry and command element. DSN routes the archived Telemetry data back to the LRO MOC via the CCSDS SLE interface.

### 4.2.15 (DSN-4) DSN Station Monitor Packets

This interface consists of the DSN status packets, which contain the general station information, the downlink performance related to data quality, data statistics, RF status, and uplink time.

#### 4.2.15.1 Product Details

| | |
|---|---|
| Time interval | Every 5 seconds |
| File duration | NA |
| File or Data Generation Frequency | Every DSN station contact |
| Delivery method (real-time, SCP, FTP, etc) | Real-time UDP socket to LRO MOC |

| | |
|---|---|
| Data Volume | Variable |
| Accuracy (if it applies) | Based on DSN-MON-0158 documentation |
| Other pertinent details | Based on DSN-MON-0158 documentation<br>Quality Status reset before next station contact<br>DSN Quality statistics are defined per antenna pad identifier, not just a station qualifier |

#### 4.2.15.2 Format

The DSN Station Status Packets contain the data as specified by the DSN MON-0158 format. For each DSN station contact, the station provides the data quality statistics, as listed in DSN-MON-0158) every 5 seconds. The station status packets are encased within Standard Formatted Data Units (SFDU) Block.

These data quality statistics are reset before the next station contact. Since the data sent as a binary form, no sample product is reference in Appendix B.

## 4.3 SCIENCE OPERATION CENTER PRODUCTS AND DESCRIPTIONS

This section contains the interface products generated by the seven SOCs. These products are all sent to the LRO Mission Operations Center. The LOLA SOC transmits the LOLA Improved Gravity Model to the Flight Dynamics Facility, and to the LRO MOC, to assist in the improved orbit determination process. Each science center has its own unique subsection to define the specific products that the SOCs generate and send to the MOC.

For products that the SOCs generate, they are normally identified as either command files or specific instrument command sequences; these are command products that need to be sent to the MOC for uplink to the corresponding instrument.

### 4.3.1 (CRaTER-1) (DLRE-1) (LAMP-1) (LEND-1) (LOLA-1) (LROC-1) (MIRF-1) LRO Operations Activity Request

This is the LRO Operations Activity Request, which any SOC can use to identify routine requests of standard activities, such as commands, instrument procedures activation, ground support, or any other features that the SOC and LRO MOC have identified as possible routine operations that have been thoroughly checked and validated during the instrument integrations and test phase.

Each SOC generates the LRO Operations Activity Request and forwards the inputs to the LRO MOC. The MOT merges any SOC Activity Requests with command input for the spacecraft and orbiter health and safety commands and any specific maneuver commands based on mission profile support phases.

If the activity requests contains any commands, the commands in the file must be defined in the LRO Telemetry and Command Handbook – Database (431-HDBK-000053). If the command contains submnemonics, they must be specified with the command.

#### 4.3.1.1 Product Details

| | |
|---|---|
| Time interval | NA |
| File duration | NA |
| File or Data Generation Frequency | File delivered 48 hours prior to the requested activity, assuming the activity currently exists. Otherwise best effort based on time required to generate new procedures or test new instrument commands.<br>Additional time required if SOC delivers via backup protocol |
| Delivery method (real-time, SCP, FTP, etc) | scp to LRO MOC<br>Backup is via Fax/email |
| Data Volume | Variable; based on contents, but nominally less that 1KBytes |
| Accuracy (if it applies) | NA |
| Other pertinent details | NOTE: The time interval will be relaxed if the request is based on an Orbiter anomaly |

#### 4.3.1.2 Format

The Activity Request File is intended to capture all information necessary to execute the activity described. All fields identified are required, if a field is not required enter "NA", this includes the initial submission of an activity request number field. The following sections describe each field. A linefeed character terminates each field. The following table identifies the file contents and provides additional information on the data entered for each field

***Table 4-28 LRO Operations Activity Request Definitions***

| Field name | Field Characteristics |
|---|---|
| OAR Request Date | Date when the requestor submitted the OAR to the MOC; in yyyy-mm-dd format; where<br>yyyy = 4 digit year designation (2008 – 2013)<br>mm = 2 digit month designator (01 – 12), with leading zeros<br>dd = 2 digit day of month designator (01 -31) with leading zeros<br>**The OAR requestor is required to enter this field**. |
| OAR Approved Date | Date when the MOT approves the OAR to the MOC; in yyyy-mm-dd format; where<br>yyyy = 4 digit year designation (2008 – 2013)<br>mm = 2 digit month designator (01 – 12), with leading zeros<br>dd = 2 digit day of month designator (01 -31) with leading zeros<br>**The OAR requestor should enter NA for this field.** |

| Field name | Field Characteristics |
|---|---|
| OAR Planned Execution Date | This field will contain the MOT identified expected date when the OAR is expected to execute; in yyyy-mm-dd format; where<br>yyyy = 4 digit year designation (2008 – 2013)<br>mm = 2 digit month designator (01 – 12), with leading zeros<br>dd = 2 digit day of month designator (01 -31) with leading zeros<br>**The OAR requestor should enter NA for this field.** |
| OAR Status | This field contains the indication as to whether the MOT has accepted/rejected the OAR; the MOT completes this field<br>**The OAR requestor should enter NA for this field.** |
| OAR Status Detail | This field contains the explanation if the MOT “rejects” OAR; otherwise, the MOT enters an NA<br>**The OAR requestor should enter NA for this field.** |
| OAR Name | This field contains the name of the activity that the SOC is requesting.<br>The field is a short description of the activity. When possible, this field should identify an existing LRO Flight Procedure Document.<br>**The OAR requestor is required to enter this field**. |
| OAR Number | This field is intended for tracking purposes.<br>The MOT assigns the OAR number when received. The MOT will assign numbers for both approved and unapproved OARs.<br>**The OAR requestor should enter NA for this field.** |
| OAR Requested By | Name of person making the request. The LRO Operations Agreement with each organization will identify the individuals, a primary and backup.<br>The MOT will only act on requests submitted by those individuals identified in the approved LRO Operations Agreement<br>**The OAR requestor is required to enter this field.** |
| OAR Requestor Phone Number | The OAR Requestor must provide a telephone number in this field.<br>As the MOT reviews and implements the request, the MOT will contact the requestor at the telephone number provided to answer any questions regarding the request.<br>**The OAR requestor is required to enter this field.** |
| OAR Requestor Email Address | The Requestor must provide an email address in this field.<br>The MOT will send an email to this address and all email addresses on record for this requesting organization, which verifies MOT receipt of the OAR. The MOT will send another email when the OAR is approved or rejected<br>**The OAR requestor is required to enter this field.** |
| OAR Request Org | The Requesting organization indicates the affiliation of the person requesting the change<br>**The OAR requestor is required to enter this field.** |

| Field name | Field Characteristics |
|---|---|
| OAR Type | The activity type field gives an indication to the MOT as to which area is affected by the request. One of the following types:<br>GROUND OPERATION – activity will affect only ground assets; e.g., requesting the MOT to generate a specific product<br>INSTRUMENT OPERATION – activity will affect the instrument; e.g., sending a command, updating a FSW Table, downlinking a specific memory location<br>SPACECRAFT OPERATION – activity will affect the spacecraft; e.g., sending specific commands, updating C&DH flight software or changing a table onboard the spacecraft<br>**The OAR requestor is required to enter this field.**<br>**NOTE: The SOCs should NEVER use the SPACECRAFT OPERATIONS type. The only allowable values in the SOC-generated OAR are GROUND OPERATION or INSTRUMENT OPERATION.** |
| OAR Execution Window | This field identifies the window for when the SOC requests execution of the requested activity.<br>**The OAR requestor can supply one of the following valid inputs:**<br>**NA**<br>**NET** yyyy-mm-dd;<br>**NLT** yyyy-mm-dd where<br>yyyy = 4 digit year designation (2008 – 2013)<br>mm = 2 digit month designator (01 – 12), with leading zeros<br>dd = 2 digit day of month designator (01 -31) with leading zeros<br>NOTE: The MOT will schedule the request at the next available opportunity if the requestor enters an 'NA' in this field. |
| OAR Constraints | 1:N lines of free form text describing constraints for executing activity, e.g. Only during eclipse<br>The OAR constraints field identifies to the MOT limitations on when the activity may be executed. In most instances, flight procedure documents will identify constraints related to the operation.<br>If additional constraints are required, they should be included in this field.<br>**The OAR requestor can either supply NA or enter a valid constraint data into this field.** |
| OAR Sequence | This field specifies the activity to be executed.<br>The MOT will execute the activity according to the instructions provided. Instructions can be as simple as execute Flight Procedure XYZ at next available ground station contact. When the Flight Procedure already exists and is approved for operational use, the MOT will execute the procedure at the time specified. When it is necessary to execute the activity at a specific time, the Requestor should identify absolute times in the format of YYYY-DOY-HH:MM:SS for each step in the activity where applicable. All absolute times in this field shall be represented in Coordinated Universal Time (UTC).<br>**The OAR requestor is required to enter this field**. |

A sample LRO Operations Activity Request is provided in Appendix B, Figure B.3-1.

The following file-naming convention is used for files transmitted between the various SOC facilities and the LRO MOC. The filename consists of up to 22 characters; it also contains a three -character file extension name. There is an underscore (_) between the first four fields and a period (.) between the last two fields. The form of the filename is as follows:

<FILENAMEDESIGNATOR>_YYYY_DOY_NN.<file extension>

where File name designator = [8 – 10 characters]
CRAT_OAR for CRaTER
DLRE_OAR for Diviner
LAMP_OAR for LAMP
LEND_OAR for LEND
LOLA_OAR for LOLA
LROC_OAR for LROC
MINIRF_OAR for Mini-RF

Date = YYYY_DOY; where
YYYY = 4ASCII digits for year
DOY – 3 ASCII digits for day or year
NOTE: Date field identifies when SOC generated request

Version = NN; where nn= 2 ASCII Digits to reflect the version number; first version = 01

file extension = [3 characters] Standard file extension for all text input files received from SOC;
txt to indicate that the file is text information

A sample LRO Activity Request file name for each of the SOCs is provided:

| | |
|---|---|
| CRaTER SOC | CRAT_OAR_YYYY_DOY_NN.txt |
| DLRE SOC | DLRE_OAR_YYYY_DOY_NN.txt |
| LAMP SOC | LAMP_OAR_YYYY_DOY_NN.txt |
| LEND SOC | LEND_OAR_YYYY_DOY_NN.txt |
| LOLA SOC | LOLA_OAR_YYYY_DOY_NN.txt |
| LROC SOC | LROC_OAR_YYYY_DOY_NN.txt |
| MINI RF SOC | MINIRF_OAR_YYYY_DOY_NN.txt |

### 4.3.2 (LOLA-5), (LROC-4), (MIRF-4) Target Request

This is file that contains target request from the specified SOC to perform imaging; the MOC uses this information to develop the attitude slew plan, which is eventually incorporated into the composite command load.

The SOC-generated target requests contain the information related to when the SOC is requesting an off-nadir slew, the corresponding slew angle and time durations at the off-nadir slew.

#### 4.3.2.1 Product Details

| | |
|---|---|
| Time interval | NA; based on when off-nadir requests are scheduled |
| File duration | Up to 3-4 days of future target requests (current day to current day + 4) |
| File or Data Generation Frequency | Daily; NLT Noon local |
| Delivery method (real-time, SCP, FTP, etc) | scp to LRO MOC |
| Data Volume | Variable; based on contents, but nominally less that 1KBytes |
| Accuracy (if it applies) | Target time and duration accurate to 1 second<br>Off-nadir angle accurate to .01 degree |
| Other pertinent details | File delivered no later than noon, Eastern for scheduling the first day's command sequences into the command uplink |

#### 4.3.2.2 Format

The file is a comma-delimited, ASCII file that contains the time of the requested target, a corresponding off-nadir angle, and a time duration for staying off-nadir; the fields are defined in the following table:

| Field name | Field Characteristics |
|---|---|
| Timetag:<br>year<br>day of year and<br>time of day | YYYY-DDD–HH:MM:SS, (Time is UTC time representation), where<br>YYYY => 4 ASCII digits of year (2008 – 2013); followed by the hyphen (-) character<br>DDD => 3 ASCII digits for day of year (1 – 366); followed by the hyphen (-) character<br>HH:MM:SS => 6 ASCII digits, separated by the : (colon) character; used to represent the hours, minutes, and seconds of day |
| Off-nadir angle | 7 ASCII Characters representing the targeted off-nadir angle; where<br>first character is a positive/negative sign indicator (+ or -)<br>Next 2 characters represent the whole value of angle (0 to 90)<br>Next character is the decimal separator<br>Next 3 characters represent the decimal portion for the angle (0 – 999) |
| Off-nadir duration | Up to 5 ASCII Characters representing the duration (in seconds) for the off-nadir angle; where<br>5 characters represent the duration time (in seconds) (0 – 99999) |

The following file-naming convention is used for files transmitted between the LROC SOC and the LRO MOC. The filename consists of 25 characters; it also contains a three-character file extension name. There underscores (_) between the file name fields and a period (.) between the file name and file extension fields. The form of the filename is as follows:

<instrument id>_<file content>_<YYYYDOY>_<yyyydoy>_<version number>.<file extension>

| | | | |
|---|---|---|---|
| where | instrument id | = | [4 characters]<br>LROC for the LROC SOC<br>LOLA for the LOLA SOC<br>MINI for the MINI-RF SOC |
| | file content | = | [7 characters] Intent of the command load.<br>TARGETS |
| | Start Date | = | YYYYDOY where<br>YYYY => 4 ASCII digits of year (2008 – 2013)<br>DOY => 3 ASCII digits for day of year (1 – 366) Note: DOY represents the start time of data within the file, not the file creation time |
| | Stop Date | = | yyyydoy where<br>yyyy => 4 ASCII digits of year (2008 – 2013)<br>doy => 3 ASCII digits for day of year (1 – 366) Note: DOY represents the stop time of data within the file, not the file creation time |
| | version number | = | [3 characters] V, followed by a two-digit version number. The initial version is 00, next is 01 … up to 99. |
| | file extension | = | [3 characters] Standard file extension for all input files received from SOC; it will be named for the input file type:<br>txt => for textual files |

A sample file name for an LROC generated target request is defined as LROC_TARGETS_2009131_2009133_V00.txt.

Similarly, both MINI-RF and LOLA would have a similar file name concept with their specific instrument ID as noted in the above table (e.g., LOLA_TARGETS_2009147_2009149_V01.txt or MINI_TARGETS_2009150_2009152_V00.txt

A sample Target Request is provided in Appendix B, Figure B.3-2.

### 4.3.3 (DLRE-2) (LAMP-2) (LOLA-3) (MIRF-2) Instrument FSW Load

This file contains the FSW image and tables for the specified instrument; it contains the tested and verified files that the SOC will send on an as needed basis, as required to correct/update instrument Flight Software table and/or files.

The corresponding SOC facility generates its unique FSW load request and forwards the image file to the LRO MOC.

#### 4.3.3.1 Product Details

| | |
|---|---|
| Time interval | NA |
| File duration | NA; FSW Load contains no time frame data |
| File or Data Generation Frequency | As needed to meet needs of SOC group to upload new instrument loads |
| Delivery method (real-time, SCP, FTP, etc) | scp to LRO MOC |
| Data Volume | Variable; based on contents, but nominally less that 64 KBytes |
| Accuracy (if it applies) | NA |
| Other pertinent details | File delivered 2-3 days prior to requested uplink to allow sufficient time to verify load against the FLATSAT simulator<br>The DLRE FSW Load is rate buffered based on a parameter provided within the FSW Load file (Data Record #2); see below |

#### 4.3.3.2 Format

The Instrument FSW Load consists of the complete file/table image to be re-loaded, or a starting address, number of bytes to load and then the new table/file image portion.

In a load file, comments begin with either semi-colon (;) or hash (#) and continue to the end of the line. The MOC's T&C system ignores any blank lines and lines containing only comments. The first non-blank, non-comment line is the abstract record; this is copied to the formatted image load file but otherwise ignored. It is intended as a comment to identify the load file name.

Figure 4-7 provides a representation of each field within an Instrument FSW Load file. As noted in this figure there are several lines at the start of the load file that provide reference information related to the file name and other mission or instrument specific processing parameters. There may be several comment lines as listed in the figure, but these lines are not required and as noted above, the LRO T&C system will ignore these lines.

The remainder of the file contains the load image in a hexadecimal data form; the load data begins with the "X" and must contain an even number of hex data characters. The lines are terminated by the line feed (LF) character; the load image data lines can have an optional semi-colon (;) character, which are used to provide any additional comments. The line then terminates with the LF character. The LAMP Flight SW Load contains an extra space after the last hexadecimal data character and just prior to the semi-colon and LF characters.

```
<File Name>
<Mission>, <ID>, <Date>, <Version>, <Source>, <Pkt Size>, <SWAP>, <Data Size>, <Rate>
<Select Command>
<Inst Load Command>
<Commit Command>
;
;
;
X  00 04 02 03 0A 99 6F 7A 30 FF CA 00 00 12 12 42 60 19 01 9D 9A 4A
X  00 04 02 03 0A 99 6F 7A 30 FF CA 00 00 12 12 42 60 19 01 9D 9A 4A
X  00 04 02 03 0A 99 6F 7A 30 FF CA 00 00 12 12 42 60 19 01 9D 9A 4A
X  00 04 02 03 0A 99 6F 7A 30 FF CA 00 00 12 12 42 60 19 01 9D 9A 4A
.
.
.
X  00 04 02 03 0A 99 6F 7A 30 FF CA 00 00
```

***Figure 4-7 Instrument FSW Load File Structure***

Table 4-29 provides a more detailed explanation of each field as noted within the above figure.

### *Table 4-29 Instrument FSW Load Directive File Data Definitions*

| Parameter Name | Parameter value |
|---|---|
| File name | The SOC-generated ASCII File name corresponding to Instrument FSW Load file as defined in the following table below |
| mission name | This field is ignored by the ITOS LOAD directive.<br>Set to LRO |
| image ID | This field is ignored by the ITOS LOAD directive.<br>Load ID |
| Date | Copied to the formatted image load file but otherwise ignored.<br>UTC Time of the of the Load generation |
| Version | This field is ignored by the ITOS LOAD directive.<br>Numerical value |
| Source | This field is ignored by the ITOS LOAD directive.<br>This is the location for the Load such as RAM or EEPROM<br>DLRE could set this field to the following possible values:<br>“INRAM”, “XRAM”, and “SCANTABLES” |
| Pkt size | Maximum packet size. When the LOAD directive formats the raw image load file into packets, this is the maximum number of data bytes in each packet. The SOCs provide this value in a hexadecimal representation<br>DLRE should set this field to a decimal value of 240; hex = 00F0 |
| swap | Indicates whether or not the LOAD directive should swap bytes when generating the formatted image load file. Byte swapping is only performed if this field has one of the values SWAPBYTES or UI085.<br>NOTE: SWAPBYTES is the preferred value; the SOCs could use UI085, but it is a non-standard usage.<br>The SOCs should sue the term NOSWAP to result in no byte swapping; however, any value other than SWAPBYTES or UI085 results in no byte swapping. |
| Data Size | An optional field, which gives the size in bytes of data items to be loaded; can be ‘1’, ‘2’,’4’<br>This option controls how the load program sets the *ADDRESS* or *OFFSET* and *NUMBYTES* fields in the load command.<br>For DLRE, this field is set to an empty value |
| Rate | Specifies the uplink rate at which the MOC will forward load directive commands to the spacecraft, to be forwarded to the instrument; in terms of 1 command every <Rate> Time (in seconds) in the event that the instrument can not receive the commands as fast as the MOC can send them.<br>For example, for DLRE, this can be set to 3, which indicates that the MOC T&C system will send 1 DLRE FSW Command every 3 seconds until the file is completely uplinked. |
| Select Command | If required, the SOC should provide the correspond “Select Command” as identified from the LRO Command Database.<br>If no select command is required, the SOC should set this field to NOSELECT<br>DLRE should always set this field to NOSELECT |

| Parameter Name | Parameter value |
|---|---|
| Instrument Load Command | This provides the "Instrument Load Command" mnemonic as defined within the LRO Command database |
| Commit Command | If required to commit the load, the field should contain the commit command as contained/formatted within the LRO command database.<br>If no commit command is required set the field to NOCOMMIT<br>DLRE should always set this field to NOCOMMIT |
| Instrument Data | X – All data load lines should start with the hexadecimal delimiter X.<br>Each load line must contain an even number of hexadecimal characters<br>Each line should be limited to 60 load file characters |

The following file-naming convention is used for the files transmitted between the SOCs and the LRO MOC. The filename consists of 24 characters; it also contains a three-character file extension name. There are underscores (_) between the file name fields and a period (.) between the file name and extension fields. The form of the filename is as follows:

<instrument id>_<file content>_<YYYYDOY>_<version number>.<file extension>

where instrument id = [4 characters]
DLRE, LAMP, or LOLA, MINI

file content = [4 or 7 characters] Intent of the instrument loads.
LOAD to indicate it's a FSW Load for Mini-RF
FSWLOAD; to indicate a FSW load for the other instruments, except for FSW Loads from the Diviner SOC

Date = YYYYDOY
DOY = Identifies the file creation date since this is a load file and does not contain any date/time related commands

version number = [3 characters] V followed by a two-digit version number. The initial version is 00, next is 01 … up to 99.

file extension = [3characters] Standard file extension for all input files received from a SOC; it will be named for one of the following two input file type:
bin; to represent a binary load file for the FSW load for LAMP, LOLA, and Mini-RF SOCs
ld; to represent the File type for the DLRE FSW Load

The following paragraphs provide the sample file name concepts for CRaTER, LAMP, LEND, LOLA, LROC, and Mini-RF instrument loads and identify the corresponding Appendix B cross reference for the partial sample file.

A sample file name for a LAMP-generated FSW Load is

LAMP_FSWLOAD_YYYYDOY_Vnn.bin; a partial sample LAMP Instrument FSW Load is provided in Appendix B, Figure B.3-5.

A sample file name for a LOLA-generated FSW Load is

LOLA_FSWLOAD_YYYYDOY_Vnn.bin; a partial sample LOLA Instrument FSW Load is provided in Appendix B, Figure B.3-7

Sample file name is MINI_Load_YYYYDOY_Vnn.bin

A sample Mini-RF Load File is provided in Appendix B, Figure B.3-12

DLRE follows a different file naming scheme, which provides a unique file name concept for each of the various flight software tables that they can modify. The DLRE scheme using the following concepts:

<instrument id>_<file content>_<table descriptor>_<YYYYDOY>_<version number>.<file extension>

| | | | |
|---|---|---|---|
| where | instrument id | = | [4 characters]<br>DLRE |
| | file content | = | [7 characters] Intent of the instrument loads.<br>FSWLOAD; to indicate a DLRE FSW load |
| | Table descriptor | = | [unlimited ASCII characters]; free format for field length or file descriptor length, etc. Provides the specific intent for which table the DLRE SOC plans to modify |
| | Date | = | YYYYDOY<br>DOY = Identifies the file creation date since this is a load file and does not contain any date/time related commands |
| | version number | = | [3 characters] V followed by a two-digit version number. The initial version is 00, next is 01 … up to 99. |
| | file extension | = | [3characters] Standard file extension for all input files received from a SOC; it will be named for one of the following two input file type:<br>bin; to represent a binary load file for the FSW load for LAMP, LOLA, and Mini-RF SOCs<br>ld; to represent the File type for the DLRE FSW Load |

DLRE provides two separate files to support both a flight software update and for a scan table update. Appendix B, Figure B.3-3, provides the sample concepts for each of these products.

The sample file name for the first DLRE FSW table load for the ramping patch load is identified as: DLRE_FSWLOAD_ramping_patch_2009090_V01.ld;

### 4.3.4 (LOLA-2) LOLA Improved Lunar Gravity Model

The LOLA Gravity Model is a file that contains the updated Lunar Gravity Model that the LOLA science team generates from its internal data processing. This file is sent to both the Flight Dynamics Facility and to the LRO MOC.

This data contains an improved lunar gravity model based on the continual processing of the correlated laser ranging one-way transmit times and using S-Band and other LOLA instrument data. FDF will use the improved Lunar Gravity Model to reprocess the orbit data and to create new definitive SPICE File and ephemeris information.

The Gravity model file shall consist of coefficients of a spherical harmonic expansion of the lunar potential up to resolution of (120 x 120) degrees. The LOLA SOC should ensure that the coefficients within the file are normalized; LOLA should also ensure that the updated lunar gravity constant and reference radius are included. LOLA should provide the title of the lunar gravity field. The LOLA SOC will not provide any corrections to the coefficients based on solid lunar tides.

#### 4.3.4.1 Product Details

| | |
|---|---|
| Time interval | NA |
| File duration | NA |
| File or Data Generation Frequency | LOLA generates on a best effort basis to approach every 2 months starting at L+2 Months |
| Delivery method (real-time, SCP, FTP, etc) | scp to LRO MOC<br>MOC scp to FDF via the FD Communications Server; the backup uses the FDPC (MOC performs the scp push) |
| Data Volume | Variable; based on contents, but approximately 2 KBytes |
| Accuracy (if it applies) | NA |
| Other pertinent details | NA |

#### 4.3.4.2 Format

The LOLA SOC creates the LOLA Improved Gravity Model File; this is an ASCII-formatted file based on the LOLA processing. This file includes new lunar gravity model data including the standard deviation values for the updated parameters.

The following file-naming convention is used for files transmitted between the LROC SOC and the LRO MOC. The filename consists of 26 characters; it also contains a three-character file extension name. There are underscores (_) between the file name fields and a period (.) between the file name and file extension fields. The form of the filename is as follows:

<instrument id>_<file content>_<YYYYDOY>_<version number>.<file extension>

where instrument id = [4 characters]
LROC

file content = GRAVMODEL – used to denote this is the newly calculated LOLA Gravity Model Information

Date = YYYYDOY based on UTC Timeframe
DOY = is the creation date

version number = [3 characters] V followed by a two-digit version number. The initial version is 00, next is 01 … up to 99.

file extension = [3 characters] Standard file extension for all input files received from SOC; it will be named for the input file type:
bsp; to represent a binary SPK file

A sample LROC Activity Request file name for an ATS request is LOLA_GRAVMODEL_YYYYDOY_Vnn.txt

A sample Improved Lunar Gravity Model data file is provided as a reference in Appendix B, Figure B.3-6.

### 4.3.5 (LOLA-4) LOLA Processed OD Information

This file contains the LOLA–calculated Orbit Determination from data processing based on the telemetry data that LOLA receives from the LRO MOC as part of the real-time and post-pass s/c and instrument housekeeping and measurement telemetry, as well as the tracking data that the MOC provides to LOLA.

#### 4.3.5.1 Product Details

| | |
|---|---|
| Time interval | Data centered at 1 minute increments |
| File duration | File is a set of daily files |
| File or Data Generation Frequency | Files are created on an as-available basis |
| Delivery method (real-time, SCP, FTP, etc) | scp to LRO MOC<br>MOC scp to FDF via the FD Communications Server; the backup uses the FDPC (MOC performs the scp push) |
| Data Volume | Approximately 2 Mbytes per weekly file |
| Accuracy (if it applies) | 50 m along track, 50 m across track, and less than 1 m radial |
| Other pertinent details | NA |

#### 4.3.5.2 Format

The LOLA Processed OD Information is a set of SPK formatted files based on the LOLA Orbit Determination calculations. The LOLA SOC creates these files on a weekly basis from the data gathered over the last seven days. This SPK is consistent with other OD-like SPK files previously discussed in the FDF section.

The filename consists of 20 characters; it also contains a three-character file extension name. There are underscores (_) between the file name fields and a period (.) between the file name and file extension fields. The form of the filename is as follows:

<instrument id>_<file content>_<YYYYDOY>_<version number>.<file extension>

| | | | |
|---|---|---|---|
| where | instrument id | = | [4 characters]<br>LOLA |
| | file content | = | SPK – used to denote this is a LOLA Processed SPICE SPK File |
| | Date | = | YYYYDOY based on UTC Timeframe<br>DOY = start date corresponding to when new Processed OD Data is valid and not the creation date |
| | version number | = | [3 characters] V, followed by a two-digit version number. The initial version is 00, next is 01 … up to 99. |
| | file extension | = | [3characters] Standard file extension for all input files received from SOC; it will be named for the input file type:<br>bsp; to represent a binary SPK file |

A sample LOLA Processed OD Information file name is LOLA_SPK_YYYYDOY_Vnn.bsp

Since the LOLA Processed OD Information is a binary SPK file, no sample product is provided in Appendix B.

### 4.3.6 <u>(LOLA-6) LOLA Processed Laser Ranging Data</u>

This file contains the LOLA–processed one-way laser ranging fire time from data processing based on the telemetry that LOLA received from the LRO MOC as part of the real-time and post-pass s/c and instrument housekeeping and measurement telemetry.

#### 4.3.6.1 Product Details

| | |
|---|---|
| Time interval | Data centered at 1 second increments when laser ranging activities occur |
| File duration | File is 1 day of data<br>Nominally from 0000 GMT to 0000 GMT |
| File or Data Generation Frequency | 1 file per day |
| Delivery method (real-time, SCP, FTP, etc) | scp to LRO MOC and to the CDDIS (LOLA does the scp "push"<br>MOC scp to FDF via the FD Communications Server; the backup uses the FDPC (MOC performs the scp push) |
| Data Volume | Approximately 6 Mbytes per daily file |
| Accuracy (if it applies) | < 10 centimeters precision for the 1 second data interval (for each normal point) |
| Other pertinent details | NA |

#### 4.3.6.2 Format

The LOLA processed laser ranging information is consistent with the details as provided in the Consolidated Laser Ranging Data Format (CRD) document. This product consists of several "header" records that are used to provide general information, such as station, target, and start time; these "header" records are fixed format and similar in content to those of the Consolidated Laser Ranging Prediction Format; version 1.0 referenced document.
The file also contains "configuration" records, which contain an expanded version of data previously described by the System Configuration Indicator (SCI) and system CHange Indicator (SCH) fields.
The file contains the "data: records, which provide the laser transmit and receive times, and other highly dynamic information.
Both the configuration and data records are free format with spaces between entries.
The filename consists of 14 characters; it also contains a three-character file extension name. There are underscores (_) between the file name fields and a period (.) between the file name and file extension fields. The form of the filename is as follows:

<instrument id>_<YYYYMMDD>.<file extension>

where instrument id = [5 characters] used to define the mission and the laser ranging station site
for example LROLR

Date = YYYYMMDD ; where
YYYY = 4 digit year (2009 – 2013)
MM = 2 digit month (01 – 12)
DD = 2 digit day (01 – 31)

file extension = [3characters] Standard file extension for a Normal Point generated file:
npt;

A sample LOLA Processed laser Ranging data file corresponding to January 20, 2009 in normal point mode is LROLR_20090120.npt

Appendix B, Figure B.3-8 provides a sample version of this product.

### 4.3.7 (LOLA-7) Lunar Laser Retro-Reflector Event Information

This file contains the calculated times during which the LOLA instrument potentially could be damaged. When the LRO spacecraft enters an area near one of the lunar-based laser retro-reflectors, a lunar laser ranging experiment independent of the LRO project might send high-level laser pulses, which the LR telescope could receive. The file provides the estimated event start time and duration for which the LRO mission ops team will maneuver the HGA to avoid any harmful impact to the LOLA telescope electronics as a result of receiving a much higher laser energy level, which would damage the LOLA telescope electronics.

#### 4.3.7.1 Product Details

| | |
|---|---|
| Time interval | Time interval is NA since the actual event times are based on LRO and lunar geometry conditions; they occur about twice a month and are clustered together |
| File duration | File contains the next 28 days of retro-reflector avoidance times |
| File or Data Generation Frequency | LOLA creates this file on a weekly basis after receipt of the FDF predicted ephemeris |
| Delivery method (real-time, SCP, FTP, etc) | LOLA SOC scp pushes the file to LRO MOC |
| Data Volume | Less than 1 Kbyte per weekly file |
| Accuracy (if it applies) | Event start times and durations are accurate to the second |
| Other pertinent details | Used internally by the MOC's MPS system to identify when the HGA is commanded to an offset so as to avoid the high-energy laser impulses. |

#### 4.3.7.2 Format

The file will consist of 1-n lines of optional free-form Header data; this is used as information only and is not required for eventual ingest as a product. The file then contains N lines of data that provides the calculated event start and duration using the following format.

# Event Start Duration

YYYY-DOY-HH:MM:SS,ddd

The event duration is blank padded to 3 ASCII characters/digits and there is a comma (,) character between the Event Start and the Event Duration fields.

In the event that the file does not contain any avoidance events, the file only contains the header rows information. This empty file concept would not contain any of the data rows listed above.

The filename consists of 25 characters; it also contains a three-character file extension name. There are underscores (_) between the file name fields and a period (.) between the complete file name and file extension. The form of the filename is as follows:

<SOC product id>_<Start Date><Stop Date>_<Version Number>.<file extension>

| | | | |
|---|---|---|---|
| where | SOC product id | = | [5 characters] ; defaults to LOLA7 |
| | Start Date | = | [7 ASCII digits], in the form of: YYYYDOY ; where<br>YYYY = 4 digit for the start year (2009 – 2013)<br>DOY = 3 digits for the start day of year (01 – 366) |
| | Stop Date | = | [7 ASCII digits], in the form of: yyyydoy ; where<br>yyyy = 4 digit for the stop year (2009 – 2013)<br>doy = 3 digits for the stop day of year (01 – 366) |
| | Version Number | = | [3 ASCII digits/characters]; in the form of:<br>Vnn; where nn = 2 ASCII digits to represent the version number for this file; first version =01, and increments by 1 for each new version that LOLA needs to create with the same start/stop information |
| | file extension | = | [3ASCII characters] standard file extension for a text file:<br>txt; |

A sample filename for the first generation of the LOLA Lunar Laser Retro-reflector Event file that corresponds to a start date of May 20, 2009 and covers the next 28 days of events is: LOLA7_2009071_2009099_V01.txt

Appendix B, Figure B.3-9 provides a sample version of this product.

#### 4.3.8 (LR-1) Laser Ranging Schedule Information

This file contains the proposed times at which a laser ranging site has view of the LRO spacecraft and will support laser ranging activities. The laser ranging group creates this schedule of all laser sites that can support the LRO mission and perform laser ranging to the spacecraft.

#### 4.3.8.1 Product Details

| | |
|---|---|
| Time interval | Data provides AOS – LOS time intervals for each possible laser ranging site |
| File duration | File is valid for the upcoming week; contains 10 days of laser ranging schedule data |
| File or Data Generation Frequency | Created by the Friday before the week in question |
| Delivery method (real-time, SCP, FTP, etc) | LR FTP-es the file to the CDDIS<br>LOLA SOC scp (pulls) the file from the CCDIS and then scp push to LRO MOC<br>MOC DMS Scp pushes the file to the FDPC |
| Data Volume | Approximately 6 Kbytes per weekly file |
| Accuracy (if it applies) | Station AOS/LOS times are accurate to the second |
| Other pertinent details | NA |

#### 4.3.8.2 Format

The file contains the AOS/LOS times corresponding to when a particular laser site has view of the LRO antenna and is able to provide support to conduct laser ranging to the spacecraft.

Each line in the scheduling file will contain information regarding one scheduled pass for a system. Blank characters are used to separate the fields within the file. The following table describes each pass record contained in each line of the file:

| Field name | Field Characteristics |
|---|---|
| LR Pad Identifier | [4 ASCII Digits] – represents the International Laser Ranging Service Pad ID the following is the convention for Pad ID assignments to LR sites:<br>7125 – GO1L, SLR2000 at Greenbelt, MD<br>7080 – MDOL, McDonald Observatory at Ft. Davis, TX<br>7110 – MONL, Monument Peak, California<br>7941 – MATM, Matera Laser Ranging Observatory, Matera, Italy<br>7810 – ZIML, Zimmerwald, Switzerland<br>7825 – STL3, Mount Stromlo at Canberra, Australia<br>7840 – HERL, Herstmonceaux, England<br>7845 – GRSM, Grasse, France<br>8834 – WETL, Wettzel, Germany<br>7501 – HARL, Hartebeesthoek, South Africa (MOBLAS-6)<br>7090 – YARL, Yarragadee, Dongara, Australia (MOBLAS-5)<br>7308 – KOGC, Koganei, Tokyo, Japan |
| LR AOS Pass Date | 7 ASCII Digits representing the scheduled start pass date in the form of YYYYDDD; where<br>YYYY = start year designator (2008 - 2013)<br>DDD – start day of year designator (1 – 366) |

| Field name | Field Characteristics |
|---|---|
| LR AOS Pass Time | 5 ASCII Digits representing the scheduled start pass time; in the form of HH:MM<br>first 2 character represent the start time in hours of the LR station contact (00 – 23)<br>Next 2 characters represent the start time in minutes of the LR station contact (00 – 59) |
| LR LOS Pass Date | 7 ASCII Digits representing the scheduled stop pass date in the form of YYYYDDD; where<br>YYYY = start year designator (2008 - 2013)<br>DDD – start day of year designator (1 – 366) |
| LR LOS Pass Time | 5 ASCII Digits representing the scheduled stop pass time; in the form of HH:MM<br>first 2 character represent the start time in hours of the LR station contact (00 – 23)<br>Next 2 characters represent the start time in minutes of the LR station contact (00 – 59) |
| LR Station Qualifier | [4 ASCII Characters]; used to uniquely identify the LR station name;:<br>GO1L NGSLR, Greenbelt, MD<br>MDOL McDonald Observatory, Ft. Davis, TX<br>MONL Monument Peak, California<br>MATM Matera Laser Ranging Observatory, Matera, Italy<br>ZIML Zimmerwald, Switzerland<br>STL3 Mount Stromlo, Canberra, Australia<br>HERL Herstmonceaux, England<br>GRSM Grasse, France<br>WETL Wettzel, Germany<br>HARL Hartebeesthoek, South Africa<br>YARL Yarragadee, Dongara, Australia<br>KOGC Koganei, Tokyo, Japan |
| Comments | [1 – 37 ASCII characters]; free form text used to provide specific information for LR stations regarding the scheduled LR station pass;<br>such as: High Priority;<br>could also be blank |

The following file-naming convention is used for files transmitted between the Laser Ranging group and the LRO MOC. The filename consists of 29 ASCII characters and digits. There are underscores (_) between each of he file name fields. The form of the filename is as follows:

<system id>_<file content>_<YYYYDOY>_<YYYYDOY>__<version number>

where system id = [2 characters]
LR

file content = [8 characters]
schedule

Start Date = [8 characters] based on UTC Timeframe in the form of YYYYDOY; where
YYYY = start year of corresponding first entry in the LR schedule
DOY = start day of year corresponding to the first entry in the LR schedule

Stop Date = [8 characters] based on UTC Timeframe in the form of YYYYDOY; where
YYYY = start year of corresponding first entry in the LR schedule
DOY = start day of year corresponding to the last entry in the LR schedule

version number = [1 ASCII Digit] N, where N is 1-9 to represent the possible versions.

For a first version of a laser ranging schedule that is valid for the January 24 thru February 2, 2008, the sample Laser Ranging Schedule file name is identified as LR_schedule_2008024_2008033_1

Appendix B, Figure B.3-10 provides a sample product reference.

#### 4.3.9 (LROC-2) LROC Instrument Initialization Command Sequence

This file is one of eight initialization command loads that LROC SOC could use to initialize the LROC instrument during a startup sequence. This file is delivered electronically to the LRO MOC; the LRO MOC uplinks this file into the LROC directory location using the CFDP protocol. The instrument initialization command sequence is used to identify which set of command to use whenever the LROC instrument is initialized.

All commands in the file must be defined in the LRO Telemetry and Command Handbook – Database (431-HDBK-000053). If the command contains submnemonics, they must be specified with the command.

##### 4.3.9.1 Product Details

| | |
|---|---|
| Time interval | Command time sequences are variable; based on LROC identified startup concepts |
| File duration | NA; file is a set of relative-based time sequences for LROC initialization |
| File or Data Generation Frequency | LROC will generate up to 8 files<br>Initially generated prelaunch (required 2 months prior to launch, preferred 4 months prior to launch<br>After launch on an as-needed basis |
| Delivery method (real-time, SCP, FTP, etc) | scp to LRO MOC |

| | |
|---|---|
| Data Volume | Variable; based on contents, but nominally less that 256 KBytes |
| Accuracy (if it applies) | NA |
| Other pertinent details | Files will be delivered on an as-needed basis<br>File delivered 2-3 days prior to requested uplink to allow sufficient time to verify load against the FLATSAT simulator |

#### 4.3.9.2 Format

The LROC Instrument initialization command sequence provides the LROC instrument FSW load that the LROC SOC wants to load at startup; this file is a binary content that the instrument uses during the initialization process.

The operations team generates command that are used to load these files into the Orbiter's solid state recorder LROC directory structure. The following file-naming convention is used for files transmitted between the LROC SOC and the LRO MOC. The filename consists of 31 characters; it also contains a three-character file extension name. There are underscores (_) between the file name fields and a period (.) between the file name and file extension fields. The form of the filename is as follows:

<instrument id>_<file content>_<File Number>_<version number>.<file extension>

where instrument id = [4 characters]
LROC, followed by the underscore character (_)

file content = [7 characters] Intent of the instrument loads.
FSWLOAD; followed by the underscore character (_)

File Number = [1 ASCII Digit] n = 1 thru 8 to identify the appropriate load file; followed by the underscore character (_)

version number = [3 characters] V, followed by a two-digit version number. The initial version is 00, next is 01 … up to 99.

file extension = [3 characters] Standard file extension for all input files received from SOC; it will be named for the input file type:
bin to indicate instrument command load

Sample LROC File names that correspond to the first iteration of the eight allowable command initializations sequences:

LROC_FSWLOAD_1_V00.bin

LROC_FSWLOAD_2_V00.bin

LROC_FSWLOAD_3_V00.bin;

…

LROC_FSWLOAD_8_V00.bin;

The LROC Instrument Initialization Command Sequence is a binary formatted file and as such, there is no sample product provided in Appendix B.

### 4.3.10 (LROC-3) LROC Daily Command Sequence

This file is the text version of daily LROC sequence that identifies times of imaging and other instrument-related command parameters. This file is delivered electronically to the LRO MOC, specifically the MPS element. This file is used for visual verification of the commands that the LROC SOC transmitted within the binary command load file referenced in the previous subsection.

All commands in the file must be defined in the LRO Telemetry and Command Handbook – Database (431-HDBK-000053). If the command contains submnemonics, they must be specified with the command.

#### 4.3.10.1 Product Details

The LROC SOC will provide support through all mission phases.

| | |
|---|---|
| Time interval | Variable based on WAC/NAC camera image commands |
| File duration | 3-4 days of daily command sequences |
| File or Data Generation Frequency | daily |
| Delivery method (real-time, SCP, FTP, etc) | scp to LRO MOC |
| Data Volume | Variable; based on number of command sequences, but nominally less that 256 KBytes |
| Accuracy (if it applies) | Times accurate to 1 second |
| Other pertinent details | File delivered no later than noon, Eastern for scheduling the first day's command sequences into the command uplink |

#### 4.3.10.2 Format

The LROC Daily Command Sequence is comma delimited, ASCII file that consists of a set of absolute time sequenced (in UTC) command mnemonics and any required sub-mnemonics. All commands in the file must be defined in the LRO Telemetry and Command Formats Handbook (431-HDBK-000052). If the command contains submnemonics, they must be specified with the command.

The fields are defined in the following table:

| Field name | Field Characteristics |
|---|---|
| Timetag:<br>year<br>day of year and<br>time of day | YYYY-DDD-HH:MM:SS where,<br>YYYY => 4 ASCII digits of year<br>DDD => 3 ASCII digits for day of year<br>HH:MM:SS => 8 ASCII digits for hour, minutes, and seconds with a ":" delimiter.<br>Note the "-" delimiter" separating YYYY, DDD, and HH:MM:SS. |
| Image Priority Number | 1 digit integer number (1-5) with 1 being the highest and 5 being the lowest |
| Command with Sub-Mnemonic | Valid LROC Command and Sub-Mnemonics as defined within the T&C Formats Handbook<br>CMD, SUB1=VAL1, SUB2=VAL2,…<br>There is a comma delimiter separating the command name and sub-mnemonic name(s)/value(s). Sub-mnemonic names are followed by a "=" and then the value of the sub-mnemonic. All command, sub-mnemonics, and sub-mnemonic values should be in capital letters except when specifying hex (notation is 0x) |

The following table provides the current set of LROC identified commands. The command names and parameters presented in the tables may change over time; however, we will not modify this ICD. The official source of commands is the latest LRO command database, which the MOT delivers to the SOCs and MPS each time the MOT modifies the command database.

The "Required" column indicates whether the SOC needs to specify the sub-mnemonic. If the field reads "Exclude", the sub-mnemonic value is fixed to one number and therefore should not be included when using the corresponding command in a sequence/timeline. If the field reads "Include", the sub-mnemonic value must be set even if the operator wants to use the default value for the command. The "Discrete" column indicates whether the sub-mnemonic has discrete value definitions. If the field has an "X", the SOC must specify the discrete value and not the corresponding fixed value. For example, if the sub-mnemonic is assigned values of "OFF" and "ON" with converted values of 0 and 1 respectively, the SOC must use "OFF" or "ON" and not 0 or 1.

***Table 4-30: Current Set of Available LROC Commands***

| | Sub-Mnemonic | Required | Data Type | Discrete | Default Value | Min Value | Max Value |
|---|---|---|---|---|---|---|---|
| **CMD** | **LRLOADFILE** | | | | | | |
| SUB | SADD | Exclude | U1 | | | 0x5C | 0x5C |
| SUB | VERS | Exclude | U1 | | | 0x00 | 0x00 |
| SUB | CMDID | Exclude | U1 | | | 0xF3 | 0xF3 |
| SUB | PAD1 | Exclude | U1 | | | 0x00 | 0x00 |
| SUB | XID | Include | U12 | | 0xAAAA | | |
| SUB | FILENAME | Include | S1 | | "INIT" | | |

| | Sub-Mnemonic | Required | Data Type | Discrete | Default Value | Min Value | Max Value |
|---|---|---|---|---|---|---|---|
| SUB | PAD2 | Exclude | U1 | | | 0x00 | 0x00 |
| SUB | PAD3 | Exclude | U1 | | | 0x00 | 0x00 |
| SUB | PAD4 | Exclude | U1 | | | 0x00 | 0x00 |
| SUB | PAD5 | Exclude | U1 | | | 0x00 | 0x00 |
| SUB | PAD6 | Exclude | U1 | | | 0x00 | 0x00 |
| SUB | PAD7 | Exclude | U1 | | | 0x00 | 0x00 |
| SUB | PAD8 | Exclude | U1 | | | 0x00 | 0x00 |
| SUB | PAD9 | Exclude | U1 | | | 0x00 | 0x00 |
| SUB | PAD10 | Exclude | U1 | | | 0x00 | 0x00 |
| SUB | PAD11 | Exclude | U1 | | | 0x00 | 0x00 |
| SUB | PAD12 | Exclude | U1 | | | 0x00 | 0x00 |
| SUB | PAD13 | Exclude | U1 | | | 0x00 | 0x00 |
| SUB | PAD14 | Exclude | U1 | | | 0x00 | 0x00 |
| SUB | PAD15 | Exclude | U1 | | | 0x00 | 0x00 |
| SUB | PAD16 | Exclude | U1 | | | 0x00 | 0x00 |
| **CMD** | **LRNAC** | | | | | | |
| SUB | SADD | Exclude | U1 | | | 0x5C | 0x5C |
| SUB | VERS | Exclude | U1 | | | 0x00 | 0x00 |
| SUB | CMDID | Exclude | U1 | | | 0xF4 | 0xF4 |
| SUB | PAD | Exclude | U1 | | | 0x00 | 0x00 |
| SUB | XID | Include | U12 | | 0xAAAA | | |
| SUB | TIME | Include | TIME44 | | | | |
| SUB | IMAGEID | Include | U1234 | | 0xFFFFFFFF | | |
| SUB | EXTIME | Include | U12 | | 0 | | |
| SUB | LINES | Include | U12 | | 1 | | |
| SUB | CPNDSEL | Include | U1 | | 0 | | |
| SUB | RESERVED | Exclude | U1 | | | 0x00 | 0x00 |
| SUB | TESTPAT | Include | U1 | X | NO_TEST | | |
| SUB | SUM | Include | U1 | X | NO_SUM | | |
| SUB | COMP | Include | U1 | X | NO_COMPRESS | | |
| SUB | NACSEL | Include | U1 | X | BOTH | | |
| SUB | RSTLVLL | Include | U1 | | 0 | | |
| SUB | RSTLVLR | Include | U1 | | 0 | | |
| SUB | OFFAL | Include | U12 | | 0 | | |
| SUB | OFFAR | Include | U12 | | 0 | | |
| SUB | OFFBL | Include | U12 | | 0 | | |
| SUB | OFFBR | Include | U12 | | 0 | | |

| | Sub-Mnemonic | Required | Data Type | Discrete | Default Value | Min Value | Max Value |
|---|---|---|---|---|---|---|---|
| **CMD** | **LRWAC** | | | | | | |
| SUB | SADD | Exclude | U1 | | | 0x5C | 0x5C |
| SUB | VERS | Exclude | U1 | | | 0x00 | 0x00 |
| SUB | CMDID | Exclude | U1 | | | 0xF5 | 0xF5 |
| SUB | PAD | Exclude | U1 | | | 0x00 | 0x00 |
| SUB | XID | Include | U12 | | 0xAAAA | | |
| SUB | TIME | Include | TIME44 | | | | |
| SUB | IMAGEID | Include | U1234 | | 0xFFFFFFFF | | |
| SUB | EXTIME | Include | U12 | | 0 | | |
| SUB | FRMS | Include | U12 | | 8 | | |
| SUB | CPNDSEL | Include | U1 | | 0 | | |
| SUB | RESERVED | Exclude | U1 | | | 0x00 | 0x00 |
| SUB | TESTPAT | Include | U1 | X | NO_TEST | | |
| SUB | WACPWR | Include | U1 | X | NO_CHANGE | | |
| SUB | POLAR | Include | U1 | X | NO_POLAR | | |
| SUB | COMP | Include | U1 | X | NO_COMPRESS | | |
| SUB | BAND | Include | U1 | X | ALL_BANDS | | |
| SUB | IFRMTIME | Include | U1 | | 0 | | |

The following file-naming convention is used for files transmitted between the LROC SOC and the LRO MOC. The filename consists of 20 characters; it also contains a three-character file extension name. There are underscores (_) between the file name fields and a period (.) between the file name and file extension fields. The form of the filename is as follows:

<instrument id>_<file content>_<YYYYDOY>_<yyyydoy>_<version number>.<file extension>

where instrument id = [4 characters]
LROC

file content = [3 characters] Intent of the instrument loads. For LROC this is identified as
DCS = Daily Command Sequence

Start Date = YYYYDOY where
YYYY => 4 ASCII digits of year (2008 – 2013)
DOY => 3 ASCII digits for day of year (1 – 366) Note: DOY represents the start time of data within the file, not the file creation time

| | | |
|---|---|---|
| Stop Date | = | yyyydoy where<br>yyyy => 4 ASCII digits of year (2008 – 2013)<br>doy => 3 ASCII digits for day of year (1 – 366) Note: doy represents the stop date of the time of data within the file, not the file creation time |
| version number | = | [3 characters] V followed by a two-digit version number. The initial version is 00, next is 01 … up to 99. |
| file extension | = | [3 characters] Standard file extension for all input files received from SOC; it will be named for the input file type:<br>ict for instrument command timeline |

A sample file names for the LROC generated daily command load file that corresponds to the first iterations of daily commands for 25 January 2009 through 28 January 2009 is LROC_DCS_2009025_2009028_V00.ict

A sample LROC Daily Command Sequence File is provided in Appendix B, Figure B.3-11.

### 4.3.11 (MIRF-3) Mini-RF Command Timeline

This file contains a set of command sequences that the MOC uses to create a daily load for uplink to the Mini-RF instrument.

All commands in the file must be defined in the LRO Telemetry and Command Handbook – Database (431-HDBK-000053). If the command contains submnemonics, they must be specified with the command.

#### 4.3.11.1 Product Details

| | |
|---|---|
| Time interval | Variable based on Mini-RF commands |
| File duration | 24 hours |
| File or Data Generation Frequency | As needed whenever Mini-RF is operating |
| Delivery method (real-time, SCP, FTP, etc) | scp to LRO MOC |
| Data Volume | Variable; based on number of command sequences, but nominally less that 256 KBytes |
| Accuracy (if it applies) | Times accurate to 1 second |
| Other pertinent details | File delivered no later than noon, Eastern for uplink within the same day |

#### 4.3.11.2 Format

The Mini-RF Command Timeline is a comma-delimited, ASCII file that consists of a set of absolute time sequenced (in UTC) command mnemonics and any required sub-mnemonics. All commands in the file must be defined in the LRO Telemetry and Command Formats Handbook (431-HDBK-000052).

The fields are defined in the following table:

| Field name | Field Characteristics |
|---|---|
| Timetag:<br>year<br>day of year and<br>time of day | YYYY-DDD-HH:MM:SS where,<br>YYYY => 4 ASCII digits of year<br>DDD => 3 ASCII digits for day of year<br>HH:MM:SS => 8 ASCII digits for hour, minutes, and seconds with a ":" delimiter.<br>Note the "-" delimiter" separating YYYY, DDD, and HH:MM:SS. |
| Command with Sub-Mnemonic | Valid Mini-RF Command and Sub-Mnemonics as defined within the T&C Formats Handbook<br>CMD, SUB1=VAL1, SUB2=VAL2,…<br>There is a comma delimiter separating the command name and sub-mnemonic name(s)/value(s). Sub-mnemonic names are followed by a "=" and then the value of the sub-mnemonic. All command, sub-mnemonics, and sub-mnemonic values should be in capital letters except when specifying hex (notation is 0x) |

The following table provides the current set of Mini-RF identified commands. The command names and parameters presented in the tables may change over time; however, we will not modify this ICD. The official source of commands is the latest LRO command database, which the MOT delivers to the SOCs and MPS each time the MOT modifies the command database.

The "Required" column indicates whether the SOC needs to specify the sub-mnemonic. If the field reads "Exclude", the sub-mnemonic value is fixed to one number and therefore should not be included when using the corresponding command in a sequence/timeline. If the field reads "Include", the sub-mnemonic value must be set even if the operator wants to use the default value for the command. The "Discrete" column indicates whether the sub-mnemonic has discrete value definitions. If the field has an "X", the SOC must specify the discrete value and not the corresponding fixed value. For example, if the sub-mnemonic is assigned values of "OFF" and "ON" with converted values of 0 and 1 respectively, the SOC must use "OFF" or "ON" and not 0 or 1.

**Table 4-31: Available Mini-RF Commands**

| | Sub-Mnemonic | Required | Data Type | Discrete | Default Value | Min Value | Max Value |
|---|---|---|---|---|---|---|---|
| **CMD** | **MRACTIVATE** | | | | | | |
| SUB | EOH | Exclude | U12 | | | 0x5A5A | 0x5A5A |
| SUB | BOARD | Include | U1 | X | | 0x00 | 0xFF |
| **CMD** | **MRDEACTIVATE** | | | | | | |

| | Sub-Mnemonic | Required | Data Type | Discrete | Default Value | Min Value | Max Value |
|---|---|---|---|---|---|---|---|
| SUB | EOH | Exclude | U12 | | | 0x5A5A | 0x5A5A |
| **CMD** | **MRPARAMDMP** | | | | | | |
| SUB | EOH | Exclude | U12 | | | 0x5A5A | 0x5A5A |
| **CMD** | **MRRESET** | | | | | | |
| SUB | EOH | Exclude | U12 | | | 0x5A5A | 0x5A5A |
| **CMD** | **MRSAFE** | | | | | | |
| SUB | EOH | Exclude | U12 | | | 0x5A5A | 0x5A5A |
| **CMD** | **MRSOFTBOOT** | | | | | | |
| SUB | EOH | Exclude | U12 | | | 0x5A5A | 0x5A5A |
| **CMD** | **MRSTANDBY** | | | | | | |
| SUB | EOH | Exclude | U12 | | | 0x5A5A | 0x5A5A |
| **CMD** | **MRCOLLECT** | | | | | | |
| SUB | EOH | Exclude | U12 | | | 0x5A5A | 0x5A5A |
| SUB | COMMS_OPI | Include | U1 | | | 0 | 0xFF |
| SUB | COMMS_RX | Include | U1 | | | 0 | 0xF |
| SUB | COMMS_ENC | Include | U1 | X | | | |
| SUB | DIS_RESET | Include | U1 | X | | | |
| SUB | OPTION | Include | U1 | X | | | |
| SUB | APID | Include | U12 | | | 0x8C | 0xBC |
| SUB | WAV_ID | Include | U12 | | | 0x00 | 0x3FF |
| SUB | OPI | Include | U1 | X | | | |
| SUB | CCSDS_SPW | Include | U12 | | | | |
| SUB | VCH_ATTN | Include | U1 | | | 0x00 | 0x3E |
| SUB | HCH_ATTN | Include | U1 | | | 0x00 | 0x3E |
| SUB | BURSTS | Include | U12 | | | 1 | 0x2710 |
| SUB | EXP_ID | Include | U12 | | | 0 | 0xFFFF |
| SUB | RPF_DECFAC | Include | U1 | | | 0 | 0xF |
| SUB | PTP_INT | Include | U1 | | | 0 | 0x7 |
| SUB | APF | Include | U1 | | | 0 | 0x7 |
| SUB | BAQ | Include | U1 | | | 0x1 | 0xB |
| **CMD** | **MRMEMDMP** | | | | | | |
| SUB | EOH | Exclude | U12 | | | 0x5A5A | 0x5A5A |
| SUB | TYPE | Include | U1 | X | | | |
| SUB | ADDRESS | Include | U1234 | | | 0x00 | 0x003FFFFC |
| SUB | NUMBYTES | Include | U1234 | | | 0x00000004 | 0x00400000 |
| **CMD** | **MRCTRL** | | | | | | |
| SUB | EOH | Exclude | U12 | | | 0x5A5A | 0x5A5A |

| | Sub-Mnemonic | Required | Data Type | Discrete | Default Value | Min Value | Max Value |
|---|---|---|---|---|---|---|---|
| SUB | BOARD | Include | U1 | X | | 0x02 | 0x12 |
| SUB | NUM_REG | Include | U12 | | | 0x01 | 0x02 |
| SUB | ADD_DATA1 | Include | U1234 | | | 0x00 | 0xFFFFFFFF |
| SUB | ADD_DATA2 | Include | U1234 | | | 0x00 | 0xFFFFFFFF |
| **CMD** | **MRWAVEDMP** | | | | | | |
| SUB | EOH | Exclude | U12 | | | 0x5A5A | 0x5A5A |
| SUB | TABLE_ID | Include | U12 | | | 0x0000 | 0x03FF |
| **CMD** | **MRCRC** | | | | | | |
| SUB | EOH | Exclude | U12 | | | 0x5A5A | 0x5A5A |
| SUB | TYPE | Include | U1 | X | | | |
| SUB | CRC | Include | U12 | | | | |
| SUB | ADDRESS | Include | U1234 | | | 0x00 | 0x003FFFFC |
| SUB | NUMBYTES | Include | U1234 | | | 0x00000004 | 0x00400000 |
| **CMD** | **MRBIT** | | | | | | |
| SUB | EOH | Exclude | U12 | | | 0x5A5A | 0x5A5A |
| **CMD** | **MRDRXEXTBLREAD** | | | | | | |
| SUB | EOH | Exclude | U12 | | | 0x5A5A | 0x5A5A |
| SUB | BOARD | Include | U1 | X | | | |
| SUB | NUM | Exclude | U1234 | | | 0x00000040 | 0x00000040 |
| SUB | TBL_ID | Include | U1234 | | | 0x00000000 | 0x00000003 |
| SUB | ADDR_OS | Include | U1234 | | | 0x00000000 | 0x00003E40 |
| **CMD** | **MRDECOMPRESS** | | | | | | |
| SUB | EOH | Exclude | U12 | | | 0x5A5A | 0x5A5A |
| SUB | CRC | Include | U12 | | | | |
| SUB | FROM_TYPE | Include | U1 | X | | | |
| SUB | TO_TYPE | Include | U1 | X | | | |
| SUB | FROM_ADDRESS | Include | U1234 | | | 0x00004000 | 0x003FFFFC |
| SUB | TO_ADDRESS | Include | U1234 | | | 0x00004000 | 0x003FFFFC |
| SUB | NUMBYTES | Include | U1234 | | | 0x00000004 | 0x00400000 |
| **CMD** | **MRMEMCOPY** | | | | | | |
| SUB | EOH | Exclude | U12 | | | 0x5A5A | 0x5A5A |
| SUB | FROM_TYPE | Include | U1 | X | | 0x01 | 0x03 |
| SUB | TO_TYPE | Include | U1 | X | | | |
| SUB | FROM_ADDRESS | Include | U1234 | | | 0x00000000 | 0x003FFFFC |
| SUB | TO_ADDRESS | Include | U1234 | | | 0x00000000 | 0x003FFFFC |
| SUB | NUMBYTES | Include | U1234 | | | 0x00000004 | 0x00400000 |
| **CMD** | **MRNOOP** | | | | | | |

| | Sub-Mnemonic | Required | Data Type | Discrete | Default Value | Min Value | Max Value |
|---|---|---|---|---|---|---|---|
| SUB | EOH | Exclude | U12 | | | 0x5A5A | 0x5A5A |
| **CMD** | **MRBOOTMEMCOPY** | | | | | | |
| SUB | EOH | Exclude | U12 | | | 0x5A5A | 0x5A5A |
| SUB | FROM_TYPE | Include | U1 | X | | | |
| SUB | TO_TYPE | Include | U1 | X | | | |
| SUB | FROM_ADDRESS | Include | U1234 | | | 0x00000000 | 0x003FFFFC |
| SUB | TO_ADDRESS | Include | U1234 | | | 0x00000000 | 0x003FFFFC |
| SUB | NUMBYTES | Include | U1234 | | | 0x00000004 | 0x00400000 |
| **CMD** | **MRBOOTEXECUTE** | | | | | | |
| SUB | EOH | Exclude | U12 | | | 0x5A5A | 0x5A5A |
| SUB | ADDRESS | Include | U1234 | | | 0x00000000 | 0x003FFFFC |
| **CMD** | **MRBOOTMEMDMP** | | | | | | |
| SUB | EOH | Exclude | U12 | | | 0x5A5A | 0x5A5A |
| SUB | TYPE | Include | U1 | X | | | |
| SUB | ADDRESS | Include | U1234 | | | 0x00 | 0x003FFFFC |
| SUB | NUMBYTES | Include | U1234 | | | 0x00000004 | 0x00400000 |
| **CMD** | **MRBOOTCRC** | | | | | | |
| SUB | EOH | Exclude | U12 | | | 0x5A5A | 0x5A5A |
| SUB | TYPE | Include | U1 | X | | | |
| SUB | CRC | Include | U12 | | | | |
| SUB | ADDRESS | Include | U1234 | | | 0x00 | 0x003FFFFC |
| SUB | NUMBYTES | Include | U1234 | | | 0x00000004 | 0x00400000 |

The following file-naming convention is used for files transmitted between the Mini-RF SOC and the LRO MOC. The filename consists of 30 characters; it also contains a three-character file extension name. There are underscores (_) between the file name fields and a period (.) between the file name and file extension fields. The form of the filename is as follows:

<instrument id>_<file content>_<YYYYDOY>_<yyyydoy>_<version number>.<file extension>

where instrument id = [4 characters]
MINI for Mini-RF; followed by the underscore (_) character

file content = [4 characters] Intent of the instrument loads. CMDTL to represent a Command Timeline File

Start Date = YYYYDOY based on UTC Timeframe
DOY = start date of data in file and not the creation date

Stop Date yyyydoy based on UTC Timeframe
doy = stop date of data in file and not the creation date

version number = [3 characters] V followed by a two-digit version number. The initial version is 00, next is 01 … up to 99.

file extension = [3 characters] Standard file extension for all input files received from a SOC; it will be named for the input file type:
ict to represent instrument command timeline

For example, the first generation of the MINI-RF Command timeline for 09 Feb 2009 through 12 February 2009 would have a sample file name of MINI_CMDTL_2009040_2009043_V00.ict

A sample Mini-RF Command Timeline is provided in Appendix B, Figure B.3-13.

## 4.4 LRO FSWM Facility to LRO MISSION MOC INTERFACE PRODUCTS

This section contains the interface between the Flight SW Maintenance (FSWM) Facility and the LRO MOC; the FSWM facility resides at GSFC within the FSW Branch, Code 582. This interface is used to transfer the on-board FSW updates for table and memory loads to the Orbiter.

### 4.4.1 (FSWM-1) Orbiter FSW Load Files

This file contains the table or memory updates that are generated and verified by the FSW branch. These files are used to modify the on-board memory of the LRO single board computer. As an example, the FSWM group will generate calibration tables for uplink; these include the gyro cal, star tracker cal, and HGA cal tables. The FSWM group is responsible for the generation of other Orbiter-specific tables that support the on-board flight software.

#### 4.4.1.1 Product Details

| | |
|---|---|
| Time interval | NA |
| File duration | NA |
| File or Data Generation Frequency | As needed whenever FSWM group identifies need to modify spacecraft FSW or as directed by the project to update a specific FSW table |
| Delivery method (real-time, SCP, FTP, etc) | scp to LRO MOC |
| Data Volume | Variable; based on updated table |
| Accuracy (if it applies) | NA |
| Other pertinent details | File delivered 2-3 days prior to requested uplink to allow sufficient time to verify load against the FLATSAT simulator |

#### 4.4.1.2 Format

The Orbiter FSW Load File contains the updated memory and is a binary formatted file. Since the file is a binary format, no sample product is shown in Appendix B.

The file name for this memory/table load is defined in the FSW User's Guide.

## 4.5 LRO MISSION OPERATIONS CENTER PRODUCTS AND DESCRIPTIONS

This section contains the interface products generated by the LRO MOC. In some cases, these products were originally created by other facilities, such as the LRO Flight Dynamics Facility or the stations and transferred to the LRO MOC. The LRO MOC then controls the delivery of these files to the science centers and the Planetary Data System (PDS) facility.

These subsections provide the details related to the products that the LRO MOC transmits to each individual science center.

### 4.5.1 (MOC-7) Daily Command Load Report

This file contains the textual version of the daily uplinked command load, which the LRO MOC sent to the LRO spacecraft.

#### 4.5.1.1 Product Details

| | |
|---|---|
| Time interval | Variable based on integrated set of commands received from all groups |
| File duration | Next 24 hours of commands that the MOT approved for uplinked |
| File or Data Generation Frequency | Daily |
| Delivery method (real-time, SCP, FTP, etc) | MOC scp pushes to all SOCs |
| Data Volume | Variable; based on number of command sequences, but nominally less that 256 KBytes |
| Accuracy (if it applies) | Time accurate to 1 second |
| Other pertinent details | MOT signs approval of this textual version of the ATS Load file, which corresponds to the binary load file that the MOC uploads to the Orbiter |

#### 4.5.1.2 Format

The Daily Command Load consists of the complete textual set of integrated commands sent to the LRO spacecraft. This Daily Command Load Report consists of the integrated spacecraft housekeeping commands to manage the LRO health and safety and the received set of instrument commands for any/all science centers. This command report defines the load for next day; based on operations team approval and signature of the corresponding binary load.

The daily command load report contains the following data items:

- Header Information
- Command Summary
- File Input Summary
- Error/Constraint Summary
- ATS Summary Report

The header informational area contains an overall meta-summary concept of the information contained within the remainder of the report. This data includes:

- Mission – hard coded to LRO
- MPS Version – version of the MPS
- Command DB Version – Command database version
- Load File (Name) – for example: SC_2009201_0005_A_V01.ATS
- Load Creation Time - time the ATS load was generated
- Load Start Time (First Cmd) - execution time of first command within the ATS load
- Load Stop Time (Last Cmd) - execution time of last command within the ATS load, which will typically be the Buffer Switch command.
- ATS Buffer – ATS buffer for which the ATS load is destined
- ATS Buffer Size (Bytes) - maximum size of the ATS buffer, as determined from MPS configuration file
- Load Uplink Size (Bytes); Includes Overhead - size, in bytes, of the load, including the Packet/Frame Overhead
- Load Data Size (Bytes) – size, in bytes, of the load (Command data only)
- Number of ATS Commands - # of commands within the load
- Number of Critical Commands - # of critical commands within the load
- Estimated Time of Uplink @ 4 Kbps (Minutes) - calculated time required to uplink file
- Number of Ka-Band Supports - # of K-band supports for the ATS load period

The Command Summary will provide a counter for the number of commands, for each instrument and subsystem, contained with the ATS load. The bottom line of the summary report will provide a total number of commands for all instruments and subsystems.

The File Input Summary will identify the file names (including versions) of each input file that the mission planning system used in the generation of the ATS Load.

The Error/Constraint Summary will identify all errors or constraints that occurred in the generation process of the ATS Load, including an explanation of each error.

The Daily ATS Summary Report will provide a detailed listing of the commands included within the ATS load. The report will include the following information:

- Source - identifies the source of the command for the applicable subsystem or instrument (e.g., LA_COMMAND, LO_COMMAND, etc…)
- Command Number - ATS buffer command number

- Command Execution Time - ATS command execution time (YYYY-DOY-HH:MM:SS)
- Command Mnemonic, Submnemonic, and Value - Command mnemonics will be listed
  - When commands contain submnemonics, the submnemonic and the associated value should be reported on a separate line (below the command). The submnemonics should be indented (formatted) such that they are easily distinguished from commands.
- Activity/RTS ID - identifies the Activity ID for which the command was generated. For RTS commands, the RTS ID and RTS Number should be included in this field.
- Command Description - the command description, as extracted from the command database.
- Criticality Flag - is a flag to support easy identification of critical commands. When a critical command is included in the ATS load (determined from the criticality flag from the command database), the field will contain a flag ("C") indicating the command is critical.

The LRO MOC uses the following file-naming convention for MOC-transmitted files. The filename consists of 21 characters; it also contains a three character file extension name. There are underscores (_) between the file name designators and there is a period (.) between the file name and file extension fields. The form of the filename is as follows:

<File Designator>_<YYYYDOY>_<HHMM>_<ATS Buffer>_<version number>.<file extension>

| | | | |
|---|---|---|---|
| where | File Name | = | 21 Characters; used to identify the MOC generated file name and start date of data |
| | File Designator | = | [6 characters] to identify file (followed by underscore (_)<br>SC |
| | Date | = | [7 characters], YYYYDOY represented in UTC format and followed by underscore(_);where<br>YYYY => 4 ASCII digits of year (2008 – 2013)<br>DOY => 3 ASCII digits for day of year (1 – 366) and where day of year indicates the first day for which data are represented |
| | Time | = | [5 characters], HHMM represented in time format and followed by underscore(_);where<br>HH => 2 ASCII digits of hours (00 - 23)<br>MM => 2 ASCII digits for minutes (00 - 59) |
| | ATS Buffer | = | [1 Character]; to identify the specific ATS Buffer<br>= either A or B |

version number = [3 characters] V, followed by a two-digit version number. The initial version is 00, next is 01 … up to 99.

file extension = [3characters] Standard file extension for all input files received from a SOC; it will be named for the input file type:
txt for text files

A sample LRO Daily Command Load Report file name for buffer A is identified as SC_2006301_1235_A_V01.txt

A sample Daily Command Load Report is provided in Appendix B, Figure B.4-1.

### 4.5.2 (MOC-2) SPICE SCLK Clock Correlation File

The SCLK kernel will be cumulative file for the entire mission. During the prime mission phase, the clock on board the LRO orbiter should be accurate enough that it should never need adjustment baring some anomaly or Orbiter reset, or leap-second adjustment. Another purpose for the kernel is to easily convert to other time systems UTC, TDB or TDT, etc. using the SPICE toolkit.

#### 4.5.2.1 Product Details

| | |
|---|---|
| Time interval | Variable based on whenever MOT schedules Orbiter clock updates; could be up to seven entries per day |
| File duration | NA; file represents historical concepts for all clock correlations |
| File or Data Generation Frequency | As needed |
| Delivery method (real-time, SCP, FTP, etc) | MOC scp pushes to all SOCs |
| Data Volume | Variable; based on number of clock drift updates, but nominally less that 50 KBytes |
| Accuracy (if it applies) | Time accurate to 1 second |
| Other pertinent details | NA |

#### 4.5.2.2 Format

The Clock Correlation File is an ASCII-formatted file; the SCLK kernel is to document the clock drift rate. This allows one to project where the orbiter clock will be (in relation to UTC) in the future very accurately. If 100 ms is accurate enough then the SOCs would not need to reference this kernel. Otherwise, the SOCs will need it or some other clock correlation data.

The file contents are delimited with the following terms:

\begin text and \begin data

The number of lines within each area is variable. The \begintext designator provides the LRO MOC to sufficiently document and provide commentary that allows the end-users, the SOCs, to understand the actual data. The \begindata designator signifies the start of Clock correlation data, such as the LRO SPICE ID, clock data, number and types of partitions.

The MOC uses the following file-naming convention for this file. The filename consists of 22 characters; it also contains a three character file extension name. There are underscores (_) between the file name fields and a period (.) between the file name and file extension fields. Since this file is transferred to the NAIF for eventual archive, the file name is entirely lower-case to support the NAIF-documented conventions.

The form of the filename is as follows:

<Mission Designator>_<File Type>_<YYYYDOY>_<version number>.<file extension>

where File Name = [22 Characters]

Mission Designator = [3 characters] to identify file (followed by underscore (_)
lro

File Type = [6 Characters] followed by the underscore (_)
clkcor_

Date = [7 characters], YYYYDOY; represented in UTC format and followed by underscore(_);where
YYYY => 4 ASCII digits of year (2008 – 2013)
DOY => 3 ASCII digits for day of year (1 – 366) and where day of year indicates when the file is generated

version number = [3 characters] v, followed by a two-digit version number. The initial version is 00, next is 01 … up to 99.

file extension = [3characters] Standard file extension for the SPICE Clock Correlation File
tsc

Sample File name is lro_clkcor_2009015_v00.tsc

The SCLK kernel is an ASCII formatted file that contains commentary fields to document the data representation fields. A sample Clock Correlation File is provided in Appendix B, Figure B.4-3.

#### 4.5.3 (MOC-33) SPICE Event Kernel

The SPICE Event kernel identifies the various spacecraft, orbiter, or science events occurring on a nominal day or orbit boundary that are used to denote times of no science data capture events, such as the station keeping maneuvers.

#### 4.5.3.1 Product Details

| | |
|---|---|
| Time interval | Variable based on integrated set of activities for all identified spacecraft events that resulted in science data outages |
| File duration | Contains the previous 7-days information that identifies when there were periods of no science data collection |
| File or Data Generation Frequency | Weekly, on Monday by noon-time Eastern |
| Delivery method (real-time, SCP, FTP, etc) | scp to all SOCs (MOC performs the scp push) |
| Data Volume | Variable; number of entries that identity no science data collection |
| Accuracy (if it applies) | Time accurate to 1 second |
| Other pertinent details | NA |

#### 4.5.3.2 Format

The Events Kernel is a Binary-formatted file that consists of the complete set of event sequences (in sequential time-order) when any instrument is not collecting science data, such as during spacecraft station keeping maneuvers.

The LRO MOC uses the following file-naming convention for this file; the filename consists of 22 characters; it also contains a three character file extension name. There are underscores (_) between the file name fields and a period (.) between the file name and file extension fields.

A sample file name for the first generation of this data file is given as.

<File Designator>_<Start Date>_<Stop Date>_<Version>.<File Extension>

where File Designator = [10 characters] token identifying the file; is "lro_events" to indicate this is the Events Kernel; followed by the underscore (_) character

Start Date = [7 characters], YYYYDOY; represented in UTC format and followed by underscore(_);where
YYYY => 4 ASCII digits of year (2008 – 2013)
DOY => 3 ASCII digits for day of year (1 – 366) identifies the start date for the data contained within the file

Stop Date = [7 characters], YYYYDOY; represented in UTC format and followed by underscore(_);where
YYYY => 4 ASCII digits of year (2008 – 2013)
DOY => 3 ASCII digits for day of year (1 – 366); identifies the stop date for the data contained within the file

version number = [3 characters] v, followed by a two-digit version number. The initial version is 00, next is 01 … up to 99.

file extension = [3characters] Standard file extension for the binary sequence LRO Event Kernel file
bes

Sample File name is lro_events_2009015_2009022_v01.bes

The SPICE Event Kernel is an binary file and as such, no sample product is provided in Appendix B.

### 4.5.4 (MOC-40) SPICE FK – Frame Kernels

The Frame kernel provides the definition and specification and the relationship between the various references frames (coordinate systems) used on the Orbiter; this includes reference mounting angles and reference matrices for various spacecraft HW and actuators, as well as the science instrument mounting alignments. Multiple LRO groups provide the inputs to create this file; these inputs are in the form of various project derived documentation.

#### 4.5.4.1 Product Details

| | |
|---|---|
| Time interval | NA; file is a set of reference frames |
| File duration | NA; no times in file |
| File or Data Generation Frequency | Possibly generated twice; once pre-launch and once soon after launch (post commissioning phase) |
| Delivery method (real-time, SCP, FTP, etc) | MOC scp pushes to all SOCs |
| Data Volume | Variable; based on number of command sequences, but nominally less that 25 KBytes |
| Accuracy (if it applies) | NA |
| Other pertinent details | NA |

#### 4.5.4.2 Format

The Frames Kernel File is an ASCII-formatted file that provides LRO body, sensor and instrument alignments and rotation angles to transform from one reference frame to another.

The MOC uses the following file-naming convention for this file. The filename consists of 22 characters; it also contains a two-character file extension name. There are underscores (_) between the file name fields and a period (.) between the file name and file extension fields.

A sample file name for the first generation of this data file is given as.

<File Designator>_<YYYYDOY>_<version number>.<file extension>

where File Name = [22 Characters]

File Designator = [10 characters] to identify file (followed by underscore (_)
lro_frames

Date = [7 characters], YYYYDOY; represented in UTC format and followed by underscore(_);where
YYYY => 4 ASCII digits of year (2008 – 2013)
DOY => 3 ASCII digits for day of year (1 – 366) and where day of year indicates when the file is generated

version number = [3 characters] V, followed by a two-digit version number. The initial version is 00, next is 01 … up to 99.

file extension = [2characters] Standard file extension to identify this is an ASCII text file for the LRO Frames
tf

Sample File name is lro_frames_2009015_v01.tf

The SPICE Frames Kernel is an ASCII file and is shown in the Appendix B, Figure B.4-5.

### 4.5.5 (MOC-41) SPICE Predicted CK (Predicted S/C Orientation)

The SPICE Predicted CK file contains the predicted LRO spacecraft orientation with respect to its orbit.

#### 4.5.5.1 Product Details

| | |
|---|---|
| Time interval | Variable; slew maneuver dependent<br>Nominally every 2 seconds<br>During maneuver, it is predicated on slew type and required frequency to support slew |
| File duration | Next 7 days of predicted s/c attitude data |
| File or Data Generation Frequency | Daily<br>However, can vary based on maneuver support requirements; data generation frequency is listed in the FDF-GS&O Operations Agreement (451-MOA-002960)<br>For normal mission ops, due NLT 4 pm local or 1 hour after receipt of all necessary input files, whichever time is later |
| Delivery method (real-time, SCP, FTP, etc) | MOC scp pushes to all SOCs |
| Data Volume | Approximately 12 MBytes |
| Accuracy (if it applies) | supports accuracy requirement for slew maneuvers |
| Other pertinent details | NA |

.

#### 4.5.5.2 Format

The SPICE Predicted CK File is a binary formatted file generated by the SPICE Toolset. A sample file name for the first generation of this data file is given as moc41_2009015_2009022_v01.bc for a SPICE-binary formatted file; this file type is platform independent.

The SPICE ID for LRO is -85, as assigned by JPL; the predicted CK file will be type 3; the instrument ID associated with the spacecraft body is listed as -85000. Since this is a binary formatted file, no sample product will be shown in Appendix B.

The SPICE CK file does support embedded ASCII comments that the MOC/AGS element will insert into the file; Appendix B, Figure B.4-6 provides a sample of these types of comments that can be included in any of these SPICE CK files (both predictive and definitive).

### 4.5.6 <u>(MOC-42) SPICE Definitive CK (Definitive S/C Orientation)</u>

The SPICE Definitive CK file contains the definitive LRO spacecraft orientation.

#### 4.5.6.1 Product Details

| | |
|---|---|
| Time interval | Frequency can be up to 5 Hz |
| File duration | Previous 24 hours of data; nominally set for 0000Z of the previous day to 0000Z of current day<br>This is user-selectable time range |
| File or Data Generation Frequency | Daily; 1 file per day<br>However, can vary based on maneuver support requirements; data generation frequency is listed in the FDF-GS&O Operations Agreement (451-MOA-002960)<br>For normal mission ops (or when no maneuvers), NLT 4 pm local the day after the 24 hour dataset is delivered |
| Delivery method (real-time, SCP, FTP, etc) | MOC scp pushes to all SOCs<br>MOC scp to FDF via the FD Communications Server; the backup uses the FDPC (MOC performs the scp push) |
| Data Volume | Approximately 27 Mbytes |
| Accuracy (if it applies) | nominally best case is $10^{-15}$ for no data interpolation across time intervals<br>accuracy of the data quaternion (worst case) for a single quaternion element is approximately $10^{-8}$ (based on interpolating time if not from the same time interval) |
| Other pertinent details | NA |

#### 4.5.6.2 Format

The SPICE Definitive CK File is a binary formatted file generated by the SPICE Toolset. A sample file name for the first generation of this data file is given as moc42_2009014_2009015_v01.bc for a SPICE binary formatted file.

The SPICE ID for LRO is -85, as assigned by JPL; the predicted CK file will be type 3; the instrument ID associated with the spacecraft body is listed as -85000. Since this is a binary formatted file, no sample product will be shown in Appendix B.

The SPICE CK file does support embedded ASCII comments that the MOC/AGS element will insert into the file; Appendix B, Figure B.4-6 provides a sample of these types of comments that can be included in any of these SPICE CK files (both predictive and definitive). The spacecraft attitude system does not calculate any angular rates; the definitive spacecraft ck kernel only contains default angular rates using the SPICE Utility to create these values.

### 4.5.7 (MOC-43) SPICE Definitive HGA Orientation CK

This SPICE Definitive CK file contains the definitive orientation of the High-Gain Antenna with respect to the LRO spacecraft.

#### 4.5.7.1 Product Details

| | |
|---|---|
| Time interval | Frequency can be up to 5 Hz |
| File duration | Previous 24 hours of data; nominally set for 0000Z of the previous day to 0000Z of current day<br>This is user-selectable time range |
| File or Data Generation Frequency | Daily; 1 file per day<br>However, can vary based on maneuver support requirements; data generation frequency is listed in the FDF-GS&O Operations Agreement (451-MOA-002960)<br>For normal mission ops (or when no maneuvers), NLT 4 pm local the day after the 24 hour dataset is delivered |
| Delivery method (real-time, SCP, FTP, etc) | MOC scp pushes to all SOCs, except for DLRE and Mini-RF<br>MOC scp to FDF via the FD Communications Server; the backup uses the FDPC (MOC performs the scp push) |
| Data Volume | Approximately 27 Mbytes |
| Accuracy (if it applies) | The HGA angle accuracy is approximately $10^{-7}$ (in radians) |
| Other pertinent details | Valid only for post-LOI mission phases |

#### 4.5.7.2 Format

The SPICE Definitive HGA CK File is a binary formatted file generated by the SPICE Toolset. The data consists of the definitive HGA orientation as represented by a three-component Euler angle. The first component is set to a zero angle offset and the second and third Euler angles represent the HGA articulated angles.

A sample file name for the first generation of this data file is given as moc43_2009014_2009015_v01.bc for a SPICE Binary formatted file

The SPICE ID for LRO is -85, as assigned by JPL; the predicted CK file will be type 3; the instrument ID associated with the HGA reference is listed as -85020. Since this is a binary formatted file, no sample product will be shown in Appendix B.

The SPICE CK file does support embedded ASCII comments that the MOC/AGS element will insert into the file; Appendix B, Figure B.4-6 provides a sample of these types of comments that can be included in any of these SPICE CK files (both predictive and definitive). The spacecraft attitude system does not calculate any angular rates; the definitive High Gain Array ck kernel only contains default angular rates using the SPICE Utility to create these values.

### 4.5.8 (MOC-44) SPICE Definitive SA Orientation CK

This SPICE Definitive CK file contains the definitive orientation of the Solar Arrays with respect to the LRO spacecraft.

#### 4.5.8.1 Product Details

| | |
|---|---|
| Time interval | At 5 Hz frequency interval |
| File duration | Approximately the previous 24 hours of data nominally set for 0000Z of the previous day to 0000Z of current day<br>This is user-selectable time range |
| File or Data Generation Frequency | Daily; 1 file per day<br>However, can vary based on maneuver support requirements; data generation frequency is listed in the FDF-GS&O Operations Agreement (451-MOA-002960)<br>For normal mission ops (or when no maneuvers), NLT 4 pm local the day after the 24 hour dataset is delivered |
| Delivery method (real-time, SCP, FTP, etc) | MOC scp pushes to all SOCs, except for DLRE and Mini-RF<br>MOC scp to FDF via the FD Communications Server; the backup uses the FDPC (MOC performs the scp push) |
| Data Volume | Approximately 27 Mbytes |
| Accuracy (if it applies) | The SA angle accuracy is approximately $10^{-7}$ (in radians) |
| Other pertinent details | Valid only for post-LOI mission phases |

#### 4.5.8.2 Format

The SPICE Definitive SA CK File is a binary formatted file generated by the SPICE Toolset. The data consists of the definitive SA orientation as represented by a three-component Euler angle. The first component is set to a zero angle offset and the second and third Euler angles represent the SA articulated angles.

A sample file name for the first generation of this data file is given as moc44_2009014_2009015_v01.bc for a SPICE Binary formatted file.

The SPICE ID for LRO is -85, as assigned by JPL; the predicted CK file will be type 3; the instrument ID associated with the spacecraft body is listed as -85030. Since this is a binary formatted file, no sample product will be shown in Appendix B.

The SPICE CK file does support embedded ASCII comments that the MOC/AGS element will insert into the file; Appendix B, Figure B.4-6 provides a sample of these types of comments that can be included in any of these SPICE CK files (both predictive and definitive). The spacecraft attitude system does not calculate any angular rates; the definitive Solar Array ck kernel only contains default angular rates using the SPICE Utility to create these values.

### 4.5.9 Instrument – Spacecraft Housekeeping Data File

This file contains the selected spacecraft telemetry parameters used by the instrument; it includes information such as attitude, spacecraft temperatures, etc. Once the SOC identifies the requested telemetry points, the corresponding APIDs will be extracted and archived in separate file for the instruments.

#### 4.5.9.1 Product Details

| | |
|---|---|
| Time interval | Variable based on Orbiter Housekeeping Data collection filters and per APID |
| File duration | Variable, based on ground commands to open/close files |
| File or Data Generation Frequency | Variable based on file duration concepts above |
| Delivery method (real-time, SCP, FTP, etc) | scp from the MOC to the various SOCs<br>Files delivered as available and should be complete within twelve hours of receipt |
| Data Volume | Variable; based on APIDs and storage rate |
| Accuracy (if it applies) | NA; based on data mnemonics for specified APIDs |
| Other pertinent details | Delivered within 24 hours of ground receipt<br>The MOC transmits the LEND Spacecraft HK Data files to both the GSFC and University of Arizona SOCs<br>The MOC will rate limit Mini-RF data file transfer to the Mini-RF SOC so as not to exceed to 400 kbps |

#### 4.5.9.2 Format

The Instrument – Spacecraft Housekeeping Data File consists of the complete set of LRO spacecraft telemetry APIDs that the specific SOC has identified to support its internal processing.

The Operations team sets the base file name on a daily basis using commands to set the base filename for each instrument directory. The instrument appends a sequence counter to the end of the filename. The file name can be up to 40 characters in length, contains the complete directory path information, and includes the file extension.

The LROC-specific file naming conventions are defined in Section 4.5.11

The file name conventions and standards are defined in the following table:

***Table 4-32 SOC File Naming Conventions and Descriptions***

| File Name qualifiers | Description |
|---|---|
| Instrument ID | NNNN is a 4 ASCII characters used to represent the specific instrument; where NNNN = ><br>= CRAT for CRaTER Instrument data files<br>= DLRE for the DLRE instrument files<br>= LAMP for the LAMP instrument files<br>= LEND for the LEND instrument files<br>= LOLA for LOLA instrument files<br>= LROC for the LROC instrument files<br>= MIRF for the Mini-RF instrument files |
| Filetype Designation | NN is a 2 ASCII character used to identify that this is part of the spacecraft HK data file corresponding to the instrument<br>= SC |
| YYYYDDD | YYYYDDD is a 7 character year and Day of year designations, such as<br>YYYY => 4 character year designator (2008 – 2013)<br>DDD => 3 character day of year designator (001 – 366) |
| serial counter | NNNNNNN is a seven character sequentially incrementing number used to uniquely identify the files; (0000001 – 9999999) |
| file name extension | 2 or 3 character designation used to identify the file type<br>= .hk for instrument housekeeping data files<br>= .sci for raw science data files |

The LRO MOC strips off the 64-byte header from the S/C housekeeping data file; the MOC runs a utility that selects the SOC-requested APIDs and stores them into a file. The file is a binary file that only contains the SOC-requested APID data packets.

The following table identifies the MOC-generated products, the contents and a sample file name concept.

| Product ID | Contents | File Name |
|---|---|---|
| MOC-3 | CRaTER – Spacecraft Housekeeping Data File | CRAT_SC_YYYYDDD_NNNNNNN.hk |
| MOC-8 | DLRE – Spacecraft Housekeeping Data File | DLRE_SC_YYYYDDD_NNNNNNN.hk |
| MOC-12 | LAMP – Spacecraft Housekeeping Data File | LAMP_SC_YYYYDDD_NNNNNNN.hk |
| MOC-16 | LEND – Spacecraft Housekeeping Data File | LEND_SC_YYYYDDD_NNNNNNN.hk |
| MOC-20 | LOLA – Spacecraft Housekeeping Data File | LOLA_SC_YYYYDDD_NNNNNNN.hk |
| MOC-25 | LROC – Spacecraft Housekeeping Data File | LROC_SC_YYYYDDD_NNNNNNN.hk |
| MOC-28 | Mini-RF – Spacecraft Housekeeping Data File | MIRF_SC_YYYYDDD_NNNNNNN.hk |

The Instrument – Spacecraft Housekeeping Data File is the collection of requested APIDs and contains the associated telemetry mnemonics in binary form. The MOC creates these files based on the SOC-requested APID; the MOC will document this information using the corresponding SOC Operations Agreement.

Since these files are a binary representation of the data, there is no sample product provided in Appendix B.

#### 4.5.10 Instrument Housekeeping Data Files

This file contains the stored instrument housekeeping telemetry data.

##### 4.5.10.1 Product Details

| | |
|---|---|
| Time interval | Variable based on Instrument APID generation |
| File duration | Variable; based on stored commands to open/close files |
| File or Data Generation Frequency | Variable based on file duration concepts above |
| Delivery method (real-time, SCP, FTP, etc) | scp from the MOC to the various SOCs<br>Files delivered as available and should be complete within twelve hours of receipt |
| Data Volume | Variable; based on APIDs and storage rate |
| Accuracy (if it applies) | NA; based on data mnemonics for specified APIDs |
| Other pertinent details | Delivered within 24 hours of ground receipt<br>The MOC transmits the LEND Instrument HK Data files to both the GSFC and University of Arizona SOCs<br>The MOC will rate limit Mini-RF data file transfer to the Mini-RF SOC so as not to exceed to 400 kbps |

##### 4.5.10.2 Format

The Instrument Housekeeping Data File consists of the complete set of instrument telemetry values. The Operations team sets the base file name on a daily basis using commands to set the base filename for each instrument directory. The LRO FSW appends a sequence counter to the end of the filename. The file name can be up to 40 characters in length, contains the complete directory path information, and includes the file extension.

The following table provides the product Identifiers, the contents, and a sample file name concept.

| Product ID | Contents | File Name |
|---|---|---|
| MOC-4 | CRaTER Housekeeping Data File | CRAT_YYYYDDD_NNNNNNN.hk |
| MOC-9 | DLRE Housekeeping Data File | DLRE_YYYYDDD_NNNNNNN.hk |
| MOC-13 | LAMP Housekeeping Data File | LAMP_YYYYDDD_NNNNNNN.hk |
| MOC-17 | LEND Housekeeping Data File | LEND_YYYYDDD_NNNNNNN.hk |
| MOC-21 | LOLA Housekeeping Data File | LOLA_YYYYDDD_NNNNNNN.hk |

| | | |
|---|---|---|
| MOC-26 | LROC Housekeeping Data File | LROC_YYYYDDD_NNNNNNN.hk |
| MOC-29 | Mini-RF Housekeeping Data File | MIRF_YYYYDDD_NNNNNNN.hk |

The Flight Software system adds a 64-byte header to every file type before the first byte of instrument housekeeping data. This 64 byte header is defined in Section 4.6.4, specifically Table 4-9, of the LRO Telemetry and Command Formats Handbook (431–HDBK–000052).

These Housekeeping Data Files are a collection of requested APIDs and contains the associated telemetry mnemonics in binary form.

Since these files are a binary representation of the data, there is no sample product provided in Appendix B.

### 4.5.11 Instrument Raw Measurement Data Files

This file contains the raw measurement data files after CFDP processing. The Instrument Raw Measurement Data Files are a collection of image data files or collected science measurement telemetry data in a binary form as noted in the Instrument ICD. The MOC will electronically transfer the Instrument Raw Measurement Data Files to the appropriate SOC at the completion of the Ka-Band pass from the WS1 station contact and receipt within the MOC.

#### 4.5.11.1 Product Details

| | |
|---|---|
| Time interval | Variable based on Science Instrument Data collection modes |
| File duration | Variable; based on stored commands to open/close files for instruments except LROC. LROC files are stored on a per image basis |
| File or Data Generation Frequency | Variable based on file duration concepts above |
| Delivery method (real-time, SCP, FTP, etc) | scp from the MOC to the various SOCs<br>Files delivered as available and should be complete within twelve hours of receipt |
| Data Volume | Variable; based on Science Instrument Data collection mode |
| Accuracy (if it applies) | NA; based on data mnemonics for specified APIDs |
| Other pertinent details | Delivered within 24 hours of ground receipt<br>The MOC transmits the LEND Instrument Raw Measurement Data files to both the GSFC and University of Arizona SOCs<br>The MOC will rate limit Mini-RF data file transfer to the Mini-RF SOC so as not to exceed to 400 kbps |

#### 4.5.11.2 Format

The Raw Measurement Data Files is a collection of requested APIDs and contains the associated telemetry mnemonics or an image file in a binary form. As such, there are no sample products provided in Appendix B.

LROC and Mini-RF use the SpaceWire interface on the orbiter to transfer science data from their instruments to the C&DH flight software for storage. These instruments efficiently use this interface by inserting variable length fill bits into this data stream to ensure that the SpaceWire data packets are always full.

When the MOC receives these instrument files, the MOC performs additional file processing to remove the SpaceWire fill bits, which recreates the original instrument file, as it existed onboard the Orbiter. The MOC regenerates the corresponding instrument science meta-summary file that provides the correct file statistics for the new file size and the new MD5 checksum calculation.

The Flight Software system adds a 64-byte header before the first byte of the raw instrument science data. This 64 byte header is defined in Section 4.6.4, specifically Table 4-9, of the LRO Telemetry and Command Formats Handbook (431–HDBK–000052).

The Operations team sets the base file name on a daily basis using commands to set the base filename for each instrument directory. The LRO FSW appends a sequence counter to the end of the filename. The file name can be up to 40 characters in length, contains the complete directory path information, and includes the file extension.

LROC controls their specific file naming convention since they provide the file name as part of an input command load that the MOC receives and uplinks to the spacecraft. The file naming convention still adheres to the 40 character file name limitations as previously referenced as part of the FSW Users' Guide.

For the Wide Angle Camera (WAC) and both Narrow Angle Cameras (NAC), the file name convention adheres to the following naming scheme, which is taken form the input commands: TTTTHHHHHHHH.ext; where

TTTT (3-4 characters) = NACL or NACR or WAC

8 characters Image ID represented as a Hex ID

ext = 3 character extension; raw (sci) for raw image files

The following table identifies the MOC-generated products, the contents and a sample file name concept.

| Product ID | Contents | File Name |
|---|---|---|
| MOC-5 | CRaTER Raw Measurement Data File | CRAT_YYYYDDD_NNNNNNN.sci |
| MOC-10 | DLRE Raw Measurement Data File | DLRE_YYYYDDD_NNNNNNN.sci |
| MOC-14 | LAMP Raw Measurement Data File | LAMP_YYYYDDD_NNNNNNN.sci |
| MOC-18 | LEND Raw Measurement Data File | LEND_YYYYDDD_NNNNNNN.sci |
| MOC-22 | LOLA Raw Measurement Data File | LOLA_YYYYDDD_NNNNNNN.sci |
| MOC-27<br><br>MOC-39 | LROC Left Narrow Angle Camera Image Data File<br>LROC Right Narrow Angle Camera Image Data File<br>LROC Wide Angle Camera Image Data File | naclHHHHHHHH<br>nacrHHHHHHHH<br>wacHHHHHHHH |
| MOC-31 | Mini-RF Raw Measurement Data File | MIRF_YYYYDDD_NNNNNNN.sci |

### 4.5.12 (MOC46 – MOC60) Meta Summary Reports

The Meta Summary Report contains a transaction id, filename (source and destination), file size, checksum, outcome (success/failure), and reason of failure if outcome was failure, file completion map, and start/end time. All characters in the report are ASCII.

#### 4.5.12.1 Product Details

| | |
|---|---|
| Time interval | NA |
| File duration | NA; file corresponds to the Instrument HK or Raw Measurement Data Files and provides the meta-data over that time duration |
| File or Data Generation Frequency | 1 file per Instrument HK or Raw measurement Data File |
| Delivery method (real-time, SCP, FTP, etc) | scp from the MOC to the various SOCs |
| Data Volume | Less than 1 KByte |
| Accuracy (if it applies) | NA |
| Other pertinent details | Delivered within 24 hours of ground creation<br>The MOC transmits the LEND Meta Summary Report files to both the GSFC and University of Arizona SOCs |

#### 4.5.12.2 Format

The LRO Ground System receives Orbiter and instrument files during the high rate Ka-Band supports. The WS1 station and MOC DPS systems perform data processing, which closes the loop for CFDP transfers. Under nominal conditions, the receiving DPS receives complete files that have no data gaps; missing packets should not occur on LRO since CFDP will continue to request the missing data packets. However there are possible contingency scenarios which could result in the Orbiter sending the files in Class 1 (Unreliable Mode) or the ground system could cancel the file downlink transaction before completing.

The meta-summary file provides an overview of the file statistics information for the corresponding science housekeeping or measurement data files. The metasummary file nominally provides file transaction information for how the sender and receiver coordinated the file transfer and identifies if the receiver entity received the file in totality or if the receiving entity only received the file with some missing packets.

The receiving Data Processing System (DPS) creates the corresponding metasummary file based on how it received the transmitted science file and if it encountered any unrecoverable errors during the file transfer. To identify the location of any missing data, the DPS will use the contents of the file completion map to record where the missing data segments occur in the file.

The LROC and Mini-RF science instruments send their data over the SpaceWire, so these science instrument files will have special considerations when the DPS element encounters data gaps as a result of either a Class 1 file transfer or a partial file transfer. After the DPS element encounters the first gap, it provides no additional processing on the file since there is no easy way for the DPS element to resync based on the SpaceWire headers. Any additional DPS processing could corrupt the file. In this instance, both the LROC and Mini-RF science data meta-summary report is different from the other instruments as noted in

Table 4-34, which provides a description of the Meta-Summary Report contents specifically tailored for LROC and Mini-RF science data files.

For other science files that the ground system receives without any errors or missing gaps, the meta-summary report (nominal meta-file contents) only contains the first 12 items. For processing option 1 (default mode), the next two items (13 and 14) are added to the meta-summary file. For processing option 2 (removal of partial packets and zero filled data), three additional items (15-18) are added to the meta-summary file report.

Figure 4-8 shows the missing data gaps that are a result of extra MOC processing to remove full packets associated with missing downlinked data

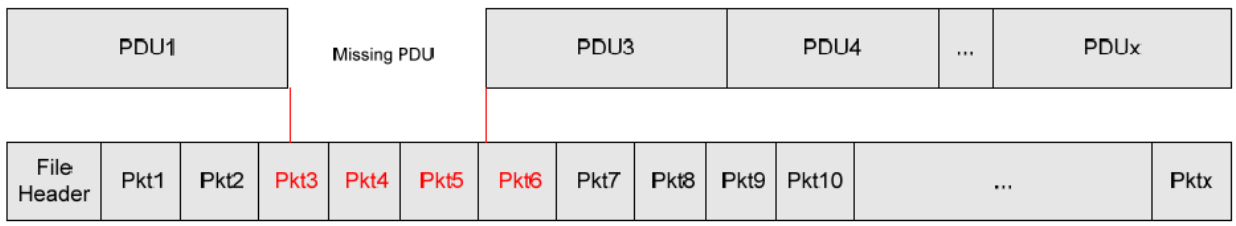
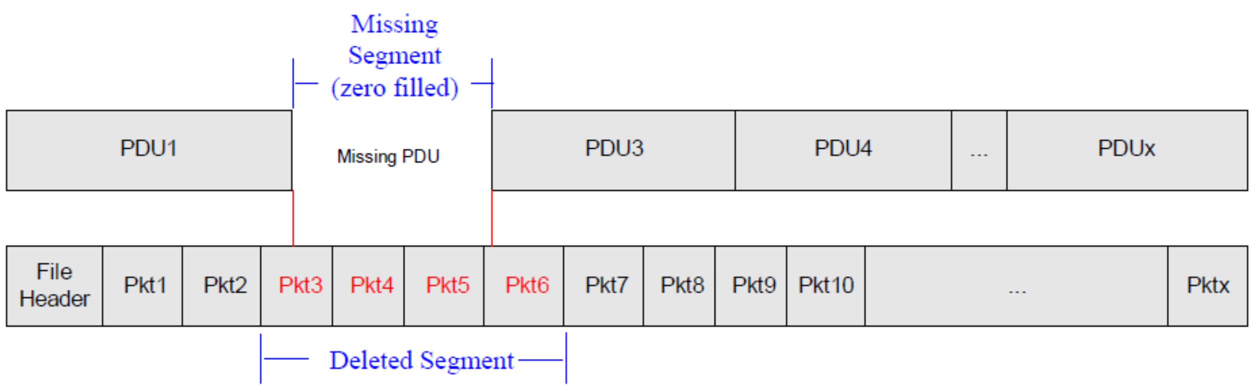



***Figure 4-8 Missing Segment Boundaries***

The normal DPS processing flow whenever it encounters missing segments is to replace the missing segments with zeros. The partial packets are left in the data file. Based on the specific file contents and formats, the partial packets may, or may not, contain packet headers; this packet header concept is valid only for instruments that create packetized data. Following this processing the DPS creates the corresponding metasummary file, which provides the details on the missing segments. IF desired, the DPS element can perform additional processing on the data file to remove partial packets and inserted zeros in the file. There are two options available:

1. Transfer the file to the SOC with the inserted zeros in the file where missing data gaps exist. This option is the default processing mode.
2. Remove the partial packets from the file and remove the zero-fill data, which DPS originally inserted. If the SOC chooses this option, then Figure 4-9 would provide an example of the file with the deleted packets.



### *Figure 4-9 Missing and Deleted Segment Boundaries*

Table 4-33 provides a description of the Meta-Summary Report contents

### *Table 4-33 Meta-Summary Report Description*

| Item | Field name | Field Characteristics |
|---|---|---|
| 1 | Transaction ID | Identification number of the transaction. |
| 2 | Source file name | Complete pathway and file name of the source file. |
| 3 | Destination file name | Complete pathway and file name of the destination file. |
| 4 | Transaction Started | Date/Time when CFDP started (YYYY-DDD-HHMMSS) |
| 5 | Class | Numeric representation association with the CFDP transfer (=1 or 2) |
| 6 | File Size | Size of file in bytes. |
| 7 | Temp file name | Complete pathway and file name for the temporary file location; primarily for data file recovery purposes should a transaction fail or get hung in the middle of a transfer |
| 8 | Transaction completed | Date/Time when CFDP completed (yyyy-ddd-hhmmss) |
| 9 | CFDP File Checksum | Standard Checksum of data contained in file. |
| 10 | MD5 File Checksum | Linux checksum value |
| 11 | File transfer status | Success or<br>Unsuccessful and Failure condition (e.g., cancel requested). |
| 12 | File complete percentage | Numerical value used to identify percentage of downlinked file successfully retrieved.<br>= 100.0000 or nn.mmmm, where nn is number between 0 – 99 and mmmm is the decimal number value between 0000 and 9999 |
| 13 | Number of gaps in file (Note1) | Numeric value for number of data gaps. |
| 14 | File completion map (Note1) | Number of missing byes = numeric value, such as 565583678<br>byte offset for the first gap, such as 11133123.<br>File deletion map line should occur for each missing gap |
| 15 | Processed File Size (Note2) | Provides the size of the new file created as a result of processing (Number of Bytes) |
| 16 | Processed File MD5 Checksum (Note2) | This checksum will be used to verify file integrity when the file is transferred between ground system elements |
| 17 | File Completion Percentage (Note2) | For modified files (means a file that has gone through an extra level of processing to manipulate data received from the original file); applicable only to processed files:<br>[(Total original file size – SUM (Deleted Segment size))/Total original file size] *100 |
| 18 | File Deletion Map(Note2) | For modified files:<br>List of deleted data segments, including the number of bytes deleted and the offset at where that occurred. Byte count starts at byte 0.<br>File deletion map line should occur for each missing gap |
| Note1: These two fields are only present if the downlinked file did not complete successfully; e.g., Only has missing data segments (reference Figure 4-8). | | |

| Item | Field name | Field Characteristics |
|---|---|---|
| Note2: These fields are only present, above and beyond Note1, if the downlinked file did not complete successfully and the MOC deleted other data segments associated with the missing data (reference Figure 4-9) | | |

For LROC and Mini-RF science files, the LRO MOC only delivers complete files. As part of the processing on the LROC and Mini-RF science files, the meta-summary files contain two additional fields that provide complete file statistics after the removal of the fill bits. This utility regenerates the corresponding instrument science meta-summary file that provides the correct file statistics for the new file size and the new MD5 checksum calculation.

Table 4-34 provides a description of the Meta-Summary Report contents specifically tailored for LROC and Mini-RF science data files:

### *Table 4-34 Meta-Summary Report Description for LROC and Mini-RF Science Files*

| Item | Field name | Field Characteristics |
|---|---|---|
| 1 | Transaction ID | Identification number of the transaction. |
| 2 | Source file name | Complete pathway and file name of the source file. |
| 3 | Destination file name | Complete pathway and file name of the destination file. |
| 4 | Transaction Started | Date/Time when CFDP started (YYYY-DDD-HHMMSS) |
| 5 | Class | Numeric representation association with the CFDP transfer (=1 or 2) |
| 6 | File Size | Size of file in bytes. |
| 7 | Temp file name | Complete pathway and file name for the temporary file location; primarily for data file recovery purposes should a transaction fail or get hung in the middle of a transfer |
| 8 | Transaction completed | Date/Time when CFDP completed (yyyy-ddd-hhmmss) |
| 9 | CFDP File Checksum | Standard Checksum of data contained in file. |
| 10 | MD5 File Checksum | Linux 16-byte checksum value |
| 11 | File transfer status | Success or<br>Unsuccessful and Failure condition (e.g., cancel requested). |
| 12 | File complete percentage | Numerical value used to identify percentage of downlinked file successfully retrieved.<br>= 100.0000 or nnn.mmmm, where nnn is number between 0 – 100 and mmmm is the decimal number value between 0000 and 9999 |
| 13 | File Size No Fill | Recalculated file size after SpaceWire fill bits are removed. |
| 14 | MD5 File Checksum No Fill | Linux 16-byte checksum value after the DOPS element has removed the SpaceWire fill bits |

A sample file name for the first generation of this data file has the following convention:

<downlinked filename>.<file extension>

where downlinked filename = Name of file that is downlinked from orbiter, name is same as the orbiter copy.

file extension = [4 characters] meta

The following table identifies the MOC-generated products, the contents and a sample file name concept.

| Product ID | Contents | File Name |
|---|---|---|
| MOC-46<br>MOC-47 | CRaTER Housekeeping Meta Summary File<br>CRaTER Raw Measurement Meta Summary File | CRAT_YYYYDDD_NNNNNNN.hk.meta<br>CRAT_YYYYDDD_NNNNNNN.sci.meta |
| MOC-48<br>MOC-49 | DLRE Housekeeping Meta Summary File<br>DLRE Raw Measurement Meta Summary File | DLRE_YYYYDDD_NNNNNNN.hk.meta<br>DLRE_YYYYDDD_NNNNNNN.sci.meta |
| MOC-50<br>MOC-51 | LAMP Housekeeping Meta Summary File<br>LAMP Raw Measurement Meta Summary File | LAMP_YYYYDDD_NNNNNNN.hk.meta<br>LAMP_YYYYDDD_NNNNNNN.sci.meta |
| MOC-52<br>MOC-53 | LEND Housekeeping Meta Summary File<br>LEND Raw Measurement Meta Summary File | LEND_YYYYDDD_NNNNNNN.hk.meta<br>LEND_YYYYDDD_NNNNNNN.sci.meta |
| MOC-54<br>MOC-55 | LOLA Housekeeping Meta Summary File<br>LOLA Raw Measurement Meta Summary File | LOLA_YYYYDDD_NNNNNNN.hk.meta<br>LOLA_YYYYDDD_NNNNNNN.sci.meta |
| MOC-56<br>MOC-57<br><br>MOC-58 | LROC Housekeeping Meta Summary File<br>LROC Narrow Angle Camera Image Meta Summary File<br>LROC Wide Angle Camera Image Meta Summary File | LROC_YYYYDDD_NNNNNNN.hk.meta<br>naclHHHHHHHH.meta<br>nacrHHHHHHHH.meta<br>wacHHHHHHHH.meta |
| MOC-59<br>MOC-60 | Mini-RF Housekeeping Meta Summary File<br>Mini-RF Raw Measurement Data File | MIRF_YYYYDDD_NNNNNNN.hk.meta<br>MIRF_YYYYDDD_NNNNNNN.sci.meta |

The following three figures in Appendix B provide the various samples for meta-summary files:
Meta-summary Report for successful completion (No gaps) – Figure B.4-8

Meta-Summary Report for incomplete files (Missing Data Segments) – Figure B.4-9

Meta-Summary Report for incomplete files (Deleted Data Segments) – Figure B.4-10

Meta-Summary Report for LROC Science files (No Missing Data Segments) – Figure B.4-11

#### 4.5.13 Real-time VC0 housekeeping data

The LRO MOC forwards real-time data to each of the science centers. The LRO MOC's telemetry and command system (e.g., ITOS) attempts to initiate a TCP/IP socket connection with each of the SOCs at the start of a real-time pass. In the event of a socket connection failure, ITOS attempts to reconnect up to three times. If the connection request does not work, there is no real loss of data since the real-time data will always be transferred within a subsequent VC1 data stream in a latter station contact. The real-time VC0 consists of the requested APIDs (or the entire VC0 data stream). ITOS uses a 12-byte ITOS annotation header to provide basic quality statistics. The following figure and table provides the data layout for this 12-byte header and provides the field descriptor information.

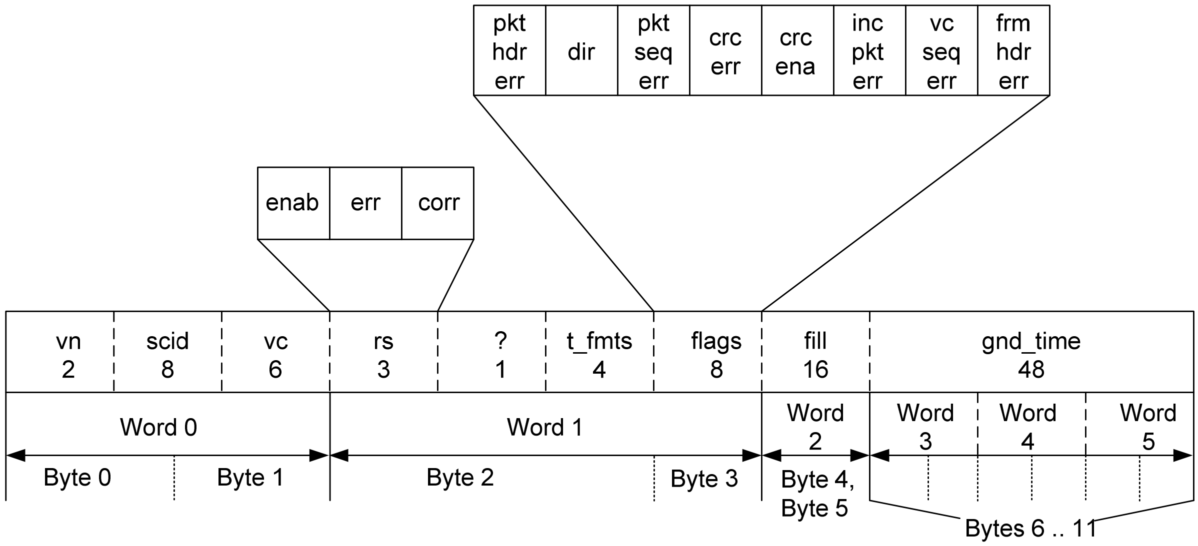



***Figure 4-10 ITOS Annotation Header Layout***

The fields, represented within this figure are defined with the following table:

***Table 4-35 ITOS Annotation Header Field Definitions***

| Field | Word | Bit(s) | Description |
|---|---|---|---|
| frame version | 0 | 0-1 | Version field from CCSDS transfer frame hdr. |
| frame s/c ID | 0 | 2-9 | Spacecraft ID from CCSDS transfer frame hdr. |
| frame VC ID | 0 | 10-15 | Virtual channel ID from CCSDS transfer frame hdr. |
| Reed-Solomon enabled | 1 | 0 | If set, Reed-Solomon error detection and correction enabled. |
| Reed-Solomon error | 1 | 1 | If set, uncorrectable Reed-Solomon error(s) encountered. |
| Reed-Solomon corrected | 1 | 2 | If set, the Reed-Solomon code corrected one or more errors. |
| reserved | 1 | 3 | |
| time format | 1 | 4-7 | Defines time code format; list of values are:<br>'0' = none<br>'1' = PB1 code<br>'2 – 3' = reserved<br>'4' = PB4 code<br>'5 – 7' = reserved<br>'8' = relative TIME42, a time in CCSDS Unsegmented Code (CUC)<br>'9' = absolute TIME42, a date in CUC, default for annotation headers created by ITOS<br>'10 – 15' = reserved |
| packet header error | 1 | 8 | If set, packet header extracted from frame with uncorrectable error. |

| Field | Word | Bit(s) | Description |
|---|---|---|---|
| data direction reversed | 1 | 9 | If set, data received in reverse bit order. |
| packet sequence error | 1 | 10 | If set, this packet's sequence count is not the successor or the previous packet with the same application ID on the same VC. |
| frame error | 1 | 11 | If set, uncorrectable error detected in one or more frames from which this packet was extracted. |
| frame error enabled | 1 | | 12 if set, frame error checking was enabled. |
| incomplete packet | 1 | 13 | If set, packet is incomplete, and filled to it's indicated length beginning at `*fill location*'. |
| VC sequence error | 1 | 14 | If set, a transfer frame from which this packet was extracted was not the successor of the previous frame on the same virtual channel. |
| frame header error | 1 | 15 | A frame from which this packet was extracted had an incorrect version or spacecraft ID. |
| fill location | 2 | 0-15 | Byte offset from the end of the packet primary header of packet fill data, if `*incomplete packet*' is set. |
| ground received time | 3-5 | 0-15 | Ground received time extracted from frame wrappers in format defined by `*time format*' above. |

The following table identifies the MOC-generated real-time data products, which the LRO MOC sends to the various SOCs.  Since these are real-time socket connections, there are no associated file names.

| Product ID | Contents |
|---|---|
| MOC-6 | CRaTER Real-time VC0 Housekeeping Data |
| MOC-11 | DLRE Real-time VC0 Housekeeping Data |
| MOC-15 | LAMP Real-time VC0 Housekeeping Data |
| MOC-19 | LEND Real-time VC0 Housekeeping Data |
| MOC-23 | LOLA Real-time VC0 Housekeeping Data |
| MOC-24 | LROC Real-time VC0 Housekeeping Data |
| MOC-32 | Mini-RF Real-time VC0 Housekeeping Data |

#### 4.5.13.1 Product Details

| | |
|---|---|
| Time interval | Variable based on Orbiter VC0 Data collection filters and per APID |
| File duration | NA |
| File or Data Generation Frequency | NA |
| Delivery method (real-time, SCP, FTP, etc) | Real-time socket from MOC to each SOC |
| Data Volume | Variable |
| Accuracy (if it applies) | NA |
| Other pertinent details | The MOC delivers real-time data to both GSFC LEND SOC and to the University of Arizona LEND SOC<br>Best effort to deliver data in real-time |

#### 4.5.13.2 Format

The Real-time VC0 housekeeping data consists of the set of telemetry mnemonics from the SOC requested list of APIDs; the SOC identifies which specific VC0 APIDS or the complete VC0 data stream it wishes to receive in the real-time socket connection.

The Real-time VC0 housekeeping data is a collection of APIDs and contains the associated telemetry mnemonics in a binary form. As such, there is no sample product provided in Appendix B.

### 4.5.14 <u>(MOC-73) Archived CRaTER VC0 Telemetry File</u>

The LRO MOC creates an archived version of the CRaTER real-time telemetry feed only in the event that the MOC/ITOS system failed to connect to the CRaTER SOC during any real-time station contact. The MOT creates this file and transfers it to the CRaTER SOC during the next operational day.

#### 4.5.14.1 Product Details

| | |
|---|---|
| Time interval | Variable based on Orbiter VC0 Data collection filters and per APID |
| File duration | 1 file per station contact |
| File or Data Generation Frequency | Created by MOT next business day<br>File ONLY created if the real-time feed failed with CRaTER SOC |
| Delivery method (real-time, SCP, FTP, etc) | scp to the CRaTER SOC |
| Data Volume | Variable, based on Orbiter VC0 Data collection filters and per APID |
| Accuracy (if it applies) | NA |
| Other pertinent details | NA |

#### 4.5.14.2 Format

The LRO MOC creates this file based on the SOC-requested APIDs associated with the original VC0 real-time data connection. This data file contains the identical set of APIDS that the MOC would have transferred during the real-time connection as noted for MOC product, MOC-6 – CRaTER Real-time VC0 Housekeeping Data. This product contains the ITOS 12-byte ITOS annotation header to provide basic quality statistics; Section 4.5.13 provides the details for this annotation header.

This file name conforms to the following file name convention:

<File Designator>_<YYYYDOY_HHMM>.<file extension>

where File Name = [19 Characters]

File Designator = 4 Characters, with the following designation:
CRAT

YYYYDOY = [12 characters], YYYYDOY-HHMM; represented in UTC format of the station AOS, where
YYYY => 4 ASCII digits of year (2008 – 2013)
DOY => 3 ASCII digits for day of year (1 – 366), followed by the underscore (_) character
HHMM => 4 ASCII digits of the Hours and Minutes of the station AOS (0000 – 2359)

file extension = [3characters] Standard file extension for all input files received from a SOC; it will be named for the input file type:
vc0 for a VC0 Archive file

A sample file name that corresponds to a failed CRaTER real-time connection from January 15, 2009 with a station AOS of 1235 GMT is CRAT_2009015_1235.vc0

The Archived CRaTER VC0 Telemetry File is a collection of APIDs and contains the associated telemetry mnemonics in a binary form. Since this file contains data only in a binary form, there is no sample provided in Appendix B.

### 4.5.15 (MOC-30) Mini-RF Operations Opportunity

This file contains potential targets of operations opportunity (time periods) for which the Mini-RF instrument could be commanded on to take science measurements.

### 4.5.15.1 Product Details

| | |
|---|---|
| Time interval | NA, provides specific time intervals for possible Mini-RF operations |
| File duration | 1 week |
| File or Data Generation Frequency | Wednesday, noon time local for the next operational week, which begins on the Monday |
| Delivery method (real-time, SCP, FTP, etc) | MOC scp pushes to the Mini-RF SOC |
| Data Volume | Variable, based on number of possible Mini-RF Operations (< 1 Kbytes) |
| Accuracy (if it applies) | NA |
| Other pertinent details | NA |

### 4.5.15.2 Format

The Mini-RF Operations Opportunity is an ASCII formatted file that contains selected time ranges in which the Mini-RF instrument could be command on to take science data.

The file is a comma, separated ASCII formatted file with no other blanks or white spaces between fields. The following table provides the file format details related to this product

| Field name | Field Characteristics |
|---|---|
| TOO Indication | Either 3 or 6 ASCII characters that the MOT uses to identify if Mini-RF has a possible target of opportunity or if the MOT has deleted this potential opportunity<br>= ADD; indicates that Mini-RF can use the following times<br>= DELETE; indicates the following times are no longer available |
| Start Time | 17 ASCII Digits and characters to identify start time, in the form of:<br>YYYY-DDD-HH:MM:SS where,<br>YYYY => 4 ASCII digits of year (2009 – 2013); followed by (-)<br>DDD => 3 ASCII digits for day of year (1 – 366); followed by (-)<br>HH:MM:SS => 8 ASCII digits for hour, minutes, and seconds with a ":" delimiter. |
| Stop Time | 17 ASCII Digits and characters to identify start time, in the form of:<br>YYYY-DDD-HH:MM:SS where,<br>YYYY => 4 ASCII digits of year (2009 – 2013); followed by (-)<br>DDD => 3 ASCII digits for day of year (1 – 366); followed by (-)<br>HH:MM:SS => 8 ASCII digits for hour, minutes, and seconds with a ":" delimiter. |

The LRO MOC uses the following file-naming convention for this file. The filename consists of 19 characters; it also contains a three character file extension name. There are underscores (_) between the file name fields and there is a period (.) between the file name and file extension fields. The form of the filename is as follows:

<File Designator>_<YYYYDOY>_<yyyydoy>_<version number>.<file extension>

| where | | | |
|---|---|---|---|
| | File Name | = | [19 Characters] |
| | File Designator | = | 7 Characters, with the following designation:<br>MINITOO |
| | YYYYDOY | = | [7 characters], YYYYDOY; that indicate the start date, followed by underscore(_);where<br>YYYY => 4 ASCII digits of year (2009 – 2013)<br>DOY => 3 ASCII digits for day of year (1 – 366) and where the day of year indicates the first day for which there might be an opportunity; |
| | yyyydoy | = | [7 characters], yyyydoy; that represent the stop date, followed by underscore(_);where<br>YYYY => 4 ASCII digits of year (2008 – 2013)<br>DOY => 3 ASCII digits for day of year (1 – 366) and where the day of year indicates the last day for which there might be an opportunity; |
| | version number | = | [3 characters] V, followed by a two-digit version number. The initial version is 00, next is 01 … up to 99. |
| | file extension | = | [3characters] Standard file extension for all input files received from a SOC; it will be named for the input file type:<br>txt for text files |

A sample File name is MINITOO_2009015_2009022_V00.txt

A sample product is provided in Appendix B, Figure B.4-7

### 4.5.16 (MOC-62) RTS Command Load Report

This file contains the textual version of the relative time sequenced (RTS) uplinked command load, which the LRO MOC sent to the LRO spacecraft.

#### 4.5.16.1 Product Details

| | |
|---|---|
| Time interval | Variable based on integrated set of relative time sequenced commands associated with the specified RTS identifier |
| File duration | NA |
| File or Data Generation Frequency | NA, as needed to modify a specified RTS |
| Delivery method (real-time, SCP, FTP, etc) | MOC scp pushes to SOCs that modify a relative Time Sequence Command Load |
| Data Volume | Variable; based on number of command sequences, but nominally less that 256 KBytes |
| Accuracy (if it applies) | Time accurate to 1 second |
| Other pertinent details | NA |

#### 4.5.16.2 Format

The RTS Command Load Report consists of the complete textual set of integrated RTS commands associated with a specific RTS Sequence number. This command report defines the load; based on operations team approval and signature of the corresponding binary load.

The RTS Report will include a Header to provide the following information:

- Mission - hard coded to LRO
- MPS Version - version of the MPS
- Command DB Version - Command database version
- Load File (Name) - files name SC_145_DeltaVOps_V01.RTS

  NOTE: When an RTS load with the same table number and file description as a previously defined RTS, the mission planning system increment the version number.

- Load Creation Time – time the RTS load was generated
- RTS Slot – RTS buffer, or table ID for the RTS Load
- RTS Buffer Size (Bytes) – maximum size of the RTS buffer, as determined from MPS configuration file (should always be 300 bytes, since RTS load will include padding)
- Load Data Size (Bytes) – size, in bytes, of the load (Command data only)
- Number of RTS Commands - # of commands within the load
- Number of Critical Commands - # of critical commands within the load
- Estimated Time of Uplink @ 4 Kbps (Minutes) – calculated time required to uplink file

The Command Summary will provide a counter for the number of commands, for each instrument and subsystem, contained with the RTS load. The bottom line of the summary report will provide a total number of commands for all instruments and subsystems.

The Error/Constraint Summary will identify all errors or constraints that occurred in the generation process of the RTS Load. In addition to the error/constraint, the summary will also provide an explanation of each error, including the mitigation of the error/constraint.

The RTS Summary Report will provide a detailed listing of the commands included within the RTS load. The report will include the following information (Note that the fields slightly differ from ATS Summary Report):

- Command Number – RTS buffer command number
- Relative Offset Time – the relative offset time for each RTS command (HH:MM:SS), relative to previous command
- Command Mnemonic, Submnemonic, and Value – Command mnemonics will be listed

  When commands contain submnemonics, the submnemonic and the associated value should be reported on a separate line (below the command). The submnemonics should be indented (formatted) such that they are easily distinguished from commands. In addition, an asterisk (*) should be inserted in the command number field for command submnemonics (e.g., there is no command number associated with submnemonics).
- Command Description – the command description, as extracted from the command database.
- Criticality Flag – is a flag to support easy identification of critical commands. When a critical command is included in the RTS load (determined from the criticality flag with the command database), the field will contain a flag ("C") indicating the command is critical.

The LRO MOC uses the following file-naming convention for MOC-transmitted files.

There are underscores (_) between the file name designators and there is a period (.) between the file name and file extension fields. The form of the filename is as follows:

| | | | |
|---|---|---|---|
| where | File Name | = | SC_145_DeltaV_V01.txt |
| | File Name Details | = | Stored Command (SC);<br>RTS # (e.g., 145);<br>RTS Description (e.g., DeltaV);<br>Version (e.g., V01) |
| | file extension | = | [.txt] identifies that this file is an ASCII RTS Command Report text file. |

For example, a sample file name for a Relative Time Sequence Command Report is identified as: SC_145_DeltaV_V01.txt. A sample RTS Command Load is provided in Appendix B, Figure B.4-2.

### 4.5.17 (MOC-71) Data Recorder Model Report

The Data Recorder Model, which provides an analysis of spacecraft data recorder, predicts the memory margin based on instrument operational concepts, SOC inputs, ground contacts, and external reports. The purpose of the model is to predict, based on planned activities and available Ka-Band supports, the amount of recorder memory (number of remaining bits) available for LROC images.

To illustrate the recorder model, take for example the following scenario using Figure 4-11.

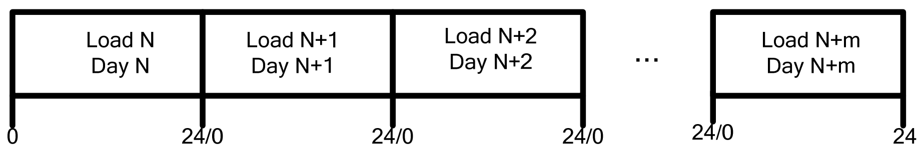



***Figure 4-11: Recorder Model Scenario***

The Orbiter is currently executing Load N on Day N. The MOT must provide a recorder model report to the LROC SOC on the morning of Day N, which span multiple days (N+1 through N+m). The MOT will generate this report based on a variable duration, which is based upon how much information the MOT has available at that time.
Once receiving the report, the LROC SOC will use it to generate the daily command sequence, which will span the same duration as the recorder model report. After receiving the LROC daily command sequence and the other daily products, the MOT can build the ATS load for day N+1.

#### 4.5.17.1 Product Details

| | |
|---|---|
| Time interval | NA; file contents are based on LRO Orbit designations |
| File duration | Corresponds to the time interval for the LROC Daily Command Sequence; for example if LROC sends a command timeline for (Wed – Fri), then the Data Recorder Model provides information for the same time interval |
| File or Data Generation Frequency | The file is generated on a daily basis or whenever LROC transmits a revised LROC Daily Command Sequence |
| Delivery method (real-time, SCP, FTP, etc) | MOC scp pushes the file to the LROC SOC |
| Data Volume | Variable |
| Accuracy (if it applies) | NA |
| Other pertinent details | Used by MOT personnel<br>Product is delivered to LROC for SOC review and analysis |

#### 4.5.17.2 Format

The file contains detailed information regarding the contents of LROC data recorder unit. The file is an ASCII-formatted file that contains multiple lines that correspond to header and data information. The file will contain the following fields:

### *Table 4-36 Data Recorder Memory Model Description*

| Field name | Field Characteristics |
|---|---|
| File Content Header Information | One line of ASCII information that identifies the Product ID and the Product name:<br>Product ID defaults to MOC-71<br>Product name defaults to Data Recorder Model<br>There is a space between these 2 fields; the line ends with a Carriage Return/Line Feed |
| Instruments per VR Number | provides 5 lines of ASCII information.<br>The first two lines provide a default identifier for the word Instruments; the second line provides the "underlining" aspect for the word Instruments<br>The next 3 lines provide the VR to Instrument assignments, in the form of:<br>VRn = <Free Form ASCII Text>; specifically:<br>VR1 = LROC/Mini-RF<br>VR2 = CRaTER/DLRE/LAMP/LEND/LOLA<br>VR3 = Spacecraft Housekeeping |
| VR Capacity | The capacity of the selected VR, in Gigabits; provides 3 lines of ASCII information to provide capacity for each Virtual Recorder:<br>VR1 = 390.32 Gbits<br>VR2 = 14.00 Gbits<br>VR3 = 8.00 Gbits |
| Ka-Band Supports | The number of Ka-band supports for the given day; identified by a header row followed by 1:N lines of data, in the form of:<br>WOTIS Ka Band Passes Minutes Rate (Mbps)<br>(AOS Date/time) – (LOS Date/time) MM.nn 100 |
| Avg. LRO NAC Image Size<br>Avg. LRO WAC Image Size | The average size of an LROC NAC image: 2.3042 Gbits<br>The average size of an LROC WAC image: 0.0000 Gbits |
| Next Header Row Definition Area | Provides additional column header information for the remaining data lines, which provide information on the following details<br>Commanding (Gbits) and Available memory (Gbits); followed by an ASICC set of underscores |

| Field name | Field Characteristics |
|---|---|
| Detailed Column Details | Additional column headers separated by ASCII blanks; another row follows that provides a set of underscore characters for each column header.<br><br>After this set of 2 lines of column headers, the remainder of the report consists of ASCII digits that provide the details as identified in the following rows: |
| Asc Node Time | 14 ASCII Digits and characters in the form of:<br>YYYYDOY.HHMMSS; where,<br>YYYY = 4 digits of year<br>DOY = 3 digits for the day of year<br>HHMMSS = 6 digits to represent the hours, minutes, and seconds of the ascending node time; there is a period (.) separator between the YYYDOY and the HHMMSS |
| Orbit Number | 1 – 5 ASCII Digits that represent the orbit number; starts with 1 and monotonically increase for each ascending node crossing |
| MRF | Either a single – or an ASCII set of digits (NN.mmm, in Gbits) to represent the corresponding amount of generated Mini-RF data taken during that orbit |
| LROCNAC | Either a single – or an ASCII set of digits (NN.mmm, in Gbits) to represent the corresponding amount of generated LROC NAC images taken during that orbit |
| LROCWAC | Either a single – or an ASCII set of digits (NN.mmm, in Gbits) to represent the corresponding amount of generated LROC WAC images taken during that orbit |
| KBandDL(Gbits) | Either a single – or an ASCII set of digits (NNN.mmm, in Gbits) to represent the corresponding amount of data that the orbiter can potential downlink during the orbit for all associated Ka-Band station contacts |
| LROC IMAGES AVALABLE | 3 ASCII Digits used to represent the available remaining number of LROC images, in the form of: nnn, where nnn can be any positive number from 1 to 168 |

| Field name | Field Characteristics |
|---|---|
| VR1(390.32) | Amount of memory and percentage available for this partition in the form of:<br>NNN.mmmm ( dd%); where<br>NNN.mmmm provide 3 ASCII digits before the decimal point and 4 ASCII digits after the decimal point for the available VR1 memory (in Gbits)<br>dd are 2 ASCII digits to represent the VR1 percentage remaining |
| VR2(14.00) | Amount of memory and percentage available for this partition in the form of:<br>NNN.mmmm ( dd%); where<br>NNN.mmmm provide 3 ASCII digits before the decimal point and 4 ASCII digits after the decimal point for the available VR2 memory (in Gbits)<br>dd are 2 ASCII digits to represent the VR2 percentage remaining |
| VR3(8.00) | Amount of memory and percentage available for this partition in the form of:<br>NNN.mmmm ( dd%); where<br>NNN.mmmm provide 3 ASCII digits before the decimal point and 4 ASCII digits after the decimal point for the available VR3 memory (in Gbits)<br>dd are 2 ASCII digits to represent the VR3 percentage remaining |

A sample file name for a Data Recorder Model file has the following convention:

<File Name Descriptor>_<Start Date & Time>_Stop Date & Time>.<file extension>

| | | | |
|---|---|---|---|
| where | File Name Descriptor | = | [21 ASCII Characters] Recorder_Memory_Model, followed by the hyphen (-) field separator |
| | Start Date & Time | = | [14 ASCII digits and characters]; with the following convention:<br>[4 ASCII Digits for Start Year] (2009 – 2013)<br>[3 ASCII Digits for start DOY] (001 – 366), followed by an underscore (_)<br>[6 ASCII Digit Time Stamp] in hhmmss format, followed by an hyphen (-). (Note: The Start Date/Time identify the start of the data within the memory model file |

| | | |
|---|---|---|
| Stop Date & Time | = | [14 ASCII digits and characters]; with the following convention:<br>[4 ASCII Digits for Start Year] (2009 – 2013)<br>[3 ASCII Digits for start DOY] (001 – 366), followed by an underscore (_)<br>[6 ASCII Digit Time Stamp] in hhmmss format, followed by an hyphen (-). (Note: The Stop Date/Time identify the end of the data within the memory model file |
| file extension | = | [.txt] Identifies a text file |

For example, a sample file name for the Data Recorder Model that the MOC created, which corresponds to a valid memory model for a date range of 24 September 2009 to 30 September 2009 is identified as: Recorder_Memory_Model-2009267_000000-2009273_221717.txt.

A sample Recorder Memory Model is provided for reference in Appendix B as Figure B.4-21.

## 4.6 MOC PRODUCTS TO STATIONS

The following sections identify the interfaces sent by the LRO MOC to the various ground stations supporting the LRO mission. Nominally, these interfaces are used to transmit command from the LRO MOC to the corresponding station. The command structure that the LRO MOC uses is dependant upon the station that is scheduled to be the interface for sending commands to the LRO spacecraft. The following conventions are used by the LRO MOC to support the interface with each of the corresponding stations:

- EOS Ground Message Header for commanding through either WS1, USN stations or the Space Network using TDRSS uplink
- SLE Command structure for interfacing with DSN stations

The EOS Ground Message header is 24 bytes long and has the following data structure as identified in Figure 4-12;

Table 4-37 provides a reference definition for the fields contained within the EOS Ground message Header. After the 24-byte header, the commands are formatted into the variable length Command Length Transmission Units (CLTUs).

| Ground Message Header | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Message Type (1) | Fill/ Spare (1) | Source Id (1) | Destination Id (1) | Fill/ Spare (1) | Message GMT (7) | SC ID (2) | Seq. # (2) | SW Ver. # (2) | Message Length (2) | Fill/ Spare (4) | CLTU (variable) |

***Figure 4-12 EOS Ground Message Header***

### *Table 4-37 EOS Ground Message Header Definitions*

| Name | Format | Size (bytes) | Value | Data Characteristics |
|---|---|---|---|---|
| Message Type or Test Message Type | Unsigned integer | 1 | 03 | Range for message type = 0-127<br>Range for test message type = 128-255<br>(Test message type equals message type plus 128.) This field uniquely identifies the message and indicates to the receiver what message format to expect and process. |
| Fill/Spare (reserved for future use) | Unsigned integer | 1 | 0 | Value = 0 |
| Source Identification | Unsigned integer | 1 | 0 | Range = 0-255; not used for LRO |
| Destination Identification | Unsigned integer | 1 | 0 | Range = 0-255; not used for LRO |
| Fill/Spare (reserved for future use) | Unsigned integer | 1 | 0 | Value = 0 |
| Message Generation Time and Date | NASA PB5 code format | 7 | variable | Contains Greenwich mean time (GMT) |
| Spacecraft ID | Unsigned integer | 2 | 0xA5 | LRO will use the CCSDS uplink SCID value of A5 |
| Message Sequence Number | Unsigned integer | 2 | 0 | Range = 0-65,535; one-up counter that wraps around, on reaching the largest value, to smallest value. This number is one-up per source identification and is assigned by the originator. This field is not used for LRO. |
| Software Version Number | Unsigned integer | 2 | 0 | Range = 0-255 (first byte identifies major EDOS release; second byte represents version of major release, either initial version or an update) This field is not used for LRO. |
| Message Length | Unsigned integer | 2 | variable | Range = 24-65,535 (number of bytes in message); For LRO, this value includes the length of the LRO ground message header, as well as the attached CLTU |
| Fill/Spare (reserved for future use) | Unsigned integer | 4 | 0 | Value = 0 |

For the DSN, the ground generated CLTUs are formatted into a Space Link Extension (SLE) Forward Command Link Transmission Unit (F-CLTU). The format previously discussed in Section 4.2.13 SLE Telemetry Header, is identical for the SLE F-CLTU formats.

### 4.6.1 (MOC-34) (MOC-36) Real-time Orbiter Commands (WS1 and USN and SN)

This product is the real-time Orbiter Commands via CLTUs to both the SCN station (WS1) and the four currently allocated USN stations using the EOS Ground Message Header. The SN also uses this EOS Command Message Header; The LRO MOC may use the SN command uplink during the first several hours of the mission.

#### 4.6.1.1 Product Details

| | |
|---|---|
| Time interval | Can only be up to 8 commands to execute at the identical 1 second interval |
| File duration | NA |
| File or Data Generation Frequency | Prior to every station contact, as required to support Orbiter health and safety |
| Delivery method (real-time, SCP, FTP, etc) | Real-time TCP socket to designated station |
| Data Volume | Variable, based on real-time commanding or if commanding via CFDP file uplink |
| Accuracy (if it applies) | NA |
| Other pertinent details | One command per CLTU |

#### 4.6.1.2 Format

The SCN Real-time Orbiter Commands consists of the commands formatted into CLTUs and transmitted to either the WS1 station or the appropriate USN station supporting the mission.

The SCN Real-time Orbiter Commands (for WS1 and USN interfaces) are sent in a binary form over a socket connection from the LRO MOC. Since this is a binary representation of the data, no sample product is listed in Appendix B.

### 4.6.2 (MOC-35) DSN Real-time Orbiter Commands

This product is the real-time Orbiter Commands via CLTUs to DSN stations using the Space Link Extension (SLE). For the DSN, the ground generated CLTUs are formatted into an SLE Forward Command Link Transmission Unit (F-CLTU). The format previously discussed in Section 4.2.13, SLE Telemetry Header, is identical for the SLE F-CLTU structure. The LRO MOC and the DSN will perform the following steps to ensure an SLE command interface with the DSN and to ensure commands are transmitted to the Orbiter:

- The LRO MOC issues a CLTU-BIND operation to establish an association
- DSN generates the Acquisition and Idle Sequences on the physical channel in accordance with the physical link operational procedure (PLOP-2) in effect
- The LRO MOC performs the CLTU-START operation

- The LRO MOC performs the CLTU-TRANSFER-DATA operation
- The LRO MOC sends Additional CLTUs using the CLTU-TRANSFER-DATA operation
- At the time specified for the start of radiation, DSN injects the first CLTU into the physical channel and modulated onto the RF carrier
- DSN processes successive CLTUs in a similar fashion
- The LRO MOC transfers the last CLTU to DSN
- DSN completes processing the buffered CLTUs
- The LRO MOC performs the CLTU-STOP operation
- The LRO MOC performs CLTU-UNBIND operations to release the association
- At the end of the scheduled service period, DSN transitions to unmodulated carrier, then typically turns off the RF link

#### 4.6.2.1 Product Details

| | |
|---|---|
| Time interval | Can only be up to 8 commands to execute at the identical 1 second interval |
| File duration | NA |
| File or Data Generation Frequency | Prior to every station contact, as required to support Orbiter health and safety |
| Delivery method (real-time, SCP, FTP, etc) | Real-time TCP socket to designated station |
| Data Volume | Variable, based on real-time commanding or if commanding via CFDP file uplink |
| Accuracy (if it applies) | NA |
| Other pertinent details | One command per CLTU<br>Uses the Space Link Extension Concepts |

#### 4.6.2.2 Format

The DSN Real-time Orbiter Commands consists of the commands in CLTUs and formatted within the SLE wrappers. The SCN Real-time Orbiter Commands (for WS1 and USN interfaces) are sent in a binary form over a socket connection from the LRO MOC. Since this is a binary representation of the data, no sample product is listed in Appendix B.

## 4.7 NAVIGATION AND ANCILLARY INFORMATION FACILITY (NAIF) INTERFACE AND PRODUCTS

The following sections provide the details related to the interfaces and products distributed by NASA's Navigation and Ancillary Information Facility (NAIF) for use by the LRO mission. The NAIF is located at the Jet Propulsion Laboratory to lead the design and implementation of the "SPICE" ancillary information system. SPICE is used throughout the lifecycle of space science missions to help scientists and engineers design missions, plan scientific observations, analyze science data and conduct various engineering functions associated with flight projects. These products are generated by the NAIF and the LRO MOC will receive these files when notified and then distribute the files to the necessary Science Operations Centers.

The user can receive more information as well as a SPICE toolkit or review the set of products by using the following NAIF web site:

http://naif.jpl.nasa.gov/naif/data.html

The user can download any of the identified sample products or review a textual product by checking the NAIF web site.

### 4.7.1 (NAIF-1) SPICE Planetary SPK

The SPICE Planetary SPK file is one of the generic SPICE products that the LRO MOC receives (FTP pulls) from the NAIF/PDS repository whenever the NAÏF generates a new version.

The LRO MOC uses a generic term of dexxx since this NAIF provides an updated version on an non-routine basis. For each new release, the NAIF updates the xxx designation with a 3-digit construct. The most recent version that the NAIF generated is identified as de421.

#### 4.7.1.1 Product Details

| | |
|---|---|
| Time interval | NA |
| File duration | NA, good until the next regeneration of the product by NAIF |
| File or Data Generation Frequency | Regenerated, as identified by NAIF personnel |
| Delivery method (real-time, SCP, FTP, etc) | MOC initiates an FTP pull from the NAIF<br>MOC scp pushes to all SOCs |
| Data Volume | Variable; current version is approximately 16Mbytes |
| Accuracy (if it applies) | As defined by NAIF |
| Other pertinent details | NA |

#### 4.7.1.2 Format

The current version of this NAIF-supplied product for the planetary SPICE ephemeris file is identified with the following file name
de421.bsp.

The SPICE Planetary SPK is a binary formatted file. As such, there is no sample product provided in Appendix B.

### 4.7.2 (NAIF-2) SPICE LSK – Leap Second

The SPICE LSK – Leap Second File is another of the generic SPICE products that the LRO MOC receives (FTP pulls) from the NAIF/PDS repository whenever the NAÏF generates a new version. This logical product actually consists of two separate files based on the user's platform;

the file contains all of the leap second adjustments and when these adjustments should be used. This file supports the conversion between ephemeris time and UTC. The LRO MOC will forward the correct version of the file to the SOCs based on the SOC specific platform.

#### 4.7.2.1 Product Details

| | |
|---|---|
| Time interval | NA; the file contains the specific times at which a leap-second is applied |
| File duration | NA |
| File or Data Generation Frequency | Regenerated, as identified by NAIF personnel |
| Delivery method (real-time, SCP, FTP, etc) | MOC initiates an FTP pull from the NAIF<br>MOC scp pushes to all SOCs |
| Data Volume | Variable |
| Accuracy (if it applies) | Associated UTC time corresponding to the Leap-second is accurate to milliseconds |
| Other pertinent details | MOC will forward either the PC-based file or the Unix-based file<br>Specific details are left for the MOC to SOC Operations Agreements |

#### 4.7.2.2 Format

The NAIF provides two separate versions of the leap-second file. There are versions for both Window-based PC platforms and a separate version for Linux or Mac OS systems.

The current version of this NAIF-supplied product is either one of the following two versions based on whether the user system is Windows-based or Linux/Mac-based.

- naif0008.tls for Unix-style text file; it is suitable for use on any Unix-based systems, including PC/Linux or Mac/OSX systems
- naif0008.tls.pc for PCs running Windows

The SPICE LSK – Leap Second File is a textual formatted file. However, since this is a NAIF supplied product the user should reference the NAIF web site for the specific file format concepts.

### 4.7.3 (NAIF-3) SPICE Generic PCK (Planetary Constants)

The SPICE Generic PCK file is another of the generic SPICE products. This “logical” product consists of two files that the LRO MOC receives (FTP pulls) from the NAIF/PDS repository whenever the NAÏF generates a new version. .

#### 4.7.3.1 Product Details

| | |
|---|---|
| Time interval | Data samples provided at 60 minute increments |
| File duration | Contains a year of information |
| File or Data Generation Frequency | Regenerated, as identified by NAIF personnel |
| Delivery method (real-time, SCP, FTP, etc) | MOC initiates an FTP pull from the NAIF<br>MOC scp pushes to all SOCs |
| Data Volume | Variable; < 1 MByte |
| Accuracy (if it applies) | NA |
| Other pertinent details | NA |

#### 4.7.3.2 Format

The DE-421 based kernel file provides the orientation of Lunar Principal Axis (PA) reference frame; the specific file that the MOC pulls from the NAIF is:

moon_pa_de421_1900-2050.bpc

The NAIF also creates a Generic text PCK kernel, which contains orientation data for the sun, planets, natural satellites, and selected asteroids. This file is identified as:
pck00008.tpc

The NAIF generates these SPICE Generic PCK files; these are binary formatted files. Since this is a binary formatted file, no sample product will be shown in Appendix B.

### 4.7.4 <u>(NAIF-4) SPICE Lunar Reference Frame</u>

This logical file is another of the generic SPICE products. This “logical” product consists of two files that the LRO MOC receives (FTP pulls) from the NAIF/PDS repository whenever the NAÏF generates a new version.

This file contains the various lunar constants or other reference frame information required to support a mission orbiting the moon.

#### 4.7.4.1 Product Details

| | |
|---|---|
| Time interval | NA |
| File duration | File is valid until next recalculations and regeneration |
| File or Data Generation Frequency | Regenerated, as identified by NAIF personnel |
| Delivery method (real-time, SCP, FTP, etc) | MOC initiates an FTP pull from the NAIF<br>MOC scp pushes to all SOCs |
| Data Volume | Variable; < 1 Kbytes |
| Accuracy (if it applies) | NA |
| Other pertinent details | NA |

#### 4.7.4.2 Format

The first file is the Lunar frames kernel, which contains the latest specifications of lunar reference frames realizing the Lunar Principal Axis (PA) and Mean Earth/Polar Axis (ME) reference system. This file is identified as:

moon_071218.tf

The reference frames specified by this kernel are associated with the lunar libration data provided by JPL's DE-418 planetary ephemeris. The NAIF provides "frame association" kernels that simplify changing the body-fixed frame associated with the Moon.

The user should only use one of these two bases on whether the user want to translate into the “principal-axis” reference frame or the “mean-earth” reference frame.

moon_assoc_me.tf
moon_assoc_pa.tf

These SPICE Lunar Reference Frame Files are text- formatted file. However, since these are NAIF supplied products, the user should reference the NAIF web site for the specific file format concepts.

## 4.8 LAUNCH SITE (KSC) PRODUCT AND DESCRIPTIONS

This section contains the interface products generated by either the LRO MOC or the launch site at Kennedy Space Center (KSC)

This section provides the details on the interfaces between the Kennedy Space Center (the launch site) or the launch vehicle and the LRO MOC.

### 4.8.1 (KSC-1) (KSC-2)Real-time Orbiter Telemetry

This interface provides a telemetry flow path from the KSC launch site for real-time. This interface supports both the pre-launch verification tests, when the orbiter and instrument suites are at KSC prior to the launch, as well as the actual launch duration. This interface is between two ITOS systems. The one at KSC acts as the initial interface with the orbiter and then sends the telemetry data to the ITOS located at the LRO MOC.

#### 4.8.1.1 Product Details

| | |
|---|---|
| Time interval | Based on simulated tests in support of launch criteria (tests and rehearsals) |
| File duration | NA |
| File or Data Generation Frequency | Pre-Launch: As required to support mission simulations or rehearsals<br>Launch Required to support actual launch duration for data flow from KSC |
| Delivery method (real-time, SCP, FTP, etc) | Real-time socket connection to LRO MOC |
| Data Volume | Variable; based on Orbiter telemetry rates |
| Accuracy (if it applies) | 100 % of real-time VC0 or VC1 telemetry data sent to the MOC from the launch site |
| Other pertinent details | Only required during pre-launch (L-3 M) up through Launch |

#### 4.8.1.2 Format

The Real-time Orbiter Telemetry is a collection of APIDs and contains the associated telemetry mnemonics in binary form. As such, there is no sample product provided in Appendix B.

### 4.8.2 <u>(KSC-3) Archived VC0 Orbiter Telemetry</u>

This interface provides a telemetry flow path from launch Site for both real-time and archived files. This interface is used during pre-launch verification tests, when the orbiter and instrument suites are at KSC prior to the launch. This interface is between two ITOS systems. The one at KSC acts as the initial interface with the orbiter and then sends the telemetry data to the ITOS located at the LRO MOC.

#### 4.8.2.1 Product Details

| | |
|---|---|
| Time interval | Based on simulated tests in support of launch criteria (tests and rehearsals) |
| File duration | Based on simulated station support duration and downlink rate |
| File or Data Generation Frequency | Pre-Launch: As required to support sims or rehearsals |
| Delivery method (real-time, SCP, FTP, etc) | scp to LRO MOC |
| Data Volume | Variable; based on APID filter rates and test durations |
| Accuracy (if it applies) | 100 % of archived VC0 telemetry data sent to the MOC from the launch site |
| Other pertinent details | Only required during pre-launch (L-3 M) up through Launch |

#### 4.8.2.2 Format

This archived file name convention is identical to the convention as previously defined in Section 4.2.3.

The Archived VC0 Orbiter Telemetry is a collection of APIDs and contains the associated telemetry mnemonics in binary form.  As such, there is no sample product provided in Appendix B.

### 4.8.3 <u>(KSC-4) Archived VC1 Telemetry Data</u>

This interface provides a telemetry flow path from launch Site for both real-time and archived files. This interface is used during pre-launch verification tests, when the orbiter and instrument suites are at KSC prior to the launch.  This interface is between two ITOS systems.  The one at KSC acts as the initial interface with the orbiter and then sends the telemetry data to the ITOS located at the LRO MOC.

#### 4.8.3.1 Product Details

| | |
|---|---|
| Time interval | Based on simulated tests in support of launch criteria (tests and rehearsals) |
| File duration | 1 hour, or 1MByte |
| File or Data Generation Frequency | Pre-Launch: As required to support sims or rehearsals |
| Delivery method (real-time, SCP, FTP, etc) | scp to LRO MOC |
| Data Volume | Approximately 1 MB file |
| Accuracy (if it applies) | 100 % of archived VC1 telemetry data sent to the MOC from the launch site |
| Other pertinent details | Only required during pre-launch (L-3 M) up through Launch |

#### 4.8.3.2 Format

This archived file name convention is identical to the convention as previously defined in Section 4.2.4.

The Archived VC1 Orbiter Telemetry is a collection of APIDs and contains the associated telemetry mnemonics in binary form.  As such, there is no sample product provided in Appendix B.

### 4.8.4 <u>(KSC-5)Archived VC2 Telemetry Data</u>

This interface provides a telemetry flow path from launch Site for both real-time and archived files. This interface is used during pre-launch verification tests, when the orbiter and instrument suites are at KSC prior to the launch.  This interface is between two ITOS systems.  The one at KSC acts as the initial interface with the orbiter and then sends the telemetry data to the ITOS located at the LRO MOC.

#### 4.8.4.1 Product Details

| | |
|---|---|
| Time interval | Based on simulated tests in support of launch criteria (tests and rehearsals) |
| File duration | 1 hour, or 1MByte |
| File or Data Generation Frequency | Pre-Launch: As required to support sims or rehearsals |
| Delivery method (real-time, SCP, FTP, etc) | Scp to LRO MOC |
| Data Volume | Approximately 1 MByte file |
| Accuracy (if it applies) | 100 % of archived VC2 telemetry data sent to the MOC from the launch site |
| Other pertinent details | Only required during pre-launch (L-3 M) up through Launch |

#### 4.8.4.2 Format

This file name convention corresponding to the Archived VC2 data files conform to the file names created on-board the spacecraft.

The Archived VC2 Telemetry Data File is a collection of APIDs and the associated telemetry mnemonics in binary form; as such, there is no sample product provided in Appendix B.

### 4.8.5 (KSC-6) Archived VC3 telemetry Data

This interface provides a telemetry flow path from launch Site for both real-time and archived files. This interface is used during pre-launch verification tests, when the orbiter and instrument suites are at KSC prior to the launch. This interface is between two ITOS systems. The one at KSC acts as the initial interface with the orbiter and then sends the telemetry data to the ITOS located at the LRO MOC.

#### 4.8.5.1 Product Details

| | |
|---|---|
| Time interval | Based on simulated tests in support of launch criteria (tests and rehearsals) |
| File duration | 1 hour, or 1MByte, or 1 LROC Image (either WAC or NAC) |
| File or Data Generation Frequency | Pre-Launch: As required to support sims or rehearsals |
| Delivery method (real-time, SCP, FTP, etc) | scp to LRO MOC |
| Data Volume | 1 MB file up to 250 MByte files based on specific science instrument |
| Accuracy (if it applies) | 100 % of archived VC3 telemetry data sent to the MOC from the launch site |
| Other pertinent details | Only required during pre-launch (L-3 M) up through Launch |

#### 4.8.5.2 Format

This file name convention corresponding to the Archived VC2 data files conform to the file names created on-board the spacecraft.

The Archived VC3 Orbiter Telemetry is a collection of APIDs and the associated telemetry mnemonics in binary form; as such, there is no sample product provided in Appendix B.

### 4.8.6 (LV-1) Launch Vehicle Post Separation Vector

This information is the Post-separation vector from the launch vehicle provider; nominally, this exchange is internal to the FDF, as the ELV team, under contract to the LV, will provide the vector electronically. This interface is used post-launch and occurs several minutes after the actual separation of LRO from the launch vehicle.

#### 4.8.6.1 Product Details

| | |
|---|---|
| Time interval | NA |
| File duration | NA |
| File or Data Generation Frequency | Once Post-Launch at approximately 30 minutes after LRO separation from Launch Vehicle<br>During pre-launch tests and simulations, a dummy version of this file may be transmitted to test the interface protocol and receipt at the destination |
| Delivery method (real-time, SCP, FTP, etc) | FTP to LRO FDF Facility (B28 @ GSFC)<br>Backup is to FAX to B28 at 301-286-1668). |
| Data Volume | 1-2 pages of LV separation information |
| Accuracy (if it applies) | Best estimate based on available real-time tracking data |
| Other pertinent details | Only required immediately after launch |

#### 4.8.6.2 Format

The Expendable Launch Vehicle FDF team (under contract to the United Launch Alliance contractor) electronically supplies this product to the Flight Dynamic's Orbit Team. This product is a binary file and as such, no sample product is provided in Appendix B.

## 4.9 LRO MOC PRODUCT INTERFACE WITH THE LAUNCH SITE

This section describes the interface between the LRO MOC and KSC support facilities. These interfaces are used in both a pre-launch and post-launch configuration.

### 4.9.1 (MOC-38) Telemetry to KSC

The interface is used for post launch data flows between the MOC and the launch site at the Kennedy Space Center. This interface is between two ITOS systems. The ITOS located at the LRO MOC receives the post-launch telemetry data via the orbiter and transmits the post-launch telemetry data to the ITOS system located at KSC.

#### 4.9.1.1 Product Details

| | |
|---|---|
| Time interval | Based on data downlink rate (~2Kbps) |
| File duration | NA |
| File or Data Generation Frequency | Pre-Launch: As required to support sims<br>Post-Launch Phase As required for Orbiter telemetry transfer during the post-launch |
| Delivery method (real-time, SCP, FTP, etc) | Real-time TCP socket connection from Prime ITOS to ITOS residing at KSC |
| Data Volume | Variable based on support durations and downlink rate |
| Accuracy (if it applies) | 100 % of telemetry data sent from the MOC to the launch site |
| Other pertinent details | Only required during pre-launch (L-3 M) and immediately after launch (L+3 D) |

#### 4.9.1.2 Format

This interface is a collection of requested APIDs and contains the associated telemetry mnemonics in binary form. As such, there is no sample product provided in Appendix B.

### 4.9.2 (MOC-37) Commands to KSC

This interface is used for testing and mission rehearsals and provides the conduit for sending commands to the LRO spacecraft prior to launch. This interface is between two ITOS systems. The ITOS located at the LRO MOC generates the commands and transmits the commands to the ITOS system located at KSC.

#### 4.9.2.1 Product Details

| | |
|---|---|
| Time interval | Can only be up to 8 commands to execute at the identical 1 second |
| File duration | Command file (ATS load is for a 1-day period) |
| File or Data Generation Frequency | Pre-Launch: As required to support simulations and rehearsals |
| Delivery method (real-time, SCP, FTP, etc) | Real-time TCP socket connection from Prime T&C Workstation |
| Data Volume | NA |
| Accuracy (if it applies) | 100 % of command data sent from the MOC |
| Other pertinent details | Only required during pre-launch (L-3 M) and immediately after launch (L+1H) |

.

#### 4.9.2.2 Format

This interface is a collection of real-time command within a CLTU data structure and contains the associated command mnemonics in binary form. As such, there is no sample product provided in Appendix B.

### 4.9.3 (MOC-69) LRO-Provided Separation Data File

The LRO-Provided Separation Data File is a MOC-generated report that provides a combination of data as received from Flight Dynamics and the Attitude Ground System, which is hosted in the MOC. Flight Dynamics provides an initial post-launch orbital element set as defined by the standard set of Keplerian elements. The MOC/AGS component generates body tip-off rates and then appends the AGS-calculated data onto the FD-generated data.

#### 4.9.3.1 Product Details

| | |
|---|---|
| Time interval | NA; data is time stamped with the separation epoch only |
| File duration | NA; data is generated only once post-launch |
| File or Data Generation Frequency | Once; post-launch |
| Delivery method (real-time, SCP, FTP, etc) | MOC scp-es the data file to the launch contractor (United Launch Alliance) |
| Data Volume | Less than 1 KByte |
| Accuracy (if it applies) | Best available based on received station tracking data as the initial Separation vector received from the launch site |
| Other pertinent details | NA |

#### 4.9.3.2 Format

The LRO-Provided Separation Data File is an ASCII formatted file in which each line contains one "record" of the overall file. The first several lines contained the FD-calculated Keplerian element information; the remaining fields are the AGS-calculated body tip-off rates. The following table provides the overall file contents and format.

The file contains best estimated values for the launch separation information as calculated from the initial launch separation vector and supplemented using available tracking data.

The file will contain 3 "header" records that provide a summary of the file name and date and time of creation; each of these "header" records have the # character in the first column.

The "data" records immediately follow the "header" records and each line contains one item associated with the best estimated separation data. The following table provides the details regarding the "data" records fields:

### *Table 4-38 Best Estimated Separation Data Description*

| Field name | Field Characteristics |
|---|---|
| Orbital Insertion Information (from FDF-44 product) | |
| Date of launch vehicle separation | 8 ASCII digits that represent the True equinox of date; with the following format: MMDDYYYY |
| Time of launch vehicle separation | 6 ASCII digits that represent the True equinox of date; with the following format HHMMSS |
| Semi-major Axis (Km) | Floating point value, format: nnnnnnnn.nnnnnn |
| Eccentricity (Unitless) | Floating point value; format 0.nnnnnnnnnn |
| Inclination (Degrees) | Floating point value: format: nnn.nnnnnn; not zero padded |
| Right Ascension of Ascending Node (Degrees) | Floating point value: format: nnn.nnnnnn; not zero padded |
| Argument of perigee (Degrees) | Floating point value: format: nnn.nnnnnn; not zero padded |
| True Anomaly (Degrees) | Floating point value: format: nnn.nnnnnn; not zero padded |
| Orbiter Separation Data (S/C Body Frame) | |
| Separation Rate X Axis (degrees/sec) | Floating point value: format: nnn.nnnnnn; not zero padded |
| Separation Rate Y Axis (degrees/sec) | Floating point value: format: nnn.nnnnnn; not zero padded |
| Separation Rate Z Axis (degrees/sec) | Floating point value: format: nnn.nnnnnn; not zero padded |
| Sun Vector X Axis (Unitless) | Floating point value: format: nnn.nnnnnn; not zero padded |
| Sun Vector Y Axis (Unitless) | Floating point value: format: nnn.nnnnnn; not zero padded |
| Sun Vector Z Axis (Unitless) | Floating point value: format: nnn.nnnnnn; not zero padded |

A sample file name for this data file has the following convention:

<File identifier>_<Time>.<file extension>

where File Identifier = [5 characters]; that identifies the file type identifier: File Type (MOC69); followed by the underscore (_) character

| | | |
|---|---|---|
| Time | = | [14 ASCII Digits] Specifies the date (day & time) when the MOC completes the product generation.<br>YYYYDOY-HHMM where,<br>YYYY => 4 ASCII digits of year<br>DOY => 3 ASCII digits for day of year<br>HHMM => 4 ASCII digits for hour and minutes<br>NOTE: This date/time represents when the MOC/AGS element created/updated the file |
| file extension | = | [3 characters] txt |

For example, a sample filename for this product is identified as: MOC69_2008320-0210.txt

Appendix B, Figure B.4-20 provides a sample format of the file contents containing the LRO provided Separation Data product.

## 4.10 LRO MOC PRODUCT INTERFACE WITH THE FLIGHT DYNAMICS FACILITY

This section describes the interface between the LRO MOC and FDF. These interfaces are used in both a pre-launch and post-launch configuration.

### 4.10.1 (MOC-63) Propulsion System Data

This file contains the temperature and pressure data from the propulsion system. The MOC creates this file on an as-needed basis for FDF use. FDF uses this information in planning and modeling an upcoming maneuver and for post-maneuver analysis.

#### 4.10.1.1 Product Details

| | |
|---|---|
| Time interval | Data samples provided at downlinked data frequency based on APIDs and real-time Filter tables downlink rates |
| File duration | 30 minutes prior to planned maneuver to 10 minutes after maneuver,<br>Other file durations as requested by FDF using OAR |
| File or Data Generation Frequency | Daily 2-3 days prior to delta-V maneuver<br>12 hours prior to the Delta-V<br>for 24 hours after a maneuver<br>Immediately after executed maneuver; within 30 minutes<br>Other file delivery is based on using OAR |
| Delivery method (real-time, SCP, FTP, etc) | scp to FDF via the FD Communications Server; the backup uses the FDPC (MOC performs the scp push); using MOC subdirectory location |
| Data Volume | Variable; based on APID and the downlink rate |
| Accuracy (if it applies) | Temperature/pressure accuracy dependent on associated telemetry mnemonic<br>Time sampling accurate to 1 second |
| Other pertinent details | NA |

#### 4.10.1.2 Format

The Propulsion System Data file is a comma separated values (csv) text file, which consists of a of the requested time, temperature and pressure mnemonic values.

The data should correspond to the data for each tank (time, temperature, and pressure); the file should also contain the time and thruster counts for the four NT thrusters and the eight AT thrusters.

The first eight lines of the file contain header information that identifies the file generation parameters, as noted:

```
ASCII Report
Input Definition File:  C:\itps\Data\IDF\MOC63_PROPDATA.idf
Report Date:  03/31/2008
DMDB file(s): C:\itps\Data\dmdb\LRODB_033108.dmdb
Decom start:  2008/022/00:00:00
Decom stop:  2008/023/00:00:00
```

The file contains a header row that identifies the date/time field format (Year and S/C Time) and the corresponding spacecraft mnemonic.  The remaining file contains the data values for the year, s/c time and the selected mnemonic values for the report.

The following table provides the details of the product format

| Field name | Field Characteristics |
|---|---|
| Header Record | Year<br>S/C Time<br>CDHEPRESSTNKTEMP – Identifier for Mnemonic 1 name<br>CDLPRXDCR – Identifier for Mnemonic 2 Name |
| Data Records 1 : N | YYYY; (e.g., 2008)<br>DDD-HH:MM:SS.mmm (e.g., 022-18:03:13.237)<br>Mnemonic Value 1 – based on the selected mnemonic (e.g., 2291)<br>Mnemonic Value 2 – based on the selected mnemonic (e.g., -0.35021) |

The LRO MOC uses the following file-naming convention for MOC-transmitted files.

The filename consists of 23 characters; it also contains a three character file extension name. There are underscores (_) between the file name designators and there is a period (.) between the file name and file extension fields. The form of the filename is as follows:

<System Identifier>_<FileName>_<YYYYDOY_HHMMSS>.<file extension>

| | | | |
|---|---|---|---|
| where | System Identifier | = | [5 ASCII digits and characters]; with the following system Identifier convention:<br>MOCnn; where nn=63 for this product Identifier; followed by the underscore (_) character |
| | FileName | = | [8 characters] which are used to identify the File Type (PROPDATA), followed by the underscore (_) character |
| | Creation Time | = | [14 characters] Specifies start time of file (first telemetry point within the file).<br>YYYYDOY_HHMMSS where,<br>YYYY => 4 ASCII digits of year<br>DOY => 3 ASCII digits for day of year; followed by the underscore (_) character<br>HHMMSS => 6 ASCII digits for hour, minutes, and seconds |
| | file extension | = | [6 characters] csv |

A sample LRO Propulsion System Data file name is:

MOC63_PROPDATA_2008320_021030.csv.

A sample LRO Propulsion System Data is provided in Appendix B, Figure B.4-12

In addition to the comma separated values ASCII file, the MOC provides a plotted version of the data in a "pdf" formatted file. A sample file name associated for this plotted data is:

MOC63_PROPDATA_2008320_021030_plot.pdf.

#### 4.10.2 (MOC-65) Definitive Spacecraft Body Frame Attitude File

This file provides the orientation of the spacecraft body axes in the mean of J2000 frame; this orientation is represented using quaternions.

##### 4.10.2.1 Product Details

| | |
|---|---|
| Time interval | Data samples provided at 1 minute intervals |
| File duration | Previous 24 hours of spacecraft quaternion data<br>Nominally from 0000Z previous day to 0000Z of current day |
| File or Data Generation Frequency | Daily when generating other Attitude products |
| Delivery method (real-time, SCP, FTP, etc) | MOC scp to FDF via the FD Communications Server; the backup uses the FDPC (MOC performs the scp push); using MOC subdirectory location |
| Data Volume | Approx 100 Kbytes for the data file |
| Accuracy (if it applies) | Time sampling accurate to millisecond |
| Other pertinent details | NA |

#### 4.10.2.2 Format

The file will contain a descriptive header followed by a data record for each output time. The following is a preliminary example of the spacecraft body frame attitude file header:

C Spacecraft_Body_Attitude_File
C Satellite_ID LRO
C StartTime 2008 123 0.000000
C StopTime 2008 123 0.000000
C CoordinateFrame MJ2000
C YYYY DDD SSSSS.SSS Component_1(q1) Component_2(q2) Component_3(q3) Component_4(q4)

The data record has the following contents; the columns are space delimited:

***Table 4-39. Spacecraft Body Attitude File Data Record Format***

| Column | Item | Format | Units |
|---|---|---|---|
| 1 | Year | YYYY | years |
| 2 | Day of the Year | DDD | day |
| 3 | Seconds of Day | SSSSS.SSS | seconds |
| 4 | $q_1$ quaternion element defining the orientation of the satellite body axes with respect to the Mean of J2000.0 frame at the specified time | ±0.xxxxxxxx | unitless |
| 5 | $q_2$ quaternion element defining the orientation of the satellite body axes with respect to the Mean of J2000.0 frame at the specified time | ±0.xxxxxxxx | unitless |
| 6 | $q_3$ quaternion element defining the orientation of the satellite body axes with respect to the Mean of J2000.0 frame at the specified time | ±0.xxxxxxxx | unitless |
| 7 | $q_4$ quaternion element defining the orientation of the satellite body axes with respect to the Mean of J2000.0 frame at the specified time | ±0.xxxxxxxx | unitless |

The records will be timetagged in UTC time (not MET). The complete filename consists of 25 characters; it also contains a three character file extension name. There are underscores (_) between the file name designators and there is a period (.) between the file name and file extension fields. The form of the filename is as follows:

<File Designator>_<File Duration ><Version Identifier>.<file extension>

| | | | |
|---|---|---|---|
| where | File Designator | = | [5 ASCII characters and digits] which are used to identify the File Identifier; in the form of mocnn; where (nn = 65), followed by the underscore (_) character |
| | File Duration | = | [15 ASCII Digits] Specifies the file start and stop dates (separated by the underscore (_) character)<br>YYYYDOY where,<br>YYYY => 4 ASCII digits of start year<br>DOY => 3 ASCII digits for start day of year<br>yyyydoy where,<br>yyyy => 4 ASCII digits of stop year<br>doy => 3 ASCII digits for stop day of year |
| | Version Identifier | = | [3 ASCII Digits and characters] specifies the version number; vnn; where nn = 01 for the initial file version the version number monotonically increments for each new release (01, 02, 03, etc) |
| | file extension | = | [3 characters] txt |

A sample LRO Definitive Spacecraft Body Frame Attitude File name is for the 0000GMT of January 15, 2009 to 0000 GMT of January 16, 2009 is:

moc65_2009015_2009016_v01.txt

Appendix B, Figure B.4-13 provides a sample of a file containing the Definitive Spacecraft Body Attitude File Data File product.

### 4.10.3 (MOC-66) Spacecraft HGA Motion File

This file provides the orientation of the unit vector along the HGA boresight in the Mean of J2000.0 frame.

#### 4.10.3.1 Product Details

| | |
|---|---|
| Time interval | Data samples provided at 1 minute intervals |
| File duration | Previous 24 hours of spacecraft HGA unit vector data<br>Nominally from 0000Z previous day to 0000Z of current day |
| File or Data Generation Frequency | Daily when generating other Attitude products |
| Delivery method (real-time, SCP, FTP, etc) | scp to FDF via the FD Communications Server; the backup uses the FDPC (MOC performs the scp push); using MOC subdirectory location |
| Data Volume | Approx 100 Kbytes for the data file |
| Accuracy (if it applies) | Time sampling accurate to millisecond |
| Other pertinent details | NA |

#### 4.10.3.2 Format

This file provides a descriptive header followed by a data record for each output time. The following is a preliminary example of the file header:

C HGA_Motion_File
C Satellite_ID LRO
C StartTime 2008 123 0.000000
C StopTime 2008 123 0.000000
C CoordinateFrame MJ2000
C YYYY DDD SSSSS.SSS X_Direction Y_Direction Z_Direction

The data records have the following contents:

**Table 4-40. HGA Motion File Data Record Format**

| Column | Item | Format | Units |
|---|---|---|---|
| 1 | Year | YYYY | year |
| 2 | Day of Year | DDD | day |
| 3 | Seconds of Day | SSSSS.SSS | seconds |
| 4 | X component of a unit vector along the HGA boresight in the Mean of J2000.0 frame $\left(\hat{B}^{b}_{HGA}\right)_1$ | ±0.xxxxxxxx | unitless |
| 5 | Y component of a unit vector along the HGA boresight in the Mean of J2000.0 frame $\left(\hat{B}^{b}_{HGA}\right)_2$ | ±0.xxxxxxxx | unitless |
| 6 | Z component of a unit vector along the HGA boresight in the Mean of J2000.0 frame $\left(\hat{B}^{b}_{HGA}\right)_3$ | ±0.xxxxxxxx | unitless |

Appendix B, Figure B.4-14 provides a sample of a file containing the Raw Spacecraft HGA Motion File product.

### 4.10.4 <u>(MOC-67) Spacecraft Solar Array Motion File</u>

This file provides the orientation of the unit vector along the normal to the solar array in the Mean of J2000.0 frame.

#### 4.10.4.1 Product Details

| | |
|---|---|
| Time interval | Data samples provided at 1 minute interval |
| File duration | Previous 24 hours of spacecraft's Solar array data<br>Nominally from 0000Z previous day to 0000Z of current day |
| File or Data Generation Frequency | Daily when generating other Attitude products |
| Delivery method (real-time, SCP, FTP, etc) | scp to FDF via the FD Communications Server; the backup uses the FDPC (MOC performs the scp push); using MOC subdirectory location |
| Data Volume | Approx 100 Kbytes for the data file |
| Accuracy (if it applies) | Time sampling accurate to millisecond |
| Other pertinent details | NA |

#### 4.10.4.2 Format

***Table 4-41. SA Motion File Data Record Format***

| Column | Item | Format | Units |
|---|---|---|---|
| 1 | Year | YYYY | year |
| 2 | Day of Year | DDD | day |
| 3 | Seconds of Day | SSSSS.SSS | seconds |
| 4 | X component of a unit vector along the normal to the solar array in the Mean of J2000.0 frame | ±0.xxxxxxxx | unitless |
| 5 | Y component of a unit vector along the along the normal to the solar array in the Mean of J2000.0 frame | ±0.xxxxxxxx | unitless |
| 6 | Z component of a unit vector along the normal to the solar array in the Mean of J2000.0 frame | ±0.xxxxxxxx | unitless |

Appendix B, Figure B.4-15 provides a sample of a file containing the Spacecraft Solar Array Motion File product.

### 4.10.5 <u>(MOC-68) OBC Generated Attitude Data File</u>

The OBC Generated Attitude Data File is a comma-separated values (CSV) file created by the MOC's Trending system for use by the FD Maneuver Team. The Trending definition file defines the data mnemonics associated with this file.

The MOC creates this file using the following requested APID 240, which corresponds to the OBC calculated attitude data; calculated and target attitude quaternion data.

#### 4.10.5.1 Product Details

| | |
|---|---|
| Time interval | Variable based on Orbiter VC1 Data collection filters and per APID; nominally this will be at 5 Hz rate |
| File duration | Covers the duration of a specified maneuver; includes the maneuver slew to orientate the spacecraft before/after the maneuver<br>includes +/- 5 minutes around the maneuver |
| File or Data Generation Frequency | 1 file per orbit (for stored HK data files)<br>1 per station contact (for real-time supports) |
| Delivery method (real-time, SCP, FTP, etc) | MOC scp-es the data file to the FD Communications Server (MOC scp pushes) |
| Data Volume | Variable; based on APID 240 and the downlink rate |
| Accuracy (if it applies) | data accuracy will depend on the type of data within the specified APIDs (EU, Discrete, etc…), as well as the sampling frequency of each individual mnemonic GMT provided in the data files for each row should contain accuracy up to the sub-second |
| Other pertinent details | MOT creates a set of files (1 file per orbit) that contains the requested data duration (with overlap both before and after the requested time period) |

#### 4.10.5.2 Format

The OBC Generated Attitude Data ASCII formatted file in which the data fields are comma separated. The file contains eight lines of header information followed by one line of a data header definition that provided the descriptor information for the remaining data lines. The eight-line header data provides the following fields and information:

```
ASCII Report
Input Definition File:  C:\itps\Data\IDF\MOC68_240.idf
Report Date:  04/07/2008
DMDB file(s): C:\itps\Data\dmdb\LRODB_033108.dmdb
Decom start:  2008/303/10:15:00
Decom stop:  2008/303/13:00:00
```

The file then contains a variable number of data lines that have the following format for each identified column.

***Table 4-42 OBC Calculated Attitude Data File (MOC-68) Description***

| Field name | Field Characteristics |
|---|---|
| Header Record | Year<br>S/C Time<br>SWACATTQ1 – Identifier for Mnemonic Name<br>SWACATTQ2 – Identifier for Mnemonic Name<br>SWACATTQ3 – Identifier for Mnemonic Name<br>SWACATTQ4 – Identifier for Mnemonic Name<br>SWACTARGETQ1 – Identifier for Mnemonic Name<br>SWACTARGETQ2 – Identifier for Mnemonic Name<br>SWACTARGETQ3 – Identifier for Mnemonic Name<br>SWACTARGETQ4 – Identifier for Mnemonic Name<br>SWACUSEDATTQSRC – Identifier for Mnemonic Name<br>SWACSELTQTYPE – Identifier for Mnemonic Name<br>SWACATTERR1 – Identifier for Mnemonic Name<br>SWACATTERR2 – Identifier for Mnemonic Name<br>SWACATTERR3 – Identifier for Mnemonic Name<br>SWACSELRATE1 – Identifier for Mnemonic Name<br>SWACSELRATE2 – Identifier for Mnemonic Name<br>SWACSELRATE3 – Identifier for Mnemonic Name<br>SWACRATEERRMAG – Identifier for Mnemonic Name<br>SWACATTERRMAG – Identifier for Mnemonic Name |
| Data Records 1 : N | YYYY; (e.g., 2008)<br>DDD-HH:MM:SS.mmm (e.g., 022-18:03:13.237)<br>Mnemonic Value 1 – 4 based on the Attitude Q mnemonic (e.g., 0.259326)<br>Mnemonic Value 5 – 8 based on the Target Q mnemonic (e.g., 0.259333)<br>Mnemonic Value 9 based on the Attitude Q source (e.g., 2)<br>Mnemonic Value 10 based on the Selected Q Type mnemonic (e.g., 1)<br>Mnemonic Value 11 – 13 based on the Attitude Estimated Error mnemonic (e.g., 0.000015)<br>Mnemonic Value 14 – 16 based on the Selected Body rate mnemonic (e.g., -0.000073_<br>Mnemonic Value 17 based on the Rate Error Magnitude mnemonic (e.g., 0.00013)<br>Mnemonic Value 18 based on the Attitude Error Magnitude mnemonic (e.g., 0.000018) |

A sample file name for the first generation of this data file has the following convention:

<File identifier>_<APID>_<Start Time>.<file extension>

| | | | |
|---|---|---|---|
| where | File Identifier | = | [5 characters]; that identifies the file type identifier:<br>File Type (MOC68); followed by the underscore (_) character |
| | APID | = | [3 ASCII Digits]; that identify the specific APID for this product |
| | Start Time | = | [14 ASCII Digits] Specifies the Orbiter day/time.<br>YYYYDOY_HHMMSS where,<br>YYYY => 4 ASCII digits of year<br>DOY => 3 ASCII digits for day of year<br>HHMMSS => 6 ASCII digits for hour, minutes, and seconds |
| | file extension | = | [3 characters] csv |

For example, a sample text file of the OBC calculated Attitude data file is identified as: MOC68_240_2008320_021030.csv

Appendix B, Figure B.4-16 provides a sample of the data file containing the OBC Generated Attitude Data product.

In addition to the comma separated values ASCII file, the MOC provides a plotted version of the data in a "pdf" formatted file. A sample file name associated for this plotted data is:

MOC68_240_2008303_101500_plot.pdf.

#### 4.10.6 (MOC-72) LRO Thruster Data

The LRO Thruster Data File is a comma-separated values (CSV) file created by the MOC's Trending system for use by the FD Maneuver Team. The Trending definition file defines the data mnemonics associated with this file.

The MOC creates this file using the APID 255 that contains the information related to the AT and NT Thrusters that LRO uses to perform maneuvers.

#### 4.10.6.1 Product Details

| | |
|---|---|
| Time interval | Variable based on Orbiter VC1 Data collection filters and per APID; nominally this will be at 5 Hz rate |
| File duration | Covers the duration of a specified maneuver; includes the maneuver slew to orientate the spacecraft before/after the maneuver<br>includes +/- 5 minutes around the maneuver |
| File or Data Generation Frequency | 1 file per orbit (for stored HK data files)<br>1 per station contact (for real-time supports) |
| Delivery method (real-time, SCP, FTP, etc) | MOC scp-es the data file to the FD Communications Server (MOC scp pushes) |
| Data Volume | Variable; based on the APID and the downlink rate |
| Accuracy (if it applies) | Data accuracy will depend on the type of data within the specified APIDs (EU, Discrete, etc…), as well as the sampling frequency of each individual mnemonic GMT provided in the data files for each row should contain accuracy up to the sub-second |
| Other pertinent details | MOT creates a set of files (1 file per orbit) that contains the requested data duration (with overlap both before and after the requested time period) |

#### 4.10.6.2 Format

The LRO Thruster Data is an ASCII formatted file in which the data fields are comma separated. The file contains eight lines of header information followed by one line of a data header definition that provided the descriptor information for the remaining data lines. The eight-line header data provides the following fields and information:

```
ASCII Report
Input Definition File:  C:\itps\Data\IDF\MOC72_THRUSTER.idf
Report Date:  04/07/2008
DMDB file(s): C:\itps\Data\dmdb\LRODB_033108.dmdb
Decom start:  2008/303/10:15:00
Decom stop:  2008/303/13:00:00
```

The file then contains a variable number of data lines that have the following format for each identified column.

### *Table 4-43 Propulsion Data File (MOC-72) Description*

| Field name | Field Characteristics |
|---|---|
| Header Record | Year<br>S/C Time<br>SWACDHTIMEINMODE – Identifier for Mnemonic Name<br>SWACDVTIMEINMODE – Identifier for Mnemonic Name<br>SWACDHSYSANGMOMERRMAG – Identifier for Mnemonic Name<br>SWACDVSENTPULSEAT1 – Identifier for Mnemonic Name<br>SWACDVSENTPULSEAT2 – Identifier for Mnemonic Name<br>SWACDVSENTPULSEAT3 – Identifier for Mnemonic Name<br>SWACDVSENTPULSEAT4 – Identifier for Mnemonic Name<br>SWACDVSENTPULSEAT5 – Identifier for Mnemonic Name<br>SWACDVSENTPULSEAT6 – Identifier for Mnemonic Name<br>SWACDVSENTPULSEAT7 – Identifier for Mnemonic Name<br>SWACDVSENTPULSEAT8 – Identifier for Mnemonic Name<br>SWACDVSENTPULSENT1 – Identifier for Mnemonic Name<br>SWACDVSENTPULSENT2 – Identifier for Mnemonic Name<br>SWACDVSENTPULSENT3 – Identifier for Mnemonic Name<br>SWACDVSENTPULSENT4 – Identifier for Mnemonic Name<br>SWACDVTHRONTIMEAT1 – Identifier for Mnemonic Name<br>SWACDVTHRONTIMEAT2 – Identifier for Mnemonic Name<br>SWACDVTHRONTIMEAT3 – Identifier for Mnemonic Name<br>SWACDVTHRONTIMEAT4 – Identifier for Mnemonic Name<br>SWACDVTHRONTIMEAT5 – Identifier for Mnemonic Name<br>SWACDVTHRONTIMEAT6 – Identifier for Mnemonic Name<br>SWACDVTHRONTIMEAT7 – Identifier for Mnemonic Name<br>SWACDVTHRONTIMEAT8 – Identifier for Mnemonic Name<br>SWACDVTHRONTIMENT1 – Identifier for Mnemonic Name<br>SWACDVTHRONTIMENT2 – Identifier for Mnemonic Name<br>SWACDVTHRONTIMENT3 – Identifier for Mnemonic Name<br>SWACDVTHRONTIMENT4 – Identifier for Mnemonic Name |
| Data Records 1 : N | YYYY; (e.g., 2008)<br>DDD-HH:MM:SS.mmm (e.g., 022-18:03:13.237)<br>Mnemonic Value 1 – 2 based on the Time in Mode mnemonic (e.g., 24.799999)<br>Mnemonic Value 3 based on the Target Q mnemonic (e.g., 0.259333)<br>Mnemonic Value 4-12 based on the Attitude Q source (e.g., 2)<br>Mnemonic Value 10 based on the Selected Q Type mnemonic (e.g., 1)<br>Mnemonic Value 11 – 13 based on the Attitude Estimated Error mnemonic (e.g., 0.000015)<br>Mnemonic Value 14 – 16 based on the Selected Body rate mnemonic (e.g., -0.000073_<br>Mnemonic Value 17 based on the Rate Error Magnitude mnemonic (e.g., 0.00013)<br>Mnemonic Value 18 based on the Attitude Error Magnitude mnemonic (e.g., 0.000018) |

A sample file name for the first generation of this data file has the following convention:

<File identifier>_<File Name>_<Start Time>.<file extension>

where File Identifier = [5 characters]; that identifies the file type identifier:
File Type (MOC73); followed by the underscore (_) character

File Name = [8 ASCII Characters]; that identify the specific File Name
= THRUSTER

Start Time = [14 ASCII Digits] Specifies the Orbiter day/time.
YYYYDOY_HHMMSS where,
YYYY => 4 ASCII digits of year
DOY => 3 ASCII digits for day of year
HHMMSS => 6 ASCII digits for hour, minutes, and seconds

file extension = [3 characters] csv

For example, a sample text file of the LRO Propulsion Data file is identified as:
MOC72_THRUSTER_2008303_101500.csv

Appendix B, Figure B.4-17 provides a sample of the data file containing the LRO Propulsion Data product.

In addition to the comma separated values ASCII file, the MOC provides a plotted version of the data in a "pdf" formatted file. A sample file name associated for this plotted data is:

MOC72_THRUSTER_2008303_101500.pdf.

#### 4.10.7 (MOC-74) Predictive LRO Spacecraft Body Attitude File

This is an ASCII-formatted file that the MOC-AGS element generates that corresponds to the predictive SPICE CK file. This file is consistent with the MOC-41 product; it covers the same time span. AGS generates this file at the same frequency as the MOC-41 product. The difference is that this file format is the ASCII representation of the quaternion data and not the SPICE CK format.

##### 4.10.7.1 Product Details

| | |
|---|---|
| Time interval | Data samples provided at 2 second increments |
| File duration | Next the next 7 day of predicted s/c attitude quaternion data in the body reference frame |
| File or Data Generation Frequency | Daily; Generated for delivery NLT 4 pm, Eastern |
| Delivery method (real-time, SCP, FTP, etc) | scp to FDF via the FD Communications Server; the backup uses the FDPC (MOC performs the scp push); using MOC subdirectory location |

| | |
|---|---|
| Data Volume | Approx 14.7 MBytes |
| Accuracy (if it applies) | supports accuracy requirement for slew maneuvers |
| Other pertinent details | NA |

### 4.10.7.2 Format

This file is ASCII-formatted file that contains the predictive attitude quaternions. The file contains several header rows that provide information as to when the MOC-AGS element generated the file and the time span of the file.

The format for these header rows are defined as free-form ASCII text; the following table provides the header row definitions:

| Row | Descriptor | Value |
|---|---|---|
| Row 1 | Product generator field | stk.v.7.0 (hard-coded) |
| Row 2 | Blank line separator | |
| Row 3 | Default data designation | BEGIN Attitude (hard-coded) |
| Row 4 | Blank line separator | |
| Row 5 | Blank line separator | |
| Row 6 | Number of data points values | NumberofAttitudePoints nnnnnn; where this contains the total number of points contained within the file |
| Row 7 | Blank line separator | |
| Row 8 | Start time identifier | ScenarioEpoch DD MMM YYYY HH:MM:SS.s; where the form is in day of month, month, year, followed by the start Hours, minutes and seconds |
| Row 9 | Referenced central body | CentralBody Earth (hard-coded) |
| Row 10 | Attitude Quaternion representation | CoordinateAxes J2000 (hard-coded) |
| Row 11 | Data field designations | AttitudeTimeQuaternions (hard-coded) |

The file then contains 1:N data rows in which the fields are separated by blank spaces. The last line of the file is a free-form ASCII line that has the following hard-coded form:

END Attitude

The following table provides the details of the data row format:

| Field name | Field Characteristics |
|---|---|
| Time | Time in seconds associated with the corresponding attitude quaternions SSSSS.mmmmmm => 5 ASCII digits representing the whole seconds of day followed by the period (.) separator and then 6 ASCII digits for the milliseconds of time |
| Attitude Q1 Value | ASCII value of the definitive quaternion Q1; in either of these two formats: 0.nnnnnn or -0.nnnnnn; where the – minus sign is used for negative values |
| Attitude Q2 Value | ASCII value of the definitive quaternion Q2; in either of these two formats: 0.nnnnnn or -0.nnnnnn; where the – minus sign is used for negative values |
| Attitude Q3 Value | ASCII value of the definitive quaternion Q3; in either of these two formats: 0.nnnnnn or -0.nnnnnn; where the – minus sign is used for negative values. |
| Attitude Q4 Value | ASCII value of the definitive quaternion Q4; in either of these two formats: 0.nnnnnn or -0.nnnnnn; where the – minus sign is used for negative values |

The LRO MOC uses the following file-naming convention for MOC-transmitted files.

The filename consists of 27 characters, which includes the three character file extension name. There are underscores (_) between the file name designators and there is a period (.) between the file name and file extension fields. The form of the filename is as follows:

<System Identifier>_<Start Date>_<Stop Date>_<Version Identifier>.<file extension>

where

System Identifier = [5 ASCII digits and characters]; with the following system Identifier convention:
mocnn; where nn=74 for this product identifier; followed by the underscore (_) character

Start Date = [7 ASCII Digits] Specifies the file start date (followed by the underscore (_) character)
YYYYDOY where,
YYYY => 4 ASCII digits of start year
DOY => 3 ASCII digits for start day of year

Stop Date = [7 ASCII Digits] Specifies the file start date (followed by the underscore (_) character)
yyyydoy where,
yyyy => 4 ASCII digits of stop year
doy => 3 ASCII digits for stop day of year

Version Identifier = [3 ASCII Digits and characters] specifies the version number; vnn; where nn = 01 for the initial file version the version number monotonically increments for each new release (01, 02, 03, etc) file extension = [1 ASCII characters] a

A sample LRO Predictive Attitude Quaternion Data file name is:

moc74_2008320_2008327_v01.a.

Appendix B, Figure B.4-18 provides a sample of a file containing the Definitive LRO Spacecraft Body Attitude product.

## 4.11 LRO MOC PRODUCT INTERFACES WITH CDDIS (VIA THE LOLA SOC)

This section describes the interface between the LRO MOC and CDDIS for use by all laser ranging sites that could use the LRO spacecraft for possible laser ranging activities. The LRO MOC uses the LOLA SOC as a conduit for transfer of this file.

### 4.11.1 (MOC-64) Laser Ranging GO Flag

This file provides the indication to any approved laser ranging site as to whether the LRO operations has identified that the LR sites can use the spacecraft to conduct laser ranging activities with the Orbiter.

#### 4.11.1.1 Product Details

| | |
|---|---|
| Time interval | NA |
| File duration | NA; file is correct until next update generated by MOC personnel |
| File or Data Generation Frequency | MOC updates file when state changes<br>GO ==> NOGO or<br>NOGO ==> GO |
| Delivery method (real-time, SCP, FTP, etc) | MOC scp pushes to LOLA SOC on the LRO file subdirectory<br>LOLA then forwards the file (via FTP) to the CDDIS |
| Data Volume | Approx 10 bytes for the data file |
| Accuracy (if it applies) | NA |
| Other pertinent details | NA |

#### 4.11.1.2 Format

The file is an ASCII formatted file in which the fields are separated by blanks; the file contains the following data items that a laser ranging facility would use to identify whether LR activities could be attempted. Each field is separated by a single blank ASCII character

| Field name | Field Characteristics |
|---|---|
| Spacecraft name | 10 ASCII characters; (this field is left-justified and blank-filled to pad to 10 characters<br>set to LRO |
| cospar | 7 ASCII Digits; assigned by NORAD to represent the requested target; in this instance, LRO. The 7 ASCII digits are set as follows:<br>First 2 represent the last 2 digits of the launch year; should be 09 for LRO<br>The next 3 represent the launch day of year<br>The last 2 represent the payload identifier in a multi launch configuration (or set to 01); should be assigned 01 for LRO |
| Spacecraft identifier | 4 ASCII digits that identify the spacecraft identifier<br>Set to 0059 |
| Recheck time | 2 ASCII Digit to reflect time interval (in minutes) that the facility needs to recheck the file; nominally set to 5 minutes; this field is blank padded; e.g., 5 |
| Flag | 4 ASCII characters to indicate if LR activities can be performed; this field is left-justified and blank-filled<br>“go ” ==> LR activities are allowed<br>“nogo” ==> LR Activities are prohibited |
| Text Summary | 30 ASCII Characters of free form text that provides rationale for the “go ” or “nogo” flag setting |

The LRO MOC uses the following file-naming convention as negotiated with the laser Ranging community. This file name does not conform to the standard MOC-generated file name convention. The form of the filename is as follows:

<File name>.<file extension>

where FileName = [3 characters] which are used to identify the File Name (lro), to identify that this is the LRO Go Nogo Flag file

file extension = [3 characters]; set to gng

A sample Laser Ranging GO Flag file name is: lro.gng. A sample GO-Nogo Flag File is provided in Appendix B, Figure B.4-19.

# Appendix A: – Abbreviations and Acronyms

| Abbreviation/ Acronym | DEFINITION |
|---|---|
| Acq. | Acquisition |
| ACS | Attitude Control System |
| AGS | Attitude Ground System |
| AOS | Advanced Orbiting Systems<br>Acquisition of Signal |
| APID | Application Identification<br>application process identifier |
| APL | Applied Physics Laboratory |
| ASCII | American Standard Code for Information Interchange |
| ATS | Absolute Time Sequence |
| bMOC | backup Mission Operations Center |
| Bps | bytes per second |
| CCB | Configuration Control Board |
| CCR | configuration change request |
| CCSDS | Consultative Committee for Space Data Systems |
| CDDIS | Crustal Dynamics Data Information System |
| CFDP | CCSDS File Delivery Protocol |
| CLCW | Command Link Control Word |
| CLTU | command link transmission unit |
| CM | Configuration Management |
| CMD | Command |
| CMO | Configuration Management Office |
| CNE | Center Network Environment |
| COP | Command Operating Procedures |
| COTS | commercial off the shelf |
| CRaTER | Cosmic Ray Telescope for Effects of Radiation |
| CRC | Cyclic Redundancy Check |
| DDD | DSN Data Delivery |
| DMR | Detailed Mission Requirements |
| DPS | Data Processing System |
| DSMC | Data Services Management Center |
| DSN | Deep Space Network |
| ECI | Earth Centered Inertial |
| EELV | Evolved Expendable Launch Vehicle |
| EOM | End of Mission |
| FD | Flight Dynamics |
| FDF | Flight Dynamics Facility |
| FSW | Flight Software |

| Abbreviation/ Acronym | DEFINITION |
|---|---|
| FSMF | Flight Software Maintenance Facility |
| FSWM | Flight Software Maintenance |
| FTP | File Transfer Protocol |
| GMT | Greenwich Mean Time |
| GOTS | Government off the shelf |
| GS | Ground System |
| GSE | Ground Support Equipment |
| GSFC | Goddard Space Flight Center |
| GTDS | Goddard Trajectory Determination System |
| HDR | High-rate Data Receiver |
| HGA | High Gain Antenna |
| I&T | Integration and Test |
| ICD | Interface Control Document |
| ID | Identification |
| IGSE | instrument ground support equipment |
| IIRV | improved interrange vector |
| IONet | IP Operational Network |
| IP | Internet Protocol |
| INP2 | INternet Predict, version 2 |
| ISP | FDF term; propellant specific impulse, which is a measure of the efficiency of the propulsion system |
| ITOS | Integrated Test and Operations System |
| ITRF | International Terrestrial Reference Frame |
| JPL | Jet Propulsion Laboratory |
| kbps | kilobits per second |
| km | kilometer |
| KSC | Kennedy Space Center |
| L&EO | Launch and Early Orbit |
| LAMP | Lyman-Alpha Mapping Project |
| LEND | Lunar Exploration Neutron Detector |
| LF | line feed |
| LOI | Lunar Orbit Insertion |
| LOLA | Lunar Orbiter Laser Altimeter |
| LOS | loss of signal |
| LRO | Lunar Reconnaissance Orbiter |
| LROC | Lunar Reconnaissance Orbiter Camera |
| LSB | least significant bit |
| MA | multiple access |
| Mb | megabits |

| Abbreviation/ Acronym | DEFINITION |
|---|---|
| MB | megabytes |
| MCC | Mid Course Correction |
| MCO | Mission Concept of Operations |
| MCS | master channel sequence |
| ME | Mean Earth |
| MOC | Mission Operations Center |
| MOSP | Mission Operations Support Plan |
| MOT | Mission Operations Team |
| MPS | Mission Planning System |
| MSB | most significant bit |
| NAC | Narrow Angle Camera |
| NAK | negative acknowledgement |
| NASA | National Aeronautics and Space Administration |
| Nascom | NASA Communications |
| NISN | NASA Integrated Services Network |
| NMC | Network Management Center |
| OD | Orbit Determination |
| OEM | Orbital Ephemeris Message |
| PA | principal axis – (a reference frame for a set of FDF generated products) |
| PB | playback |
| PDB | project database |
| PDS | Planetary Data System |
| PDU | Packet Data Unit |
| RF | Radio Frequency |
| RRCP | Receive, Range, Command Processor |
| RS | Reed-Solomon |
| RTS | Relative Time Sequence |
| S/C | Spacecraft |
| SA | Solar Array |
| SBC | Single Board Computer |
| SCID | spacecraft identifier |
| SCN | Space Communications Network |
| SCP | secure copy |
| SLE | Space Link Extension |
| SOC | Science Operations Center |
| SSR | Solid State Recorder |
| STGT | Second Tracking and Data Relay Satellite (TDRS) Ground Terminal |
| STDN | Spaceflight Tracking and Data Network |
| T&C | Telemetry, & Command |

| Abbreviation/ Acronym | DEFINITION |
|---|---|
| TBD | To Be Determined |
| TBR | To Be Resolved |
| TBS | To Be Supplied |
| TC | Telecommand |
| TCP | Transmission Control Protocol |
| TLM | Telemetry |
| TRAMP | Testing, Reporting, and Maintenance Program |
| TT&C | Tracking, Telemetry, & Command |
| ULA | United Launch Alliance |
| URL | Uniform Resource Locator |
| USN | Universal Space Network |
| USNO | United States Naval Observatory |
| UTC | universal time code |
| UTDF | universal tracking data format |
| VC | Virtual Channel |
| VCDU | Virtual Channel Data Unit |
| VCID | virtual channel identifier |
| WAC | Wide Angle Camera |
| WAN | wide area network |
| WGS | World Geodetic System |
| WSC | White Sands Complex |
| WSGT | White Sands Ground Terminal |

# Appendix B – Sample Product Formats

Each subsystem will have individual sections in which this document will document a sample product, which can be used as a representative format for the specified product.

## Sample FDF Products

### B.1.1 (FDF-6) INP-2 Acquisition Data Sample

15 Aug 2007 10:51:33

Inview Azimuth, Elevation, & Range

| Strand Name | YYYYDDD.HHMMSS (YYYYDDD) | Range (km) | RangeRate (km/sec) | Azimuth (deg) | Elevation (deg) |
|---|---|---|---|---|---|
| Facility/LR1S to Satellite/0059/Sensor/Omni | 2009037.000000 | 359939.91492 | -0.205789 | 80.749 | 39.798 |
| Facility/LR1S to Satellite/0059/Sensor/Omni | 2009037.000100 | 359927.52759 | -0.207172 | 80.833 | 40.007 |
| Facility/LR1S to Satellite/0059/Sensor/Omni | 2009037.000200 | 359915.04983 | -0.208803 | 80.917 | 40.215 |
| Facility/LR1S to Satellite/0059/Sensor/Omni | 2009037.000300 | 359902.46699 | -0.210674 | 81.000 | 40.422 |
| Facility/LR1S to Satellite/0059/Sensor/Omni | 2009037.000400 | 359889.76480 | -0.212780 | 81.082 | 40.629 |
| Facility/LR1S to Satellite/0059/Sensor/Omni | 2009037.000500 | 359876.92941 | -0.215113 | 81.165 | 40.835 |
| Facility/LR1S to Satellite/0059/Sensor/Omni | 2009037.000600 | 359863.94742 | -0.217665 | 81.247 | 41.041 |
| Facility/LR1S to Satellite/0059/Sensor/Omni | 2009037.000700 | 359850.80593 | -0.220428 | 81.328 | 41.245 |
| Facility/LR1S to Satellite/0059/Sensor/Omni | 2009037.000800 | 359837.49254 | -0.223393 | 81.410 | 41.449 |
| Facility/LR1S to Satellite/0059/Sensor/Omni | 2009037.000900 | 359823.99539 | -0.226551 | 81.491 | 41.652 |
| Facility/LR1S to Satellite/0059/Sensor/Omni | 2009037.001000 | 359810.30323 | -0.229892 | 81.573 | 41.855 |
| Facility/LR1S to Satellite/0059/Sensor/Omni | 2009037.001100 | 359796.40538 | -0.233406 | 81.654 | 42.056 |
| Facility/LR1S to Satellite/0059/Sensor/Omni | 2009037.001200 | 359782.29179 | -0.237082 | 81.736 | 42.257 |
| Facility/LR1S to Satellite/0059/Sensor/Omni | 2009037.001300 | 359767.95308 | -0.240908 | 81.817 | 42.457 |
| Facility/LR1S to Satellite/0059/Sensor/Omni | 2009037.001400 | 359753.38059 | -0.244875 | 81.899 | 42.657 |
| Facility/LR1S to Satellite/0059/Sensor/Omni | 2009037.001500 | 359738.56617 | -0.248969 | 81.981 | 42.856 |
| Facility/LR1S to Satellite/0059/Sensor/Omni | 2009037.001600 | 359723.50256 | -0.253179 | 82.063 | 43.054 |
| Facility/LR1S to Satellite/0059/Sensor/Omni | 2009037.001700 | 359708.18319 | -0.257492 | 82.146 | 43.251 |
| Facility/LR1S to Satellite/0059/Sensor/Omni | 2009037.001800 | 359692.60220 | -0.261897 | 82.228 | 43.447 |
| Facility/LR1S to Satellite/0059/Sensor/Omni | 2009037.001900 | 359676.75453 | -0.266380 | 82.312 | 43.643 |
| Facility/LR1S to Satellite/0059/Sensor/Omni | 2009037.002000 | 359660.63586 | -0.270928 | 82.396 | 43.839 |
| Facility/LR1S to Satellite/0059/Sensor/Omni | 2009037.002100 | 359644.24263 | -0.275529 | 82.480 | 44.033 |
| Facility/LR1S to Satellite/0059/Sensor/Omni | 2009037.002200 | 359627.57211 | -0.280169 | 82.566 | 44.227 |
| Facility/LR1S to Satellite/0059/Sensor/Omni | 2009037.002300 | 359610.62231 | -0.284836 | 82.651 | 44.420 |
| Facility/LR1S to Satellite/0059/Sensor/Omni | 2009037.002400 | 359593.39207 | -0.289515 | 82.738 | 44.613 |
| Facility/LR1S to Satellite/0059/Sensor/Omni | 2009037.002500 | 359575.88100 | -0.294195 | 82.826 | 44.805 |
| Facility/LR1S to Satellite/0059/Sensor/Omni | 2009037.002600 | 359558.08951 | -0.298860 | 82.914 | 44.997 |
| Facility/LR1S to Satellite/0059/Sensor/Omni | 2009037.002700 | 359540.01881 | -0.303500 | 83.003 | 45.188 |
| Facility/LR1S to Satellite/0059/Sensor/Omni | 2009037.002800 | 359521.67089 | -0.308099 | 83.093 | 45.379 |
| Facility/LR1S to Satellite/0059/Sensor/Omni | 2009037.002900 | 359503.04851 | -0.312646 | 83.185 | 45.569 |
| Facility/LR1S to Satellite/0059/Sensor/Omni | 2009037.003000 | 359484.15521 | -0.317127 | 83.277 | 45.759 |
| Facility/LR1S to Satellite/0059/Sensor/Omni | 2009037.003100 | 359464.99531 | -0.321531 | 83.370 | 45.949 |
| Facility/LR1S to Satellite/0059/Sensor/Omni | 2009037.003200 | 359445.57386 | -0.325844 | 83.465 | 46.138 |
| Facility/LR1S to Satellite/0059/Sensor/Omni | 2009037.003300 | 359425.89664 | -0.330054 | 83.560 | 46.327 |
| Facility/LR1S to Satellite/0059/Sensor/Omni | 2009037.003400 | 359405.97019 | -0.334150 | 83.657 | 46.515 |
| Facility/LR1S to Satellite/0059/Sensor/Omni | 2009037.003500 | 359385.80172 | -0.338119 | 83.756 | 46.704 |
| Facility/LR1S to Satellite/0059/Sensor/Omni | 2009037.003600 | 359365.39915 | -0.341951 | 83.855 | 46.892 |
| Facility/LR1S to Satellite/0059/Sensor/Omni | 2009037.003700 | 359344.77107 | -0.345635 | 83.956 | 47.080 |
| Facility/LR1S to Satellite/0059/Sensor/Omni | 2009037.003800 | 359323.92671 | -0.349159 | 84.058 | 47.268 |
| Facility/LR1S to Satellite/0059/Sensor/Omni | 2009037.003900 | 359302.87593 | -0.352514 | 84.162 | 47.456 |

***Figure B.1-1 Sample INP-2 Acquisition Data File***

### B.1.2 (FDF-10) OEM Acquisition Data Sample

```
CCSDS_OEM_VERS       = 1.0
CREATION_DATE        = 2007-05-09T15:04:34
ORIGINATOR           = GSFC

COMMENT     This is a sample OEM.  The vectors in this OEM do not necessarily
COMMENT     reflect the LRO mission orbit.  The metadata, comments, and precision
COMMENT     of the vector data do not necessarily reflect what will appear in the
COMMENT     final product.

META_START
OBJECT_NAME          = LRO
OBJECT_ID            = 2008-059A
CENTER_NAME          = EARTH
REF_FRAME            = EME2000
TIME_SYSTEM          = UTC
START_TIME           = 2009-02-06T00:00:00.00000000
STOP_TIME            = 2009-02-16T00:00:00.00000000
INTERPOLATION        = HERMITE
INTERPOLATION_DEGREE = 11
META_STOP

COMMENT     These vectors are relative to the Earth central body.
COMMENT     The vector components are X Y Z VX VY VZ.  The units are km and km/sec.

2009-02-06T00:00:00.000    15321.376603   324050.071767   163596.415680        0.040540        0.044236       -1.211973
2009-02-06T00:01:00.000    15325.532334   324052.709218   163525.417634        0.097497        0.043682       -1.154147
2009-02-06T00:02:00.000    15333.016376   324055.314077   163457.974300        0.151460        0.043150       -1.093508
2009-02-06T00:03:00.000    15343.644863   324057.887675   163394.249891        0.202290        0.042640       -1.030209
2009-02-06T00:04:00.000    15357.225841   324060.431404   163334.399175        0.249855        0.042155       -0.964412
2009-02-06T00:05:00.000    15373.559745   324062.946707   163278.567074        0.294034        0.041693       -0.896284
2009-02-06T00:06:00.000    15392.439901   324065.435077   163226.888289        0.334712        0.041257       -0.825998
2009-02-06T00:07:00.000    15413.653044   324067.898056   163179.486956        0.371783        0.040847       -0.753732
2009-02-06T00:08:00.000    15436.979855   324070.337227   163136.476320        0.405152        0.040463       -0.679672
2009-02-06T00:09:00.000    15462.195512   324072.754212   163097.958438        0.434731        0.040107       -0.604006
2009-02-06T00:10:00.000    15489.070255   324075.150669   163064.023914        0.460443        0.039779       -0.526926
2009-02-06T00:11:00.000    15517.369970   324077.528286   163034.751655        0.482220        0.039479       -0.448630
2009-02-06T00:12:00.000    15546.856774   324079.888776   163010.208662        0.500004        0.039208       -0.369317
2009-02-06T00:13:00.000    15577.289620   324082.233876   162990.449846        0.513747        0.038966       -0.289191
2009-02-06T00:14:00.000    15608.424908   324084.565341   162975.517878        0.523413        0.038754       -0.208457
```

***Figure B.1-2 Sample OEM Acquisition Data File***

### B.1.3 (FDF-7) LR Prediction Data Sample

```
H1 CPF 01  FDF 2007 08 15 13  0001 lro        Test ephem
H2 1234567  0059 12345    2009 02 06 00 00 00 2009 02 16 00 00 00    60 0 4 00 0 (
H9
10 1 54868       0.000000  0      211307984.793    -246490796.156      164692537.853
10 1 54868      60.000000  0      210242434.669    -247351616.410      164777217.690
10 1 54868     120.000000  0      209176816.621    -248204338.375      164862310.071
10 1 54868     180.000000  0      208111274.884    -249049052.189      164947585.340
10 1 54868     240.000000  0      207045943.068    -249885858.741      165032813.345
10 1 54868     300.000000  0      205980943.870    -250714869.166      165117764.045
10 1 54868     360.000000  0      204916388.460    -251536204.643      165202208.155
10 1 54868     420.000000  0      203852376.505    -252349995.626      165285917.709
10 1 54868     480.000000  0      202788995.642    -253156381.569      165368666.690
10 1 54868     540.000000  0      201726321.389    -253955510.291      165450231.581
10 1 54868     600.000000  0      200664416.667    -254747537.613      165530392.064
10 1 54868     660.000000  0      199603331.935    -255532626.591      165608931.472
10 1 54868     720.000000  0      198543104.876    -256310947.057      165685637.430
10 1 54868     780.000000  0      197483760.419    -257082674.955      165760302.346
10 1 54868     840.000000  0      196425310.411    -257847991.868      165832724.110
10 1 54868     900.000000  0      195367753.970    -258607084.190      165902706.420
10 1 54868     960.000000  0      194311077.245    -259360142.633      165970059.423
10 1 54868    1020.000000  0      193255253.676    -260107361.475      166034600.091
10 1 54868    1080.000000  0      192200243.784    -260848938.041      166096152.919
10 1 54868    1140.000000  0      191145995.661    -261585071.894      166154550.104
10 1 54868    1200.000000  0      190092444.963    -262315964.240      166209632.141
10 1 54868    1260.000000  0      189039515.221    -263041817.248      166261248.095
10 1 54868    1320.000000  0      187987117.878    -263762833.418      166309256.251
10 1 54868    1380.000000  0      186935152.894    -264479214.850      166353524.143
10 1 54868    1440.000000  0      185883508.843    -265191162.649      166393929.087
10 1 54868    1500.000000  0      184832063.432    -265898876.237      166430358.335
10 1 54868    1560.000000  0      183780683.661    -266602552.735      166462709.654
10 1 54868    1620.000000  0      182729226.507    -267302386.324      166490891.199
10 1 54868    1680.000000  0      181677539.245    -267998567.616      166514821.977
10 1 54868    1740.000000  0      180625459.982    -268691283.100      166534431.867
10 1 54868    1800.000000  0      179572818.042    -269380714.480      166549662.106
10 1 54868    1860.000000  0      178519434.704    -270067038.170      166560465.033
10 1 54868    1920.000000  0      177465123.611    -270750424.729      166566804.442
10 1 54868    1980.000000  0      176409691.450    -271431038.356      166568655.487
10 1 54868    2040.000000  0      175352938.439    -272109036.303      166566005.056
10 1 54868    2100.000000  0      174294659.076    -272784568.514      166558851.391
10 1 54868    2160.000000  0      173234642.726    -273457777.078      166547204.330
10 1 54868    2220.000000  0      172172674.274    -274128795.901      166531085.093
10 1 54868    2280.000000  0      171108534.786    -274797750.139      166510526.544
10 1 54868    2340.000000  0      170042002.245    -275464756.001      166485572.687
10 1 54868    2400.000000  0      168972852.180    -276129920.315      166456278.806
10 1 54868    2460.000000  0      167900858.408    -276793340.281      166422711.136
10 1 54868    2520.000000  0      166825793.736    -277455103.035      166384946.995
10 1 54868    2580.000000  0      165747430.649    -278115285.606      166343074.200
```

***Figure B.1-3 Sample Laser Ranging Prediction Data File***

### B.1.4 (FDF-8) Space Network Acquisition Data Sample

```
bv'□□
□□ð□□È□□□□□□□ÿÿÿÿ030000001010GIIRV WSGT
121100590100117712000000039
-000041468706-000006199623-000004529372107
 000000037203 000000009681-000000352704061
000170400400000000 1383563045
ITERM GRTS
```

***Figure B.1-4 Sample Space Network Acquisition Data File***

### B.1.5 (FDF-9) Ground Station View Period Predicts Data Sample

This first instance identifies the instance where there is valid view period information for a specific station.

****************************************************************************************************************

22 Mar 2007 07:16:27

Facility-DS24-To-Satellite-0059-Sensor-Omni

| Start Time (YYYYDDD) | Stop Time (YYYYDDD) | Duration (sec) | Start Pass | Max Elevation (deg) | Max Elev Time (YYYYDDD) |
|---|---|---|---|---|---|
| 2009037.000000 | 2009037.010727 | 4046.914 | 13 | 44.992 | 2009037.010727 |
| 2009037.012612 | 2009037.031204 | 6351.504 | 14 | 69.387 | 2009037.031204 |
| 2009037.033050 | 2009037.051642 | 6352.668 | 15 | 81.133 | 2009037.044425 |
| 2009037.053518 | 2009037.072130 | 6371.701 | 16 | 76.357 | 2009037.053518 |
| 2009037.073943 | 2009037.092628 | 6405.418 | 17 | 52.705 | 2009037.073943 |
| 2009037.094413 | 2009037.113135 | 6441.684 | 18 | 28.298 | 2009037.094413 |
| 2009037.225142 | 2009037.235853 | 4031.377 | 24 | 18.553 | 2009037.235853 |
| 2009038.002220 | 2009038.020258 | 6037.879 | 25 | 42.406 | 2009038.020258 |
| 2009038.022725 | 2009038.040704 | 5979.685 | 26 | 66.562 | 2009038.040704 |
| 2009038.043216 | 2009038.061116 | 5940.245 | 27 | 79.195 | 2009038.054837 |
| 2009038.063700 | 2009038.081532 | 5912.629 | 28 | 75.002 | 2009038.063700 |
| 2009038.084146 | 2009038.101953 | 5886.725 | 29 | 51.992 | 2009038.084146 |
| 2009038.104641 | 2009038.122413 | 5852.249 | 30 | 27.272 | 2009038.104641 |
| 2009039.000325 | 2009039.004849 | 2723.697 | 36 | 14.397 | 2009039.004849 |
| 2009039.012246 | 2009039.025248 | 5402.213 | 37 | 38.334 | 2009039.025248 |
| 2009039.032723 | 2009039.045650 | 5367.113 | 38 | 62.188 | 2009039.045650 |
| 2009039.053154 | 2009039.070055 | 5341.546 | 39 | 75.272 | 2009039.064812 |
| 2009039.073623 | 2009039.090503 | 5320.628 | 40 | 71.642 | 2009039.073623 |
| 2009039.094054 | 2009039.110913 | 5298.894 | 41 | 50.025 | 2009039.094054 |
| 2009039.114530 | 2009039.131322 | 5271.982 | 42 | 25.236 | 2009039.114530 |
| 2009040.011620 | 2009040.013734 | 1273.958 | 49 | 9.870 | 2009040.013734 |
| 2009040.021754 | 2009040.034134 | 5020.120 | 49 | 33.952 | 2009040.034134 |
| 2009040.042214 | 2009040.052834 | 3979.953 | 50 | 54.405 | 2009040.052834 |
| 2009040.062631 | 2009040.062730 | 58.902 | 51 | 63.343 | 2009040.062730 |
| 2009040.083048 | 2009040.083126 | 37.651 | 52 | 66.841 | 2009040.083048 |
| 2009040.095340 | 2009040.095345 | 4.841 | 53 | 55.021 | 2009040.095340 |
| 2009040.103507 | 2009040.103522 | 14.920 | 53 | 47.106 | 2009040.103507 |
| 2009040.115734 | 2009040.115751 | 16.699 | 54 | 31.115 | 2009040.115734 |
| 2009040.140129 | 2009040.140157 | 28.137 | 55 | 6.476 | 2009040.140129 |
| 2009041.030950 | 2009041.043008 | 4817.914 | 61 | 29.615 | 2009041.043008 |
| 2009041.051402 | 2009041.063411 | 4808.905 | 62 | 52.078 | 2009041.063411 |
| 2009041.071813 | 2009041.083815 | 4802.000 | 63 | 63.450 | 2009041.083335 |
| 2009041.092223 | 2009041.104219 | 4795.861 | 64 | 60.916 | 2009041.092223 |
| 2009041.112635 | 2009041.124624 | 4789.252 | 65 | 43.055 | 2009041.112635 |
| 2009041.133047 | 2009041.143654 | 3966.659 | 66 | 18.996 | 2009041.133047 |

This following sample identifies the instance where FDF indicates that there is no valid view period information for the indicated station, as well as valid view period information for other stations.

****************************************************************************************************************

23 Apr 2008 15:36:43

Facility-DS65-To-Satellite-0059-Sensor-HGA

| Start Time (YYYYDDD) | Stop Time (YYYYDDD) | Duration (sec) | Start Pass | Max Elevation (deg) | Max Elev Time (YYYYDDD) |
|---|---|---|---|---|---|
| 2008307.122859 | 2008307.140347 | 5687.616 | 1 | 19.025 | 2008307.140347 |
| 2008307.174042 | 2008307.185618 | 4536.769 | 2 | 16.543 | 2008307.174042 |
| 2008308.124239 | 2008308.142115 | 5916.679 | 6 | 17.328 | 2008308.142115 |
| 2008308.161316 | 2008308.191931 | 11175.330 | 7 | 24.256 | 2008308.162903 |

****************************************************************************************************************

23 Apr 2008 15:36:50

Facility-KU1S-To-Satellite-0059-Sensor-Omni

No Access Found

****************************************************************************************************************

23 Apr 2008 15:36:57

Facility-KU1S-To-Satellite-0059-Sensor-HGA

No Access Found

***Figure B.1-5 Sample Ground Station View Period Predicts Data File***

### B.1.6 (FDF-3) LRO Beta Angle Predict File Sample

```
                        05-27-2008 14:58:37


 Beta Angle and Quadrant (1-4) for Satellite-0059.


 YYYYDDD.HHMMSS    Beta Angle (Deg)  Quadrant
 ==============    ================  ========
 2009076.000000        3.45             2
 2009076.060000        3.20             2
 2009076.120000        2.95             2
 2009076.180000        2.67             2
 2009077.000000        2.41             2
 2009077.060000        2.16             2
 2009077.120000        1.95             2
 2009077.180000        1.72             2
 2009078.000000        1.46             2
 2009078.060000        1.18             2
 2009078.120000        0.92             2
 2009078.180000        0.69             2
 2009079.000000        0.47             2
 2009079.060000        0.23             2
 2009079.120000       -0.02             3
 2009079.180000       -0.25             3
 2009080.000000       -0.46             3
 2009080.060000       -0.64             3
 2009080.120000       -0.80             3
 2009080.180000       -0.96             3
```

***Figure B.1-6 Sample LRO Beta Angle Predict File***

### B.1.7 (FDF-4) LRO Definitive Ephemeris File Sample

17 May 2006 14:17:02

Satellite-0059: J2000 ECI Position & Velocity

| YYYYDDD.HHMMSS (YYYYDDD) | x (km) | y (km) | z (km) | vx (km/sec) | vy (km/sec) | vz (km/sec) |
|---|---|---|---|---|---|---|
| 2009015.000000 | 1848.296000 | 0.032259 | -0.000000 | -0.000000 | -0.000000 | 1.630310 |
| 2009015.000100 | 1845.712665 | 0.032083 | 97.772978 | -0.086092 | -0.000006 | 1.628029 |
| 2009015.000200 | 1837.969800 | 0.031495 | 195.272438 | -0.171944 | -0.000014 | 1.621195 |
| 2009015.000300 | 1825.089151 | 0.030349 | 292.225701 | -0.257310 | -0.000024 | 1.609829 |
| 2009015.000400 | 1807.107126 | 0.028439 | 388.361936 | -0.341951 | -0.000041 | 1.593966 |
| 2009015.000500 | 1784.074296 | 0.025230 | 483.412657 | -0.425631 | -0.000069 | 1.573653 |
| 2009015.000600 | 1756.055261 | 0.019928 | 577.112283 | -0.508118 | -0.000110 | 1.548940 |
| 2009015.000700 | 1723.128698 | 0.011736 | 669.198774 | -0.589176 | -0.000164 | 1.519894 |
| 2009015.000800 | 1685.387342 | 0.000155 | 759.414456 | -0.668572 | -0.000222 | 1.486595 |
| 2009015.000900 | 1642.937776 | -0.014761 | 847.507170 | -0.746080 | -0.000274 | 1.449145 |
| 2009015.001000 | 1595.899789 | -0.032435 | 933.231118 | -0.821485 | -0.000313 | 1.407656 |
| 2009015.001100 | 1544.405748 | -0.051952 | 1016.347520 | -0.894582 | -0.000335 | 1.362247 |
| 2009015.001200 | 1488.600174 | -0.072406 | 1096.624913 | -0.965169 | -0.000345 | 1.313045 |
| 2009015.001300 | 1428.639547 | -0.093136 | 1173.839741 | -1.033051 | -0.000346 | 1.260185 |
| 2009015.001400 | 1364.692055 | -0.113807 | 1247.777028 | -1.098034 | -0.000343 | 1.203819 |
| 2009015.001500 | 1296.937072 | -0.134237 | 1318.231143 | -1.159937 | -0.000338 | 1.144107 |
| 2009015.001600 | 1225.564599 | -0.154300 | 1385.006382 | -1.218589 | -0.000330 | 1.081219 |
| 2009015.001700 | 1150.774647 | -0.173859 | 1447.917478 | -1.273827 | -0.000321 | 1.015333 |
| 2009015.001800 | 1072.776596 | -0.192798 | 1506.790085 | -1.325501 | -0.000310 | 0.946634 |
| 2009015.001900 | 991.788671 | -0.210985 | 1561.461117 | -1.373467 | -0.000296 | 0.875313 |
| 2009015.002000 | 908.037442 | -0.228285 | 1611.779163 | -1.417589 | -0.000281 | 0.801569 |
| 2009015.002100 | 821.757438 | -0.244704 | 1657.605195 | -1.457740 | -0.000267 | 0.725615 |
| 2009015.002200 | 733.190158 | -0.260388 | 1698.813204 | -1.493814 | -0.000257 | 0.647672 |
| 2009015.002300 | 642.583065 | -0.275527 | 1735.290528 | -1.525721 | -0.000248 | 0.567962 |
| 2009015.002400 | 550.188659 | -0.290073 | 1766.937598 | -1.553378 | -0.000237 | 0.486701 |
| 2009015.002500 | 456.264145 | -0.303832 | 1793.667983 | -1.576712 | -0.000221 | 0.404109 |
| 2009015.002600 | 361.070979 | -0.316615 | 1815.408640 | -1.595657 | -0.000205 | 0.320415 |
| 2009015.002700 | 264.874191 | -0.328452 | 1832.100433 | -1.610159 | -0.000190 | 0.235853 |
| 2009015.002800 | 167.941555 | -0.339384 | 1843.698381 | -1.620180 | -0.000174 | 0.150660 |
| 2009015.002900 | 70.542736 | -0.349303 | 1850.171881 | -1.625695 | -0.000155 | 0.065078 |
| 2009015.003000 | -27.051565 | -0.357873 | 1851.504800 | -1.626696 | -0.000130 | -0.020653 |
| 2009015.003100 | -124.570582 | -0.364727 | 1847.695274 | -1.623187 | -0.000098 | -0.106297 |
| 2009015.003200 | -221.744100 | -0.369589 | 1838.755451 | -1.615182 | -0.000064 | -0.191625 |
| 2009015.003300 | -318.302923 | -0.372334 | 1824.711237 | -1.602701 | -0.000028 | -0.276404 |
| 2009015.003400 | -413.979383 | -0.372928 | 1805.602593 | -1.585777 | 0.000008 | -0.360400 |
| 2009015.003500 | -508.508186 | -0.371342 | 1781.483609 | -1.564456 | 0.000045 | -0.443376 |
| 2009015.003600 | -601.627404 | -0.367493 | 1752.422450 | -1.538802 | 0.000084 | -0.525102 |
| 2009015.003700 | -693.079182 | -0.361295 | 1718.500914 | -1.508888 | 0.000123 | -0.605351 |
| 2009015.003800 | -782.610393 | -0.352802 | 1679.814230 | -1.474797 | 0.000159 | -0.683903 |
| 2009015.003900 | -869.973261 | -0.342332 | 1636.470880 | -1.436627 | 0.000189 | -0.760537 |
| 2009015.004000 | -954.926290 | -0.330276 | 1588.592356 | -1.394489 | 0.000212 | -0.835041 |
| 2009015.004100 | -1037.234983 | -0.316871 | 1536.312588 | -1.348504 | 0.000235 | -0.907213 |
| 2009015.004200 | -1116.672431 | -0.302004 | 1479.777284 | -1.298802 | 0.000261 | -0.976861 |
| 2009015.004300 | -1193.019563 | -0.285447 | 1419.143468 | -1.245517 | 0.000291 | -1.043799 |
| 2009015.004400 | -1266.065583 | -0.267042 | 1354.579222 | -1.188789 | 0.000322 | -1.107845 |

***Figure B.1-7 Sample LRO Definitive Ephemeris File***

### B.1.8 (FDF-13) Lunar Orbit Ascending and Descending Node Predicts Sample

```
                                                        01-07-2008 16:31:33

Nodal Crossings for Satellite-0059.

YYYYDDD.HHMMSS        Node            Longitude     Orbit
                   A=Ascending         (deg E)      Number        Lighting
                   D=Descending
==============   ================   ==========   ============ ============

2009077.005306          A              282.57       219           Day
2009077.014940          D              102.05                     Night
2009077.024610          A              281.54       220           Day
2009077.034243          D              101.02                     Night
2009077.043913          A              280.50       221           Day
2009077.053546          D               99.99                     Night
2009077.063216          A              279.47       222           Day
2009077.072849          D               98.95                     Night
2009077.082519          A              278.44       223           Day
2009077.092152          D               97.92                     Night
2009077.101822          A              277.40       224           Day
2009077.111456          D               96.88                     Night
2009077.121126          A              276.37       225           Day
2009077.130759          D               95.85                     Night
2009077.140429          A              275.33       226           Day
2009077.150102          D               94.82                     Night
2009077.155732          A              274.30       227           Day
2009077.165405          D               93.78                     Night
2009077.175035          A              273.27       228           Day
2009077.184708          D               92.75                     Night
2009077.194338          A              272.23       229           Day
2009077.204012          D               91.71                     Night
2009077.213641          A              271.20       230           Day
2009077.223315          D               90.68                     Night
2009077.232945          A              270.16       231           Day
2009078.002618          D               89.65                     Night
2009078.012248          A              269.13       232           Day
2009078.021921          D               88.61                     Night
2009078.031551          A              268.10       233           Day
2009078.041224          D               87.58                     Night
2009078.050854          A              267.06       234           Day
2009078.060527          D               86.55                     Night
2009078.070157          A              266.03       235           Day
2009078.075831          D               85.51                     Night
2009078.085500          A              264.99       236           Day
2009078.095134          D               84.48                     Night
2009078.104804          A              263.96       237           Day
2009078.114437          D               83.44                     Night
2009078.124107          A              262.93       238           Day
2009078.133740          D               82.41                     Night
```

***Figure B.1-8 Sample Lunar Orbit Ascending and Descending Node Predicts File***

### B.1.9 (FDF-14) Lunar Orbit Terminator Crossing Predicts Sample

```
                         17-05-2006 20:08:08

Terminator Crossings for Satellite-0059.

YYYYDDD.HHMMSS                  Flag D=Entering Lunar Day
                                     N=Entering Lunar Nig
==============                  =========================

2009015.000000                                D
2009015.002850                                N
2009015.010318                                D
2009015.022800                                N
2009015.030232                                D
2009015.042711                                N
2009015.050146                                D
2009015.062621                                N
2009015.070100                                D
2009015.082531                                N
2009015.090014                                D
2009015.102440                                N
2009015.105928                                D
2009015.122350                                N
2009015.125842                                D
2009015.142259                                N
2009015.145755                                D
2009015.162208                                N
2009015.165709                                D
2009015.182117                                N
2009015.185623                                D
2009015.202026                                N
2009015.205537                                D
2009015.221935                                N
2009015.225451                                D
2009016.001844                                N
2009016.005405                                D
2009016.021753                                N
2009016.025319                                D
2009016.041702                                N
2009016.045233                                D
2009016.061611                                N
2009016.065148                                D
2009016.081521                                N
2009016.085103                                D
2009016.101431                                N
2009016.105017                                D
2009016.121341                                N
2009016.124932                                D
2009016.141251                                N
2009016.144847                                D
2009016.161202                                N
2009016.164803                                D
2009016.181113                                N
2009016.184718                                D
2009016.201024                                N
2009016.204633                                D
2009016.220935                                N
2009016.224548                                D
2009017.000846                                N
2009017.004503                                D
```

***Figure B.1-9 Sample Lunar Orbit Terminator Crossing Predicts Data File***

### B.1.10 (FDF-15) Mission Eclipse Predicts Data Sample

Satellite-0059: Mission Eclipse Predicts

09 Sep 2008 11:13:33

| Start Time YYYYDDD.HHMMSS (YYYYDDD) | Stop Time YYYYDDD.HHMMSS (YYYYDDD) | Current Condition | Duration (sec) | Occultation | Total Duration (sec) |
|---|---|---|---|---|---|
| 2009266.000000 | 2009266.001816 | Umbra | 1095.78 | Moon | 1106.20 |
| 2009266.001816 | 2009266.001826 | Penumbra | 10.42 | Moon | 1106.20 |
| 2009266.012401 | 2009266.012411 | Penumbra | 10.60 | Moon | 2849.85 |
| 2009266.012411 | 2009266.021120 | Umbra | 2828.83 | Moon | 2849.85 |
| 2009266.021120 | 2009266.021131 | Penumbra | 10.42 | Moon | 2849.85 |
| 2009266.031705 | 2009266.031715 | Penumbra | 10.60 | Moon | 2850.39 |
| 2009266.031715 | 2009266.040425 | Umbra | 2829.37 | Moon | 2850.39 |
| 2009266.040425 | 2009266.040435 | Penumbra | 10.42 | Moon | 2850.39 |
| 2009266.051009 | 2009266.051019 | Penumbra | 10.60 | Moon | 2850.84 |
| 2009266.051019 | 2009266.055729 | Umbra | 2829.83 | Moon | 2850.84 |
| 2009266.055729 | 2009266.055740 | Penumbra | 10.41 | Moon | 2850.84 |
| 2009266.070313 | 2009266.070323 | Penumbra | 10.60 | Moon | 2851.17 |
| 2009266.070323 | 2009266.075033 | Umbra | 2830.16 | Moon | 2851.17 |
| 2009266.075033 | 2009266.075044 | Penumbra | 10.41 | Moon | 2851.17 |
| 2009266.085616 | 2009266.085627 | Penumbra | 10.59 | Moon | 2851.36 |
| 2009266.085627 | 2009266.094337 | Umbra | 2830.36 | Moon | 2851.36 |
| 2009266.094337 | 2009266.094347 | Penumbra | 10.41 | Moon | 2851.36 |
| 2009266.104919 | 2009266.104930 | Penumbra | 10.59 | Moon | 2851.45 |
| 2009266.104930 | 2009266.113640 | Umbra | 2830.46 | Moon | 2851.45 |
| 2009266.113640 | 2009266.113651 | Penumbra | 10.40 | Moon | 2851.45 |
| 2009266.124222 | 2009266.124233 | Penumbra | 10.58 | Moon | 2851.46 |
| 2009266.124233 | 2009266.132943 | Umbra | 2830.49 | Moon | 2851.46 |
| 2009266.132943 | 2009266.132954 | Penumbra | 10.40 | Moon | 2851.46 |
| 2009266.143526 | 2009266.143536 | Penumbra | 10.56 | Moon | 2851.47 |
| 2009266.143536 | 2009266.152247 | Umbra | 2830.52 | Moon | 2851.47 |
| 2009266.152247 | 2009266.152257 | Penumbra | 10.39 | Moon | 2851.47 |
| 2009266.162829 | 2009266.162840 | Penumbra | 10.55 | Moon | 2851.53 |
| 2009266.162840 | 2009266.171550 | Umbra | 2830.59 | Moon | 2851.53 |
| 2009266.171550 | 2009266.171601 | Penumbra | 10.38 | Moon | 2851.53 |

***Figure B.1-10 Sample Mission Eclipse Predicts Data File***

### B.1.11 (FDF-16) Lunar Ephemeris Data Sample

18 May 2006 09:58:03

Planet-Moon: Relative J2000 ECI Position & Velocity

| YYYYDDD.HHMMSS (YYYYDDD) | x (km) | y (km) | z (km) | vx (km/sec) | vy (km/sec) | vz (km/sec) |
|---|---|---|---|---|---|---|
| 2009015.000000 | -364820.125341 | 84869.059299 | 13609.487116 | -0.298719 | -0.886814 | -0.471533 |
| 2009015.001000 | -364998.853021 | 84336.857553 | 13326.550503 | -0.297040 | -0.887191 | -0.471589 |
| 2009015.002000 | -365176.572957 | 83804.430501 | 13043.580642 | -0.295360 | -0.887565 | -0.471644 |
| 2009015.003000 | -365353.285002 | 83271.779684 | 12760.578321 | -0.293680 | -0.887937 | -0.471697 |
| 2009015.004000 | -365528.989010 | 82738.906640 | 12477.544330 | -0.292000 | -0.888306 | -0.471749 |
| 2009015.005000 | -365703.684842 | 82205.812911 | 12194.479459 | -0.290319 | -0.888673 | -0.471800 |
| 2009015.010000 | -365877.372346 | 81672.500071 | 11911.384515 | -0.288639 | -0.889037 | -0.471850 |
| 2009015.011000 | -366050.051411 | 81138.969586 | 11628.260248 | -0.286958 | -0.889398 | -0.471898 |
| 2009015.012000 | -366221.721894 | 80605.223032 | 11345.107465 | -0.285277 | -0.889757 | -0.471945 |
| 2009015.013000 | -366392.383665 | 80071.261946 | 11061.926952 | -0.283596 | -0.890113 | -0.471990 |
| 2009015.014000 | -366562.036598 | 79537.087865 | 10778.719498 | -0.281914 | -0.890467 | -0.472034 |
| 2009015.015000 | -366730.680571 | 79002.702326 | 10495.485887 | -0.280232 | -0.890818 | -0.472077 |
| 2009015.020000 | -366898.315463 | 78468.106866 | 10212.226905 | -0.278551 | -0.891167 | -0.472119 |
| 2009015.021000 | -367064.941157 | 77933.303021 | 9928.943338 | -0.276868 | -0.891513 | -0.472159 |
| 2009015.022000 | -367230.557540 | 77398.292326 | 9645.635971 | -0.275186 | -0.891856 | -0.472198 |
| 2009015.023000 | -367395.164491 | 76863.076352 | 9362.305606 | -0.273504 | -0.892197 | -0.472236 |
| 2009015.024000 | -367558.761923 | 76327.656562 | 9078.952990 | -0.271821 | -0.892535 | -0.472272 |
| 2009015.025000 | -367721.349720 | 75792.034525 | 8795.578924 | -0.270138 | -0.892871 | -0.472308 |
| 2009015.030000 | -367882.927782 | 75256.211775 | 8512.184192 | -0.268455 | -0.893204 | -0.472341 |
| 2009015.031000 | -368043.496009 | 74720.189846 | 8228.769576 | -0.266772 | -0.893535 | -0.472374 |
| 2009015.032000 | -368203.054306 | 74183.970269 | 7945.335857 | -0.265089 | -0.893863 | -0.472405 |
| 2009015.033000 | -368361.602580 | 73647.554576 | 7661.883818 | -0.263405 | -0.894189 | -0.472435 |
| 2009015.034000 | -368519.140742 | 73110.944299 | 7378.414238 | -0.261722 | -0.894512 | -0.472463 |
| 2009015.035000 | -368675.668704 | 72574.140969 | 7094.927898 | -0.260038 | -0.894832 | -0.472491 |
| 2009015.040000 | -368831.186374 | 72037.146152 | 6811.425596 | -0.258354 | -0.895150 | -0.472517 |
| 2009015.041000 | -368985.693691 | 71499.961306 | 6527.908074 | -0.256670 | -0.895466 | -0.472541 |
| 2009015.042000 | -369139.190567 | 70962.587997 | 6244.376131 | -0.254986 | -0.895778 | -0.472565 |
| 2009015.043000 | -369291.676929 | 70425.027752 | 5960.830543 | -0.253302 | -0.896089 | -0.472587 |
| 2009015.044000 | -369443.152703 | 69887.282101 | 5677.272088 | -0.251617 | -0.896396 | -0.472608 |
| 2009015.045000 | -369593.617821 | 69349.352570 | 5393.701544 | -0.249933 | -0.896702 | -0.472627 |
| 2009015.050000 | -369743.072218 | 68811.240688 | 5110.119688 | -0.248248 | -0.897004 | -0.472645 |
| 2009015.051000 | -369891.515832 | 68272.947979 | 4826.527296 | -0.246564 | -0.897304 | -0.472662 |
| 2009015.052000 | -370038.948602 | 67734.475972 | 4542.925142 | -0.244879 | -0.897602 | -0.472678 |
| 2009015.053000 | -370185.370461 | 67195.826226 | 4259.314022 | -0.243194 | -0.897897 | -0.472692 |
| 2009015.054000 | -370330.781376 | 66657.000195 | 3975.694672 | -0.241509 | -0.898189 | -0.472705 |
| 2009015.055000 | -370475.181286 | 66117.999438 | 3692.067885 | -0.239824 | -0.898479 | -0.472717 |
| 2009015.060000 | -370618.570144 | 65578.825480 | 3408.434434 | -0.238139 | -0.898767 | -0.472728 |
| 2009015.061000 | -370760.947903 | 65039.479843 | 3124.795093 | -0.236454 | -0.899052 | -0.472737 |

***Figure B.1-11 Sample Lunar Ephemeris Data File***

## B.1.12 (FDF-17) Orbiter Thruster Maneuver Plans Data Sample

```
Maneuver Plan

Plan Date (UTCG): 2008 141 15:31:20  Burn Start (UTCG): 2009 037 19:48:46  Pre-burn fuel mass (kg):    267.343  official
Maneuver:         SK01b              Burn Stop (UTCG):  2009 037 19:50:46  Post-burn fuel mass (kg):  263.505 estimated
Planned dV (m/s): 6.699              Duration (s):      119.331            Fuel mass used (kg):         3.838 estimated
                                                                           Average SC Mass (kg):     1270.050 estimated
Notes:                         LRO MOC SIM09 SK01b Planning
Ephemeris File Name:
Thrust Vector File Name:

Maneuver Configuration:         Bank     1            2
                                  NT     OFF          OFF              Prop Mode: PressureReg
                                 ACS     OFF          Off-Pulsed     ACS Stop Mode: dV

Initial Thruster Data:
                                                  Calculated     Calculated        Thrust     Effective          Duty
      Bank      Press (Pa)     Temp (degC)        Isp (sec)     Thrust (N)    Efficiency    Thrust (N)     Cycle (%)
  NT1    1       1861584.5            25.0
  NT2    2       1861584.5            25.0
  NT3    1       1861584.5            25.0
  NT4    2       1861584.5            25.0
  AT1    1       1861584.5            25.0
  AT2    2       1861584.5            25.0          231.441         13.409      1.000000        13.409        58.600
  AT3    1       1861584.5            25.0
  AT4    2       1861584.5            25.0          231.441         18.787      1.000000        18.787        82.100
  AT5    1       1861584.5            25.0
  AT6    2       1861584.5            25.0          238.702         25.307      1.000000        25.307       100.000
  AT7    1       1861584.5            25.0
  AT8    2       1861584.5            25.0          231.441         16.270      1.000000        16.270        71.100

Final Thruster Data:
                                                  Calculated     Calculated        Thrust     Effective          Duty
      Bank      Press (Pa)     Temp (degC)        Isp (sec)     Thrust (N)    Efficiency    Thrust (N)     Cycle (%)
  NT1    1       1861584.5            25.0
  NT2    2       1861584.5            25.0
  NT3    1       1861584.5            25.0
  NT4    2       1861584.5            25.0
  AT1    1       1861584.5            25.0
  AT2    2       1861584.5            25.0          231.441         13.409      1.000000        13.409        58.600
  AT3    1       1861584.5            25.0
  AT4    2       1861584.5            25.0          231.441         18.787      1.000000        18.787        82.100
  AT5    1       1861584.5            25.0
  AT6    2       1861584.5            25.0          238.702         25.307      1.000000        25.307       100.000
  AT7    1       1861584.5            25.0
  AT8    2       1861584.5            25.0          231.441         16.270      1.000000        16.270        71.100
```

***Figure B.1-12 Sample Orbiter Thruster Maneuver Plans Data File***

### B.1.13 (FDF-19) Orbiter Post Maneuver Report Data Sample

```
Maneuver Plan

Plan Date (UTCG): 2008 043 13:25:03  Burn Start (UTCG): 2008 307 12:48:17  Pre-burn fuel mass (kg):    889.578  official
Maneuver:         LOI1               Burn Stop (UTCG):  2008 307 13:23:46  Post-burn fuel mass (kg):   508.902 estimated
Planned dV (m/s): 501.477            Duration (s):      2128.890           Fuel mass used (kg):        380.676 estimated
                                                                           Average SC Mass (kg):      1722.440 estimated
Notes:                        MRT5.d Sample LOI1 Product
Ephemeris File Name:          Pre-launch nominal
Thrust Vector File Name:      Thrust Vector - Nominal

Maneuver Configuration:         Bank      1              2
                                  NT      ON             ON                Prop Mode: PressureReg
                                 ACS      On-pulsed      On-pulsed     ACS Stop Mode: Time
```

Initial Thruster Data:

| | Bank | Press (Pa) | Temp (degC) | Calculated Isp (sec) | Calculated Thrust (N) | Thrust Efficiency | Effective Thrust (N) | Duty Cycle (%) |
|---|---|---|---|---|---|---|---|---|
| NT1 | 1 | 1861584.5 | 25.0 | 232.209 | 94.667 | 1.000000 | 94.667 | 100.000 |
| NT2 | 2 | 1861584.5 | 25.0 | 232.209 | 94.667 | 1.000000 | 94.667 | 100.000 |
| NT3 | 1 | 1861584.5 | 25.0 | 232.209 | 94.667 | 1.000000 | 94.667 | 100.000 |
| NT4 | 2 | 1861584.5 | 25.0 | 232.209 | 94.667 | 1.000000 | 94.667 | 100.000 |
| AT1 | 1 | 1861584.5 | 25.0 | 213.878 | 2.137 | 1.000000 | 2.137 | 9.500 |
| AT2 | 2 | 1861584.5 | 25.0 | 213.878 | 1.035 | 1.000000 | 1.035 | 4.600 |
| AT3 | 1 | 1861584.5 | 25.0 | 213.878 | 0.360 | 1.000000 | 0.360 | 1.600 |
| AT4 | 2 | 1861584.5 | 25.0 | 213.878 | 0.157 | 1.000000 | 0.157 | 0.700 |
| AT5 | 1 | 1861584.5 | 25.0 | 213.878 | 5.646 | 1.000000 | 5.646 | 25.100 |
| AT6 | 2 | 1861584.5 | 25.0 | 213.878 | 5.489 | 1.000000 | 5.489 | 24.400 |
| AT7 | 1 | 1861584.5 | 25.0 | 213.878 | 5.781 | 1.000000 | 5.781 | 25.700 |
| AT8 | 2 | 1861584.5 | 25.0 | 213.878 | 5.669 | 1.000000 | 5.669 | 25.200 |

Final Thruster Data:

| | Bank | Press (Pa) | Temp (degC) | Calculated Isp (sec) | Calculated Thrust (N) | Thrust Efficiency | Effective Thrust (N) | Duty Cycle (%) |
|---|---|---|---|---|---|---|---|---|
| NT1 | 1 | 1861584.5 | 25.0 | 232.209 | 94.667 | 1.000000 | 94.667 | 100.000 |
| NT2 | 2 | 1861584.5 | 25.0 | 232.209 | 94.667 | 1.000000 | 94.667 | 100.000 |
| NT3 | 1 | 1861584.5 | 25.0 | 232.209 | 94.667 | 1.000000 | 94.667 | 100.000 |
| NT4 | 2 | 1861584.5 | 25.0 | 232.209 | 94.667 | 1.000000 | 94.667 | 100.000 |
| AT1 | 1 | 1861584.5 | 25.0 | 213.878 | 2.137 | 1.000000 | 2.137 | 9.500 |
| AT2 | 2 | 1861584.5 | 25.0 | 213.878 | 1.035 | 1.000000 | 1.035 | 4.600 |
| AT3 | 1 | 1861584.5 | 25.0 | 213.878 | 0.360 | 1.000000 | 0.360 | 1.600 |
| AT4 | 2 | 1861584.5 | 25.0 | 213.878 | 0.157 | 1.000000 | 0.157 | 0.700 |
| AT5 | 1 | 1861584.5 | 25.0 | 213.878 | 5.646 | 1.000000 | 5.646 | 25.100 |
| AT6 | 2 | 1861584.5 | 25.0 | 213.878 | 5.489 | 1.000000 | 5.489 | 24.400 |
| AT7 | 1 | 1861584.5 | 25.0 | 213.878 | 5.781 | 1.000000 | 5.781 | 25.700 |
| AT8 | 2 | 1861584.5 | 25.0 | 213.878 | 5.669 | 1.000000 | 5.669 | 25.200 |

***Figure B.1-13 Sample Orbiter Post Maneuver Report Data File***

### B.1.14 (FDF-18) Post Separation Report Data Sample

```
FDF18 - LRO Nominal Separation Versus Actual Sample Product

        SAT NO.   SATELLITE ID
        1234567

 TIME INTERVAL OF COMPARISON    YYYYMMDD HHMMSS.S       YYYYMMDD HHMMSS.S
                                20081028 102354.0       20081028 102500.0

 TIME INTERVAL OF COMPARISON WAS RESET FROM INPUT REQUESTED TIMESPAN


EPOCH AND ELEMENTS --- SET 1     FRN 24
 CENTRAL BODY IS EARTH   ELEMENTS ARE IN 2000

                                   COWELL
+       YYYYMMDD  HHMMSS.SSS
        20081028  102354.146

            X                  Y                  Z                    XDOT               YDOT               ZDOT
           (KM)               (KM)               (KM)                 (KM/S)             (KM/S)             (KM/S)

   -364.944200        5795.93241        3039.06887         -10.7884373        -1.31878371         1.26070620


           SMA                ECC                INC                  RAAN                AP                 MA
          (KM)                                  (DEG)                 (DEG)              (DEG)              (DEG)

    209034.998        .968643926        28.5265980          19.2908226        75.9355802         .802981825E-03

           P                  PH                 APH                  TA
         (MIN)               (KM)               (KM)                 (DEG)

    15852.1523        176.380561        405137.343          .202911138

EPOCH AND ELEMENTS --- SET 2     FRN 81
 CENTRAL BODY IS EARTH   ELEMENTS ARE IN 2000

                                   COWELL
+       YYYYMMDD  HHMMSS.SSS
        20081028  102354.146

            X                  Y                  Z                    XDOT               YDOT               ZDOT
           (KM)               (KM)               (KM)                 (KM/S)             (KM/S)             (KM/S)

   -364.944201        5795.93241        3039.06887         -10.7884373        -1.31878371         1.26070620


           SMA                ECC                INC                  RAAN                AP                 MA
          (KM)                                  (DEG)                 (DEG)              (DEG)              (DEG)

    209034.999        .968643926        28.5265980          19.2908226        75.9355802         .802981894E-03

           P                  PH                 APH                  TA
         (MIN)               (KM)               (KM)                 (DEG)

    15852.1524        176.380561        405137.344          .202911157
```

***Figure B.1-14 Sample Post Separation Report Data File (Page 1 of 2)***

```
                                   POSITION DIFFERENCE VECTOR COMPONENTS                                                  TRUE ANOMALY

                        RANGE NO.1      RANGE NO.2        RADIAL          CROSS TRACK    ALONG TRACK         DELTA-R           TA
 YYYYMMDD HHMMSS.SS         (KM)            (KM)            (KM)              (KM)           (KM)              (KM)          (DEG)
 20081028 102354.00    .655453D+04     .655453D+04     .407517D-06     -.695334D-06     .104801D-05     .132208D-05     .188955D+00
 20081028 102400.00    .657174D+04     .657174D+04     .491652D-06     -.701169D-06     .102295D-05     .133408D-05     .591436D+01
1                                          GTDS  COMPARE  PROGRAM                                              PAGE    45


                                         EPHEMERIS COMPARISON SUMMARY REPORT

                                     MINIMUM POSITION DIFFERENCE                 MAXIMUM POSITION DIFFERENCE
                                 YYYYMMDD   HHMMSS.SSS        (KM)           YYYYMMDD   HHMMSS.SSS        (KM)

                      RADIAL         20081028   102354.000      .4075166D-06   20081028   102400.000      .4916515D-06
                      CROSS TRACK    20081028   102354.000     -.6953337D-06   20081028   102400.000     -.7011691D-06
                      ALONG TRACK    20081028   102400.000      .1022948D-05   20081028   102354.000      .1048010D-05
                      DELTA-R        20081028   102354.000      .1322075D-05   20081028   102400.000      .1334085D-05


                                     MINIMUM VELOCITY DIFFERENCE                 MAXIMUM VELOCITY DIFFERENCE
                                 YYYYMMDD   HHMMSS.SSS        (KM/SEC)       YYYYMMDD   HHMMSS.SSS        (KM/SEC)
                      RADIAL         20081028   102354.000      .2177548D-11   20081028   102400.000     -.4563068D-09
                      CROSS TRACK    20081028   102354.000      .6331085D-12   20081028   102400.000     -.1354891D-09
                      ALONG TRACK    20081028   102354.000     -.2002061D-11   20081028   102400.000      .5197528D-09
                      DELTA-V        20081028   102354.000      .3025027D-11   20081028   102400.000      .7047809D-09


                                          POSITION RMS         VELOCITY RMS

                                              (KM)                 (KM/SEC)

                              RADIAL         .45155D-06           .32266D-09
                              CROSS TRACK    .69826D-06           .95806D-10
                              ALONG TRACK    .10356D-05           .36752D-09
                              TOTAL          .13281D-05           .49836D-09
```

***Figure B.1-15 Sample Post Separation Report Data File (Page 2 of 2)***

### B.1.15 (FDF-20) Predicted LRO Ephemeris File Sample

29 May 2008 08:58:26

Satellite-0059: Earth-centered J2000 Inertial Position & Velocity

| YYYYDDD.HHMMSS (YYYYDDD) | x (km) | y (km) | z (km) | x (km/sec) | y (km/sec) | z (km/sec) |
|---|---|---|---|---|---|---|
| 2009077.000000 | -76242.216843 | -351492.701477 | -181938.358603 | 0.941014 | 0.438886 | -1.553193 |
| 2009077.000100 | -76182.995465 | -351466.381242 | -182031.514985 | 1.033019 | 0.438121 | -1.551236 |
| 2009077.000200 | -76118.259030 | -351440.167159 | -182124.412447 | 1.124795 | 0.435348 | -1.544556 |
| 2009077.000300 | -76048.031606 | -351414.179108 | -182216.767595 | 1.215998 | 0.430594 | -1.533172 |
| 2009077.000400 | -75972.355781 | -351388.534927 | -182308.300791 | 1.306375 | 0.423885 | -1.517167 |
| 2009077.000500 | -75891.287752 | -351363.352501 | -182398.735664 | 1.395691 | 0.415199 | -1.496565 |
| 2009077.000600 | -75804.900261 | -351338.750234 | -182487.797692 | 1.483641 | 0.404554 | -1.471420 |
| 2009077.000700 | -75713.283932 | -351314.844288 | -182575.216830 | 1.569938 | 0.391996 | -1.441816 |
| 2009077.000800 | -75616.546329 | -351291.747936 | -182660.728398 | 1.654307 | 0.377577 | -1.407853 |
| 2009077.000900 | -75514.810462 | -351269.571290 | -182744.074083 | 1.736508 | 0.361347 | -1.369635 |
| 2009077.001000 | -75408.213811 | -351248.421684 | -182825.001507 | 1.816288 | 0.343350 | -1.327265 |
| 2009077.001100 | -75296.909280 | -351228.403497 | -182903.265581 | 1.893399 | 0.323643 | -1.280880 |
| 2009077.001200 | -75181.063938 | -351209.617610 | -182978.629446 | 1.967608 | 0.302282 | -1.230614 |
| 2009077.001300 | -75060.859306 | -351192.161437 | -183050.864701 | 2.038670 | 0.279332 | -1.176622 |
| 2009077.001400 | -74936.490706 | -351176.128067 | -183119.752926 | 2.106372 | 0.254868 | -1.119073 |
| 2009077.001500 | -74808.166101 | -351161.606143 | -183185.085671 | 2.170501 | 0.228961 | -1.058137 |
| 2009077.001600 | -74676.106163 | -351148.680251 | -183246.665507 | 2.230851 | 0.201680 | -0.994009 |
| 2009077.001700 | -74540.543397 | -351137.430368 | -183304.306770 | 2.287230 | 0.173110 | -0.926884 |
| 2009077.001800 | -74401.721595 | -351127.930660 | -183357.835935 | 2.339458 | 0.143359 | -0.856975 |
| 2009077.001900 | -74259.894407 | -351120.248896 | -183407.092354 | 2.387385 | 0.112527 | -0.784494 |
| 2009077.002000 | -74115.324688 | -351114.447144 | -183451.928038 | 2.430849 | 0.080709 | -0.709657 |
| 2009077.002100 | -73968.284544 | -351110.581374 | -183492.209178 | 2.469716 | 0.048013 | -0.632718 |
| 2009077.002200 | -73819.052493 | -351108.701452 | -183527.816771 | 2.503897 | 0.014525 | -0.553906 |
| 2009077.002300 | -73667.913103 | -351108.852564 | -183558.644705 | 2.533271 | -0.019670 | -0.473436 |
| 2009077.002400 | -73515.158471 | -351111.073377 | -183584.601069 | 2.557722 | -0.054443 | -0.391567 |

***Figure B.1-16 Sample Predicted LRO Ephemeris File***

## B.1.16 (FDF-21) Predicted Lunar Ground Track File Sample

29 May 2008 08:59:43

Satellite-0059: LLA Position

| YYYYDDD.HHMMSS (YYYYDDD) | Lon (degEast) | Lat (deg) | Alt (km) | Magnitude (km/sec) |
|---|---|---|---|---|
| 2009077.000000 | 102.893 | -0.978 | 51.146 | 1.656 |
| 2009077.000100 | 102.848 | -4.161 | 50.997 | 1.656 |
| 2009077.000200 | 102.803 | -7.343 | 50.845 | 1.656 |
| 2009077.000300 | 102.757 | -10.527 | 50.691 | 1.656 |
| 2009077.000400 | 102.710 | -13.710 | 50.538 | 1.656 |
| 2009077.000500 | 102.662 | -16.895 | 50.384 | 1.656 |
| 2009077.000600 | 102.613 | -20.079 | 50.231 | 1.656 |
| 2009077.000700 | 102.562 | -23.265 | 50.078 | 1.656 |
| 2009077.000800 | 102.509 | -26.451 | 49.927 | 1.657 |
| 2009077.000900 | 102.454 | -29.637 | 49.779 | 1.657 |
| 2009077.001000 | 102.396 | -32.824 | 49.634 | 1.657 |
| 2009077.001100 | 102.333 | -36.011 | 49.494 | 1.657 |
| 2009077.001200 | 102.267 | -39.198 | 49.358 | 1.657 |
| 2009077.001300 | 102.195 | -42.386 | 49.227 | 1.657 |
| 2009077.001400 | 102.116 | -45.575 | 49.100 | 1.657 |
| 2009077.001500 | 102.029 | -48.764 | 48.979 | 1.657 |
| 2009077.001600 | 101.931 | -51.953 | 48.863 | 1.657 |
| 2009077.001700 | 101.820 | -55.142 | 48.753 | 1.658 |
| 2009077.001800 | 101.691 | -58.332 | 48.650 | 1.658 |
| 2009077.001900 | 101.538 | -61.522 | 48.553 | 1.658 |
| 2009077.002000 | 101.352 | -64.712 | 48.464 | 1.658 |
| 2009077.002100 | 101.119 | -67.902 | 48.382 | 1.658 |
| 2009077.002200 | 100.815 | -71.091 | 48.310 | 1.658 |
| 2009077.002300 | 100.395 | -74.281 | 48.246 | 1.658 |
| 2009077.002400 | 99.773 | -77.469 | 48.189 | 1.658 |
| 2009077.002500 | 98.740 | -80.655 | 48.140 | 1.658 |
| 2009077.002600 | 96.660 | -83.836 | 48.100 | 1.658 |
| 2009077.002700 | 90.232 | -86.991 | 48.072 | 1.658 |
| 2009077.002800 | 351.225 | -89.303 | 48.052 | 1.658 |
| 2009077.002900 | 293.289 | -86.493 | 48.040 | 1.658 |
| 2009077.003000 | 288.193 | -83.329 | 48.035 | 1.658 |

***Figure B.1-17 Sample Predicted Lunar Ground Track File***

### B.1.17 (FDF-22) Definitive Lunar Ground Track File Sample

```
                                                                    29 May 2008 09:02:30
Satellite-0059:  LLA Position

YYYYDDD.HHMMSS (YYYYDDD)    Lon (degEast)     Lat (deg)    Alt (km)    Magnitude (km/sec)
------------------------    -------------     ---------    --------    ------------------
        2009076.000000            301.594       -81.992      46.649                 1.659
        2009076.000100            299.999       -78.805      46.722                 1.659
        2009076.000200            299.100       -75.614      46.808                 1.659
        2009076.000300            298.520       -72.421      46.905                 1.659
        2009076.000400            298.111       -69.227      47.013                 1.659
        2009076.000500            297.805       -66.033      47.133                 1.659
        2009076.000600            297.565       -62.839      47.266                 1.659
        2009076.000700            297.370       -59.645      47.410                 1.659
        2009076.000800            297.208       -56.451      47.563                 1.659
        2009076.000900            297.069       -53.257      47.724                 1.659
        2009076.001000            296.949       -50.064      47.894                 1.658
        2009076.001100            296.842       -46.872      48.071                 1.658
        2009076.001200            296.747       -43.680      48.255                 1.658
        2009076.001300            296.660       -40.489      48.447                 1.658
        2009076.001400            296.580       -37.298      48.647                 1.658
        2009076.001500            296.506       -34.108      48.853                 1.658
        2009076.001600            296.436       -30.919      49.065                 1.657
        2009076.001700            296.371       -27.730      49.282                 1.657
        2009076.001800            296.309       -24.543      49.504                 1.657
        2009076.001900            296.249       -21.355      49.730                 1.657
        2009076.002000            296.192       -18.169      49.958                 1.657
        2009076.002100            296.136       -14.984      50.188                 1.656
        2009076.002200            296.081       -11.799      50.419                 1.656
        2009076.002300            296.028        -8.615      50.650                 1.656
        2009076.002400            295.976        -5.432      50.884                 1.656
        2009076.002500            295.923        -2.250      51.119                 1.656
        2009076.002600            295.871         0.932      51.353                 1.655
        2009076.002700            295.819         4.112      51.586                 1.655
        2009076.002800            295.767         7.292      51.816                 1.655
        2009076.002900            295.714        10.471      52.044                 1.655
        2009076.003000            295.661        13.649      52.267                 1.654
```

***Figure B.1-18 Sample Definitive Lunar Ground Track File***

### B.1.18 (FDF-23) Orbiter State Vector Table Sample

29 May 2008 09:03:39

Satellite-0059: J2000 ECI Position & Velocity

| YYYYDDD.HHMMSS (YYYYDDD) | x (km) | y (km) | z (km) | x (km/sec) | y (km/sec) | z (km/sec) |
|---|---|---|---|---|---|---|
| 2009077.000000 | -76242.216843 | -351492.701477 | -181938.358603 | 0.941014 | 0.438886 | -1.553193 |
| 2009077.001000 | -75408.213811 | -351248.421684 | -182825.001507 | 1.816288 | 0.343350 | -1.327265 |
| 2009077.002000 | -74115.324688 | -351114.447144 | -183451.928038 | 2.430849 | 0.080709 | -0.709657 |
| 2009077.003000 | -72581.580324 | -351169.162548 | -183634.921587 | 2.598172 | -0.269198 | 0.114131 |
| 2009077.004000 | -71098.217354 | -351433.784403 | -183323.697737 | 2.267202 | -0.600814 | 0.894920 |
| 2009077.005000 | -69941.422957 | -351865.982351 | -182617.439231 | 1.538133 | -0.813046 | 1.396616 |
| 2009077.010000 | -69288.140014 | -352372.321361 | -181734.635857 | 0.632616 | -0.841626 | 1.468361 |
| 2009077.011000 | -69162.696424 | -352837.138254 | -180946.197605 | -0.175984 | -0.678242 | 1.090631 |
| 2009077.012000 | -69430.798578 | -353157.385416 | -180493.357087 | -0.645645 | -0.372198 | 0.378865 |
| 2009077.013000 | -69840.862177 | -353273.441410 | -180515.854479 | -0.637182 | -0.015054 | -0.453153 |
| 2009077.014000 | -70099.442411 | -353186.637229 | -181011.208533 | -0.153621 | 0.286707 | -1.156953 |
| 2009077.015000 | -69958.179118 | -352958.733542 | -181835.681545 | 0.661501 | 0.443229 | -1.521736 |
| 2009077.020000 | -69287.718480 | -352693.558010 | -182746.415656 | 1.565010 | 0.407701 | -1.436616 |
| 2009077.021000 | -68117.357682 | -352506.215340 | -183473.526532 | 2.284622 | 0.190443 | -0.925332 |
| 2009077.022000 | -66627.332066 | -352488.487702 | -183801.574147 | 2.602745 | -0.142851 | -0.140774 |
| 2009077.023000 | -65094.773200 | -352680.779422 | -183635.011615 | 2.422584 | -0.491634 | 0.680521 |
| 2009077.024000 | -63810.120366 | -353060.141310 | -183027.650437 | 1.797859 | -0.749976 | 1.290303 |
| 2009077.025000 | -62988.852532 | -353546.524390 | -182166.610678 | 0.918227 | -0.839116 | 1.504306 |
| 2009077.030000 | -62705.840954 | -354027.515057 | -181315.280872 | 0.050201 | -0.732447 | 1.259168 |
| 2009077.031000 | -62873.529808 | -354392.392231 | -180733.054589 | -0.545387 | -0.462150 | 0.630821 |
| 2009077.032000 | -63269.434228 | -354565.444412 | -180597.365611 | -0.691202 | -0.109456 | -0.190910 |
| 2009077.033000 | -63603.486017 | -354528.391454 | -180951.501881 | -0.344714 | 0.220242 | -0.960014 |
| 2009077.034000 | -63604.456161 | -354325.616548 | -181692.336369 | 0.390743 | 0.428822 | -1.446652 |
| 2009077.035000 | -63100.357463 | -354050.837162 | -182600.840349 | 1.295769 | 0.454125 | -1.504333 |
| 2009077.040000 | -62070.152887 | -353819.250454 | -183406.965748 | 2.098913 | 0.288543 | -1.113990 |
| 2009077.041000 | -60651.175237 | -353733.139144 | -183870.551038 | 2.558009 | -0.018220 | -0.391800 |
| 2009077.042000 | -59098.214093 | -353850.874768 | -183853.884283 | 2.533786 | -0.373392 | 0.445383 |
| 2009077.043000 | -57707.076152 | -354169.426282 | -183363.892203 | 2.032378 | -0.670001 | 1.144990 |
| 2009077.044000 | -56725.186366 | -354624.679973 | -182550.564995 | 1.205219 | -0.817136 | 1.495164 |
| 2009077.045000 | -56275.925929 | -355110.862599 | -181661.674107 | 0.303233 | -0.770503 | 1.390487 |

***Figure B.1-19 Sample LRO State Vector Table Data File***

### B.1.19 (FDF-25) Thruster Calibration Data File Sample

```
Maneuver Plan

Plan Date (UTCG): 2008 043 13:25:03  Burn Start (UTCG): 2008 307 12:48:17  Pre-burn fuel mass (kg):   889.578  official
Maneuver:         LOI1               Burn Stop (UTCG):  2008 307 13:23:46  Post-burn fuel mass (kg):  508.902 estimated
Planned dV (m/s): 501.477            Duration (s):      2128.890           Fuel mass used (kg):       380.676 estimated
                                                                            Average SC Mass (kg):     1722.440 estimated

Notes:                        LOI1 Post-Maneuver Calibration Product
Ephemeris File Name:          Pre-launch nominal
Thrust Vector File Name:      Thrust Vector - Nominal

Maneuver Configuration:         Bank      1              2
                                  NT      ON             ON                Prop Mode: PressureReg
                                 ACS      On-pulsed      On-pulsed      ACS Stop Mode: Time

Initial Thruster Data:
                                                Calculated     Calculated      Thrust      Effective          Duty
      Bank      Press (Pa)     Temp (degC)      Isp (sec)     Thrust (N)    Efficiency    Thrust (N)       Cycle (%)
  NT1    1       1861584.5            25.0        232.209         94.667      1.000000        94.667        100.000
  NT2    2       1861584.5            25.0        232.209         94.667      1.000000        94.667        100.000
  NT3    1       1861584.5            25.0        232.209         94.667      1.000000        94.667        100.000
  NT4    2       1861584.5            25.0        232.209         94.667      1.000000        94.667        100.000
  AT1    1       1861584.5            25.0        213.878          2.137      1.000000         2.137          9.500
  AT2    2       1861584.5            25.0        213.878          1.035      1.000000         1.035          4.600
  AT3    1       1861584.5            25.0        213.878          0.360      1.000000         0.360          1.600
  AT4    2       1861584.5            25.0        213.878          0.157      1.000000         0.157          0.700
  AT5    1       1861584.5            25.0        213.878          5.646      1.000000         5.646         25.100
  AT6    2       1861584.5            25.0        213.878          5.489      1.000000         5.489         24.400
  AT7    1       1861584.5            25.0        213.878          5.781      1.000000         5.781         25.700
  AT8    2       1861584.5            25.0        213.878          5.669      1.000000         5.669         25.200

Final Thruster Data:
                                                Calculated     Calculated      Thrust      Effective          Duty
      Bank      Press (Pa)     Temp (degC)      Isp (sec)     Thrust (N)    Efficiency    Thrust (N)       Cycle (%)
  NT1    1       1861584.5            25.0        232.209         94.667      1.000000        94.667        100.000
  NT2    2       1861584.5            25.0        232.209         94.667      1.000000        94.667        100.000
  NT3    1       1861584.5            25.0        232.209         94.667      1.000000        94.667        100.000
  NT4    2       1861584.5            25.0        232.209         94.667      1.000000        94.667        100.000
  AT1    1       1861584.5            25.0        213.878          2.137      1.000000         2.137          9.500
  AT2    2       1861584.5            25.0        213.878          1.035      1.000000         1.035          4.600
  AT3    1       1861584.5            25.0        213.878          0.360      1.000000         0.360          1.600
  AT4    2       1861584.5            25.0        213.878          0.157      1.000000         0.157          0.700
  AT5    1       1861584.5            25.0        213.878          5.646      1.000000         5.646         25.100
  AT6    2       1861584.5            25.0        213.878          5.489      1.000000         5.489         24.400
  AT7    1       1861584.5            25.0        213.878          5.781      1.000000         5.781         25.700
  AT8    2       1861584.5            25.0        213.878          5.669      1.000000         5.669         25.200
```

***Figure B.1-20 Sample Thruster Calibration Data File***

### B.1.20 (FDF-37) Solar Conjunction File Sample

08-15-2007 14:27:00

Solar Conjunctions for Satellite-0059.

| Station | Start Time (YYYYDDD) | Stop Time (YYYYDDD) | Duration (sec) | Solar Interference | Type |
|---|---|---|---|---|---|
| D34K | 2009039.162701 | 2009040.112044 | 68022.630 | Uplink | 1 |
| USPS | 2009039.204011 | 2009040.213229 | 89537.509 | Uplink | 1 |
| WU1S | 2009040.051043 | 2009040.173223 | 44500.262 | Uplink | 1 |
| WU2S | 2009040.051043 | 2009040.173223 | 44500.265 | Uplink | 1 |
| KU1S | 2009040.055651 | 2009040.173223 | 41731.978 | Uplink | 1 |
| KU2S | 2009040.055954 | 2009040.173223 | 41549.020 | Uplink | 1 |
| USHS | 2009040.090346 | 2009040.091650 | 784.118 | Uplink | 1 |
| USHS | 2009040.091727 | 2009040.112044 | 7396.024 | Uplink | 1 |
| DS34 | 2009040.095646 | 2009040.112044 | 5037.725 | Uplink | 1 |
| DS45 | 2009040.095646 | 2009040.112044 | 5037.725 | Uplink | 1 |
| DS24 | 2009040.105827 | 2009040.112044 | 1336.583 | Uplink | 1 |
| DS27 | 2009040.105827 | 2009040.112044 | 1336.291 | Uplink | 1 |
| LR1S | 2009040.110452 | 2009040.112044 | 951.199 | Uplink | 1 |
| SDSS | 2009040.110452 | 2009040.112044 | 951.199 | Uplink | 1 |
| USHS | 2009040.112120 | 2009040.132437 | 7397.081 | Uplink | 1 |
| DS24 | 2009040.112136 | 2009040.132437 | 7380.385 | Uplink | 1 |
| DS27 | 2009040.112136 | 2009040.132437 | 7380.410 | Uplink | 1 |
| USHS | 2009040.132512 | 2009040.152830 | 7397.642 | Uplink | 1 |
| SDSS | 2009055.145142 | 2009056.141710 | 84328.174 | Downlink | 2 |
| DS34 | 2009055.211738 | 2009055.224358 | 5179.910 | Downlink | 2 |
| DS45 | 2009055.211738 | 2009055.224358 | 5179.946 | Downlink | 2 |
| DS24 | 2009055.215501 | 2009055.224338 | 2916.308 | Downlink | 2 |
| DS27 | 2009055.215507 | 2009055.224338 | 2910.524 | Downlink | 2 |
| D34K | 2009055.230834 | 2009056.004759 | 5965.482 | Downlink | 2 |
| DS34 | 2009055.230834 | 2009056.004759 | 5965.482 | Downlink | 2 |
| DS45 | 2009055.230834 | 2009056.004759 | 5965.607 | Downlink | 2 |
| DS24 | 2009055.232255 | 2009056.151533 | 57158.182 | Downlink | 2 |
| DS27 | 2009055.232258 | 2009056.151533 | 57155.065 | Downlink | 2 |
| USPS | 2009055.234336 | 2009056.000313 | 1176.427 | Downlink | 2 |
| USHS | 2009055.235325 | 2009056.004744 | 3259.037 | Downlink | 2 |
| D34K | 2009056.012518 | 2009056.025202 | 5203.533 | Downlink | 2 |
| DS34 | 2009056.012518 | 2009056.025202 | 5203.535 | Downlink | 2 |
| DS45 | 2009056.012518 | 2009056.025202 | 5203.623 | Downlink | 2 |

***Figure B.1-21 Sample Solar Conjunction File***

### B.1.21 (FDF-38) Target Thruster Vector File Sample

| | | | |
|---|---|---|---|
| 2008303.122912 | 0.118487277 | -0.932008226 | -0.342522164 |
| 2008303.122913 | 0.118488053 | -0.932009027 | -0.342519715 |
| 2008303.122914 | 0.118488829 | -0.932009828 | -0.342517266 |
| 2008303.122915 | 0.118489605 | -0.932010630 | -0.342514816 |
| 2008303.122916 | 0.118490380 | -0.932011431 | -0.342512367 |
| 2008303.122917 | 0.118491156 | -0.932012233 | -0.342509918 |
| 2008303.122918 | 0.118491932 | -0.932013034 | -0.342507469 |
| 2008303.122919 | 0.118492707 | -0.932013835 | -0.342505020 |
| 2008303.122920 | 0.118493483 | -0.932014637 | -0.342502571 |

***Figure B.1-22 Sample Target Thruster Vector File***

## B.1.22 (FDF-39) LR Ground Station View Period Sample

```
*****************************************************************************************************************
                                                                                                17 Apr 2008 10:18:20
Facility-GGAO-To-Satellite-0059-Sensor-HGA

Start Time (YYYYDDD)    Stop Time (YYYYDDD)    Duration (sec)    Start Pass    Max Elevation (deg)    Max Elev Time (YYYYDDD)
--------------------    -------------------    -------------     ----------    -------------------    -----------------------
      2009077.071450         2009077.081311         3500.719     221                        12.990            2009077.081311
      2009077.090901         2009077.100723         3502.686     222                        21.993            2009077.100723
      2009077.110304         2009077.120131         3506.336     223                        23.486            2009077.110304
      2009077.125706         2009077.135542         3516.211     224                        18.297            2009077.125706
      2009077.145118         2009077.145223           65.680     225                         5.169            2009077.145118
      2009078.081951         2009078.091750         3479.474     234                        15.644            2009078.091750
      2009078.101351         2009078.111142         3470.950     235                        23.851            2009078.111142
      2009078.120747         2009078.130535         3467.607     236                        23.938            2009078.120747
      2009078.140148         2009078.145934         3465.870     237                        17.658            2009078.140148
      2009079.085831         2009079.091215          824.777     247                        10.298            2009079.091215
      2009079.094113         2009079.095514          841.311     248                        16.214            2009079.095514
      2009079.105146         2009079.110501          795.251     248                        22.530            2009079.110501
      2009079.113505         2009079.114829          803.603     249                        25.596            2009079.114829
      2009079.124505         2009079.125757          771.948     249                        26.243            2009079.124505
      2009079.132857         2009079.134146          769.280     250                        25.816            2009079.132857
      2009079.143827         2009079.145057          750.264     250                        20.906            2009079.143827
      2009079.152252         2009079.153507          735.030     251                        16.875            2009079.152252
      2009079.163150         2009079.164357          726.905     251                         7.477            2009079.163150
      2009080.093050         2009080.093924          513.556     260                         9.866            2009080.093924
      2009080.101921         2009080.102704          462.716     261                        17.013            2009080.102704
      2009080.112359         2009080.113222          502.881     261                        23.880            2009080.113222
      2009080.121238         2009080.122014          455.702     262                        28.037            2009080.122014
      2009080.131711         2009080.132524          492.920     262                        29.631            2009080.132524
      2009080.140556         2009080.141326          450.371     263                        29.528            2009080.140556
      2009080.151025         2009080.151827          482.600     263                        25.357            2009080.151025
      2009080.155915         2009080.160640          445.252     264                        21.023            2009080.155915
      2009080.170339         2009080.171131          471.235     264                        12.331            2009080.170339
      2009080.175235         2009080.175416          100.537     265                         5.279            2009080.175235
      2009081.100201         2009081.100805          363.935     273                        10.327            2009081.100805
      2009081.105159         2009081.105811          372.803     274                        18.442            2009081.105811
      2009081.115510         2009081.120109          358.868     274                        25.984            2009081.120109
      2009081.124513         2009081.125121          368.348     275                        31.175            2009081.125121
      2009081.134821         2009081.135416          355.082     275                        33.715            2009081.135416
      2009081.143829         2009081.144433          363.595     276                        34.151            2009081.143829
      2009081.154133         2009081.154725          351.803     276                        30.558            2009081.154133
      2009081.163146         2009081.163745          358.297     277                        26.230            2009081.163146
```

***Figure B.1-23 Sample LR Ground Station View Period File***

### B.1.23 (FDF-44) Trajectory Insertion Data Sample

```
# FDF-44 Trajectory Insertion Data
# 24 April 2009, 1340 GMT
#
Date of launch vehicle separation = 04242009 (MMDDYYYY)
Time of launch vehicle separation = 123516 (HHMMSS)
Semi-major Axis = 123456.54321(Km)
Eccentricity = 0.2346(Unitless)
Inclination  = 93.2345(Degrees)
Right Ascension of Ascending Node = 270.0345 (Degrees)
Argument of perigee = 123.8765 (Degrees)
True Anomaly = 88.2345 (Degrees)
```

***Figure B.1-24 Sample Trajectory Insertion Data File***

**Space Communications Data Products**

B.1.24 (GNSO-1) Station Support Schedules Sample

```
W0907-984,DS54,2009040001308,2009040013734,TR24,48,S1
W0907-356,WU1S,2009040001308,2009040013739,TR4,48,S1
W0907-744,WU2S,2009040001308,2009040013739,TR4,48,S1
W0907-632,KU1S,2009040001315,2009040013746,TR46,48,S1
W0907-688,KU2S,2009040001315,2009040013746,TR4,48,S1
W0907-1020,DS54,2009040002437,2009040012618,TR24,48,S1
W0907-393,WU1S,2009040002439,2009040012621,TR46,48,S1
W0907-781,WU2S,2009040002439,2009040012621,TR46,48,S1
W0907-660,KU1S,2009040002446,2009040012629,TR46,48,S1
W0907-716,KU2S,2009040002446,2009040012629,TR46,48,S1
W0907-318,SDSS,2009040003858,2009040012627,TR4,48,S1
W0907-209,WS1S,2009040003858,2009040012627,TR46,48,S1
W0907-278,SDSS,2009040003858,2009040013731,TR4,48,S1
W0907-169,WS1S,2009040003858,2009040013731,TR4,48,S1
W0907-859,DS24,2009040011620,2009040012630,TR24,49,S1
W0907-818,DS24,2009040011620,2009040013734,TR24,49,S1
W0907-985,DS54,2009040021730,2009040034141,TR25,49,S1
W0907-357,WU1S,2009040021732,2009040034145,TR5,49,S1
W0907-745,WU2S,2009040021732,2009040034145,TR5,49,S1
W0907-633,KU1S,2009040021742,2009040034151,TR45,49,S1
W0907-689,KU2S,2009040021742,2009040034151,TR5,49,S1
W0907-279,SDSS,2009040021751,2009040034132,TR5,49,S1
W0907-170,WS1S,2009040021751,2009040034132,TR5,49,S1
W0907-819,DS24,2009040021754,2009040034134,TR25,49,S1
W0907-1021,DS54,2009040022850,2009040033033,TR25,49,S1
W0907-394,WU1S,2009040022854,2009040033036,TR45,49,S1
W0907-782,WU2S,2009040022854,2009040033036,TR45,49,S1
W0907-319,SDSS,2009040022858,2009040033038,TR5,49,S1
W0907-247,WS1K,2009040022858,2009040033038,TR1,49,K1
W0907-210,WS1S,2009040022858,2009040033038,TR45,49,S1
```

***Figure B.2-1 Sample Station Support Schedules File***

### B.1.25 (WS1-2) and (USN-2) Station Weather Data Sample

The following sample is valid for both the WS1 station and any of the USN stations. The following example is for the WS1 White Sands station.

```
20080828 241 WS1S
17:07  23.9 0853.4 057.0 01
17:12  24.2 0853.4 056.0 03
17:17  24.2 0853.4 055.0 04
17:22  24.4 0853.4 056.0 08
17:27  24.7 0853.4 055.0 06
17:32  25.1 0853.4 054.0 11
17:37  25.3 0853.4 053.0 09
17:42  25.0 0853.1 054.0 04
17:47  25.3 0853.1 053.0 04
17:52  25.2 0853.1 054.0 04
17:57  25.0 0853.1 054.0 08
18:02  25.0 0853.1 054.0 08
18:07  25.0 0852.7 055.0 11
18:12  24.7 0853.1 055.0 06
18:17  24.7 0852.7 054.0 08
18:22  24.5 0852.7 055.0 04
```

***Figure B.2-2 Sample Station Weather Data File***

### B.1.26 (WS1- 8) Ka-Band RF Receiver Data File Sample

```
00000,2008-231-18:14:47.780389,GSHDRIFLVL1,    ,-044.499912261,
00000,2008-231-18:14:48.763424,GSHDRIFLVL1,    ,-044.511623382,
00000,2008-231-18:14:49.851322,GSHDRIFLVL1,    ,-044.597850799,
00000,2008-231-18:14:50.834353,GSHDRIFLVL1,    ,-044.490699768,
00000,2008-231-18:14:51.817386,GSHDRIFLVL1,    ,-044.615703582,
00000,2008-231-18:14:52.695573,GSHDRIFLVL1,    ,-044.553192138,
00000,2008-231-18:14:53.796577,GSHDRIFLVL1,    ,-044.472484588,
00000,2008-231-18:14:54.779620,GSHDRIFLVL1,    ,-044.644672393,
00000,2008-231-18:14:55.762663,GSHDRIFLVL1,    ,-044.481876373,
00000,2008-231-18:14:56.850567,GSHDRIFLVL1,    ,-044.591571807,
00000,2008-231-18:14:57.833612,GSHDRIFLVL1,    ,-044.505058288,
00000,2008-231-18:14:58.934617,GSHDRIFLVL1,    ,-044.576263427,
00000,2008-231-18:15:00.022511,GSHDRIFLVL1,    ,-044.497474670,
00000,2008-231-18:15:01.005551,GSHDRIFLVL1,    ,-044.506710052,
00000,2008-231-18:15:01.988590,GSHDRIFLVL1,    ,-044.524097442,
00000,2008-231-18:15:02.761913,GSHDRIFLVL1,    ,-044.514175415,
00000,2008-231-18:15:03.849807,GSHDRIFLVL1,    ,-044.481136322,
00000,2008-231-18:15:04.950818,GSHDRIFLVL1,    ,-044.410137176,
00000,2008-231-18:15:05.933853,GSHDRIFLVL1,    ,-044.407169342,
00000,2008-231-18:15:07.021756,GSHDRIFLVL1,    ,-044.573669433,
00000,2008-231-18:15:08.004798,GSHDRIFLVL1,    ,-044.631370544,
00000,2008-231-18:15:08.987831,GSHDRIFLVL1,    ,-044.547801971,
00000,2008-231-18:15:09.761155,GSHDRIFLVL1,    ,-044.460884094,
00000,2008-231-18:15:11.071878,GSHDRIFLVL1,    ,-044.614196777,
00000,2008-231-18:15:11.950055,GSHDRIFLVL1,    ,-044.556739807,
00000,2008-231-18:15:12.933093,GSHDRIFLVL1,    ,-044.406509399,
00000,2008-231-18:15:14.020996,GSHDRIFLVL1,    ,-044.474006652,
00000,2008-231-18:15:15.004024,GSHDRIFLVL1,    ,-044.486103057,
00000,2008-231-18:15:16.105036,GSHDRIFLVL1,    ,-044.586395263,
00000,2008-231-18:15:17.088078,GSHDRIFLVL1,    ,-044.513668060,
00000,2008-231-18:15:18.175970,GSHDRIFLVL1,    ,-044.584320068,
00000,2008-231-18:15:18.949295,GSHDRIFLVL1,    ,-044.629341125,
00000,2008-231-18:15:19.932330,GSHDRIFLVL1,    ,-044.565578460,
00000,2008-231-18:15:21.020232,GSHDRIFLVL1,    ,-044.558731079,
00000,2008-231-18:15:22.003273,GSHDRIFLVL1,    ,-044.531181335,
00000,2008-231-18:15:23.104277,GSHDRIFLVL1,    ,-044.425022125,
```

***Figure B.2-3 Sample Ka-Band RF Receiver Data File***

**Science Operations Center Products**

### B.1.27 (CRaTER-1) (DLRE-1) (LAMP-1) (LEND-1) (LOLA-1) (LROC-1) (MIRF-1) LRO Operations Activity Request Sample

| |
|---|
| OAR Request Date: 2009-06-21<br>OAR Approved Date: NA<br>OAR Planned Execution Date:NA<br>OAR Status: NA<br>OAR Status Detail: NA<br>OAR Name:DLRE Loads (FP-RT-088)<br>OAR Number: NA<br>OAR Requested By:JOHN DOE<br>OAR Requestor Phone Number:123-456-7890<br>OAR Requestor Email Address: jdoe@nasa.gov<br>OAR Request Org:DLRE SOC<br>OAR Type: INSTRUMENT OPERATION<br>OAR Execution Window: NET 2009-06-24<br>OAR Constraints:Execute according to constraints identified in Flight Procedure Document<br>OAR Sequence:<br>Execute FP-RT-088.<br>Use the file DLRE_FSWLOAD_ramping_patch_2009090_V2.ld accompanying this request when requested by Step number 8 in the referenced flight procedure. |

***Figure B.3-1 Sample LRO Operations Activity Request File***

### B.1.28 (LOLA-4), (LROC-4), (MIRF-4) Target Requests

LOLA Specific Target Request Sample

```
# LOLA_TARGETS_2009077_2009077_V00.txt
# 05-29-2008 @ 12:00:00
# 1 TARGET REQUEST SLEW EVENT GENERATED
#
2009-077-13:00:00, +01.800, 900
```

LROC Specific Target Request Sample

```
# LROC_TARGETS2009077_2009079_V04.txt
# 5-28-2008 @ 16:45.26
# 6 TARGET REQUEST SLEW EVENTS GENERATED
#
2009-077-04:54:43, +1.00, 96
2009-077-08:29:14, -6.00, 124
2009-077-13:53:10, +10.00, 147
2009-078-05:27:13, -20.00, 204
2009-078-07:21:18, -20.00, 204
2009-078-08:41:17, -16.67, 185
```

Mini-RF Specific Target Request Sample

```
# MINI_TARGETS_2009077_2009079_V00.txt
# 03-19-2009 @ 15:15.00
# 1 TARGET REQUEST SLEW EVENT GENERATED
#
2009-078-15:15:00,  +9.80,  600
```

***Figure B.3-2 Sample Target Requests File***

### B.1.29 (DLRE-2) DLRE FSW Load Samples

The following DLRE sample is specific for a scan table load.

```
/project/diviner_work/fel/Tables/MR4/DLRE_MR4_SST5_2010084_V1.ld
LRO,sst5,2009-13-14:14:30,001,SCANTABLES,00E6,NOSWAP, ,3
/NOSELECT
/DLINSTUPLOAD DSTBANK=3, ADDRESS=0x1400
/NOCOMMIT
X 00 02 0d 30 5a de 00 00 00 00 00 00 00 00 00 00
X 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
X 00 00
```

***Figure B.3-3 Sample DLRE Scan Table Load File***

The following DLRE sample is specific for a FSW load.

```
/project/diviner_work/fel/Tables/MR4/DLRE_MR4_ramping_patch_2010084_V1.ld

unknown,ignored,107-107-9:5:49,1,ignored,00E6,NOSWAP, ,3
/NOSELECT

/dlinstupload dstbank=XRAM, address=0xd634

/NOCOMMIT

X c0e0 c0f0 c083 c082 c0d0 75d0 00c0 00c0
X 01c0 02c0 03c0 04c0 05c0 06c0 0790 c620
X 7431 f0c2 8eaf 598f 0a8f 098f 08e5 5f14
X 601c 1470 0302 d798 1470 0302 d893 1470
X 0302 dc2e 2404 6003 02dc 6f75 5f01 907f
X 09e4 f0a3 f090 a47c e0b4 020e 755b 0075
X 5c14 755d 1c75 5eb2 8010 90a4 61e0 f55b
X a3e0 f55c 755d 0075 5e00 90a4 79e0 603f
X 7552 0175 53a4 7554 6375 57c6 7558 30c3
X 90d6 31e0 955c 90d6 30e0 955b 505e e0fc
X a3e0 fdc3 90a4 62e0 9dff 90a4 61e0 9cfe
X ef25 e0f5 5eee 33f5 5d8c 5b8d 5c80 3d75
X 5201 7553 a475 546c 7557 ce75 5830 c390
X d633 e095 5c90 d632 e095 5b50 1fe0 fca3
X e0fd c390 a462 e09d ff90 a461 e09c feef
X 25e0 f55e ee33 f55d 8c5b 8d5c 8558 8285
X 5783 e0fe a3e0 24ff f551 ee34 fff5 50aa
X 57a9 587b 0190 0002 1232 c1f5 5990 0003
X 1232 c1f5 5aab 52aa 53a9 5490 0005 1232
X c1ff 90a4 79e0 6004 7e04 8002 7e00 ee4f
X 4408 907f 01f0 755f 0275 4d00 9000 0212
X 3404 f582 85f0 83e4 f075 8dfd 758b 54d2
X 8e02 dc71 e54d c395 5950 2574 0425 4df5
X 4dab 52aa 53a9 5490 0002 1234 04f5 8285
X f083 e54d f075 8dfd 758b 54d2 8e02 dc71
```

***Figure B.3-4 Sample DLRE FSW Load File***

### B.1.30 (LAMP-3) LAMP Instrument FSW Load Sample

```
`LAMP_FSWLOAD_2009061_V01.BIN
LRO,lafs0010.bin,2009-061:14:27:33, 0.10,EEPROM4,128,NOSWAP,128,1
/LACHKOUTMODE
/LAMEMLD128 START_ADDR=0,MEMORY_TYPE=0x54
/LACRITCONF CONF_CMD=0x6618
;-----------------------------------------------------------
; LRO-LAMP Memory Patch Request File
;   generated by: LampLoad,     version: 0.02 - 2009/03/03
;   generated on: 2009-061:14:27:33
;   source file:  lafs0010.bin, created: 2009/03/03 14:06:23
;   source file size:  32640 bytes
;-----------------------------------------------------------
;
X 0229FE02 24247F09 020F5F02 0DD8F002 2A810002 38BF7F01 0259CA02 4DE29080 A5E0541F FEA3E090 80A51227 559080A5 1226C890 80A51227 7C9080A5 EEF07481 1227AD90
80A71227 55908098 12278890 80A71226 D3A3E4F0 A37473F0 7A8079AF 12278F7A 8079AB12 561D7B01 7A827986 125B007B 017A8279 8C125918 7B017A82  ;
X 79971258 D77B017A 82799912 52A07B01 7A8279BD 125AE97B 017A8279 C2125937 125E0290 4001E0FE C4122732 2F9080B1 1227977F 02125BB0 D3EF9400 EE940040 047F0180
027F00EF 54013333 3354F8FF 9080B1E0 54F74FFF F0908298 E05407FE EF54F84E 9080B1F0 904039E0 5480FF90 80B2E054 7F4FF090 4039E054 40FF9080  ;
X B2E054BF 1227B754 0212275C 54DF1227 B7540112 275C54EF 4FF09080 9AE07009 90401BE0 D3940440 047F0180 027F0012 2731FF90 80B2E054 FB4FF090 4031E064 F16009E0
64F26004 E0B4F304 7F018002 7F009080 B21226F2 F0125E2C EF5401FF 9080B2E0 54FE4FF0 90401CE0 5408C454 F0FF9080 B3E0547F 1227B754 04C454F0  ;
X FF9080B3 E054BF4F F07B017A 82798290 9235120B 847A8219 12546590 8281E054 01C43354 E0FF9080 B3E054DF 4FFFF090 8282E054 01C454F0 FEEF54EF 4EFF9080 B3F09040
2CE05402 25E025E0 FEEF54F7 4E9080B3 F090402C E0542013 1313541F FF9080B3 E054FB4F F090402C E0540125 E0FF9080 B3E054FD 4FF09040 2CE05410  ;
X C4540F90 80B31227 BE9081B5 E0FEA3E0 FF9080B5 E06E7003 A3E06F60 047F0180 027F0090 80B41226 E3F0125D F0EF5401 C4333354 C0FF9080 B4E054BF 4FF0E4FF 125D5590
80B41226 BBF0125C 6D9080B4 12276512 5DF6EF54 01333333 54F8FF90 80B4E054 F74FF012 5E56EF54 07FF9080 B4E054F8 4FF09081 B5E0FFA3 E09080B5  ;
X CFF0A3EF F09081B7 E0FFA3E0 9080B7CF F0A3EFF0 9081BAE0 FFA3E090 80B9CFF0 A3EFF090 81B9E090 80BBF090 8001E090 80BCF090 81B3E090 80BDF07F 01125BB0 9080BEEF
F0904011 E0FEA3E0 24FFFDEE 34FF540F FCEE54F0 FEE42DFF EE3C9080 BFF0A3EF F0125E26 EF045403 C4333354 C0FF9080 C1E0543F 4FF0125E 20EF5403  ;
X C454F0FF 9080C1E0 54CF4FFF F0908299 E0122732 FEEF54FB 4E9080C1 F0904029 E0B4A50B 90402BE0 B45A047F 0180027F 009080C1 1226F2F0 904028E0 B4A50B90 402AE0B4
5A047F01 80027F00 EF5401FF 9080C1E0 54FE4FF0 90400BE0 9080C212 2797125D FC122731 FF9080C2 E054FB4F FFF09040 02E05404 C313FEEF 54FD4E90  ;
```

*Figure B.3-5 Sample LAMP Instrument FSW Load File*

### B.1.31 (LOLA-2) LOLA Improved Lunar Gravity Model Sample

```
GRAVITY FIELD lp150q
PLANET1 301150150 0.4902801076l000E+14 .173800000E+07
GCOEFC1 2 0 -0.909010949481D-04
GCOEFC1 3 0 -0.320307167959D-05
GCOEFC1 4 0 0.321409545028D-05
GCOEFC1 5 0 -0.221009876393D-06
GCOEFC1 6 0 0.376479064475D-05
GCOEFC1 7 0 0.561330656403D-05
GCOEFC1 8 0 0.231953905520D-05
GCOEFC1 9 0 -0.354241582136D-05
GCOEFC1 10 0 -0.933036285877D-06
GCOEFC1 11 0 -0.960353139804D-06
GCOEFC1 12 0 -0.188692162540D-05
GCOEFC1 13 0 0.258650494877D-06
...
GCOEFC1 2 1 -0.186273608184D-08
GCOEFC1 3 1 0.263418358622D-04
GCOEFC1 4 1 -0.600061939740D-05
GCOEFC1 5 1 -0.103560812630D-05
GCOEFC1 6 1 0.153429993945D-05
GCOEFC1 7 1 0.753347997634D-05
GCOEFC1 8 1 -0.398659493146D-07
GCOEFC1 9 1 0.200756653373D-05
GCOEFC1 10 1 0.814236506144D-06
...
GCOEFS1 2 1 -0.142453894610D-08
GCOEFS1 3 1 0.546307860882D-05
GCOEFS1 4 1 0.165955644727D-05
GCOEFS1 5 1 -0.411585726681D-05
GCOEFS1 6 1 -0.257237276906D-05
GCOEFS1 7 1 -0.131539563288D-06
GCOEFS1 8 1 0.111757157884D-05
GCOEFS1 9 1 0.917275746511D-07
GCOEFS1 10 1 -0.989134259432D-06
```

***Figure B.3-6 Sample LOLA Improved Lunar Gravity Model***

### B.1.32 (LOLA-3) LOLA Instrument FSW Load Sample

```
<File Name>
<Mission>,<ID>,<Date>,<Version>,<Source>,<Pkt Size>,<Byte Swap>,<Data Size>,<Rate>
<Select Command>
<Instrument Load Command>
<Commit Command>
;
;
;
X 00 04 02 03 0A 99 6F 7A 30 FF CA 00 05 12 15 42 60 19 01 9A 9D 4A
X 00 04 02 03 0A 99 6F 7A 30 FF CA 00 05 12 15 42 60 19 01 9A 9D 4A
X 00 04 02 03 0A 99 6F 7A 30 FF CA 00 05 12 15 42 60 19 01 9A 9D 4A
X 00 04 02 03 0A 99 6F 7A 30 FF CA 00 05 12 15 42 60 19 01 9A 9D 4A
X 00 04 02 03 0A 99 6F 7A 30 FF CA 00 05 12 15 42 60 19 01 9A 9D 4A
X 00 04 02 03 0A 99 6F 7A 30 FF CA 00 05 12 15 42 60 19 01 9A 9D 4A
X 00 04 02 03 0A 99 6F 7A 30 FF CA 00 05 12 15 42 60 19 01 9A 9D 4A
X 00 04 02 03 0A 99 6F 7A 30 FF CA 00 00
```

***Figure B.3-7 Sample LOLA Instrument FSW Load File***

### B.1.33 (LOLA-6) LOLA Processed Laser Ranging Data Sample

```
H1 CRD 01 2008  8  6 18
H2 GO1L        7125 93 01  4
H3 LRO          8000000   59         0 2 4
H4  1 2008  6  8  0 50  0 2008  6  8  1  0  0  5 0 0 1 1 1 1 0
C0 0 532.2 lro sl2 st2 sx1
C1 0 sl2 Nd-Yag      532.20 28       50.00 6000.0 11.0 1
C3 0 st2 Truetime Cesium HTSI-ET SN01     0.0
C4 0 sx1 0.0 0.0 1.0 0.0        234576001.183925628662 0 1 1
60 lro 1 2
40  3000.000000000000 1 lro  -1 -1 -1     10000.0 0.0 0.0 0.0 0.0 0.0 1 0 0
40  3000.000000000000 5 lola -1 -1 -1       500.0 0.0 0.0 0.0 0.0 0.0 1 0 0
20  3000.000000000000 1010.10 293.15  50. 0
11  3000.000000000000    3001.233857750893 lro 5    1      28 0.0 0.0 0.0 0.0 100.0 0
11  3001.000000000000    3002.233856946230 lro 5    1      28 0.0 0.0 0.0 0.0 100.0 0
11  3002.000000000000    3003.233856171370 lro 5    1      28 0.0 0.0 0.0 0.0 100.0 0
11  3003.000000000000    3004.233855366707 lro 5    1      28 0.0 0.0 0.0 0.0 100.0 0
11  3004.000000000000    3005.233854591846 lro 5    1      28 0.0 0.0 0.0 0.0 100.0 0
11  3005.000000000000    3006.233853787184 lro 5    1      28 0.0 0.0 0.0 0.0 100.0 0
11  3006.000000000000    3007.233853012323 lro 5    1      28 0.0 0.0 0.0 0.0 100.0 0
11  3007.000000000000    3008.233852207661 lro 5    1      28 0.0 0.0 0.0 0.0 100.0 0
11  3008.000000000000    3009.233851432800 lro 5    1      28 0.0 0.0 0.0 0.0 100.0 0
11  3009.000000000000    3010.233850628138 lro 5    1      28 0.0 0.0 0.0 0.0 100.0 0
11  3010.000000000000    3011.233849853277 lro 5    1      28 0.0 0.0 0.0 0.0 100.0 0
11  3011.000000000000    3012.233849048615 lro 5    1      28 0.0 0.0 0.0 0.0 100.0 0
11  3012.000000000000    3013.233848273754 lro 5    1      28 0.0 0.0 0.0 0.0 100.0 0
11  3013.000000000000    3014.233847469091 lro 5    1      28 0.0 0.0 0.0 0.0 100.0 0

  ...

11  3118.000000000000    3119.233765095472 lro 5    1      28 0.0 0.0 0.0 0.0 100.0 0
11  3119.000000000000    3120.233764320612 lro 5    1      28 0.0 0.0 0.0 0.0 100.0 0
11  3120.000000000000    3121.233763545752 lro 5    1      28 0.0 0.0 0.0 0.0 100.0 0
11  3121.000000000000    3122.233762741089 lro 5    1      28 0.0 0.0 0.0 0.0 100.0 0
11  3122.000000000000    3123.233761966228 lro 5    1      28 0.0 0.0 0.0 0.0 100.0 0
20  3123.000000000000 1011.11 293.44  50. 0
11  3123.000000000000    3124.233761191368 lro 5    1      28 0.0 0.0 0.0 0.0 100.0 0
11  3124.000000000000    3125.233760416508 lro 5    1      28 0.0 0.0 0.0 0.0 100.0 0
11  3125.000000000000    3126.233759641647 lro 5    1      28 0.0 0.0 0.0 0.0 100.0 0
11  3126.000000000000    3127.233758866787 lro 5    1      28 0.0 0.0 0.0 0.0 100.0 0
11  3127.000000000000    3128.233758091927 lro 5    1      28 0.0 0.0 0.0 0.0 100.0 0
11  3128.000000000000    3129.233757317066 lro 5    1      28 0.0 0.0 0.0 0.0 100.0 0

  ...

11  3359.000000000000    3360.233587533236 lro 5    1      28 0.0 0.0 0.0 0.0 100.0 0
11  3360.000000000000    3361.233586847782 lro 5    1      28 0.0 0.0 0.0 0.0 100.0 0
11  3361.000000000000    3362.233586162329 lro 5    1      28 0.0 0.0 0.0 0.0 100.0 0
11  3362.000000000000    3363.233585476875 lro 5    1      28 0.0 0.0 0.0 0.0 100.0 0
11  3363.000000000000    3364.233584791422 lro 5    1      28 0.0 0.0 0.0 0.0 100.0 0
11  3364.000000000000    3365.233584135771 lro 5    1      28 0.0 0.0 0.0 0.0 100.0 0
11  3365.000000000000    3366.233583450317 lro 5    1      28 0.0 0.0 0.0 0.0 100.0 0
11  3366.000000000000    3367.233582764864 lro 5    1      28 0.0 0.0 0.0 0.0 100.0 0
11  3367.000000000000    3368.233582079411 lro 5    1      28 0.0 0.0 0.0 0.0 100.0 0
11  3368.000000000000    3369.233581423759 lro 5    1      28 0.0 0.0 0.0 0.0 100.0 0
20  3369.000000000000 1013.13 294.03  50. 0
11  3369.000000000000    3370.233580738306 lro 5    1      28 0.0 0.0 0.0 0.0 100.0 0
11  3370.000000000000    3371.233580052853 lro 5    1      28 0.0 0.0 0.0 0.0 100.0 0
11  3371.000000000000    3372.233579397202 lro 5    1      28 0.0 0.0 0.0 0.0 100.0 0
11  3372.000000000000    3373.233578711748 lro 5    1      28 0.0 0.0 0.0 0.0 100.0 0
11  3373.000000000000    3374.233578026295 lro 5    1      28 0.0 0.0 0.0 0.0 100.0 0
11  3374.000000000000    3375.233577370644 lro 5    1      28 0.0 0.0 0.0 0.0 100.0 0

  ...

H8
H9
```

***Figure B.3-8 Sample LOLA Processed Laser Ranging Data File***

### B.1.34 (LOLA-7) Lunar Laser Retro-Reflector Avoidance Event File Sample

```
# Lunar Retro Reflector Avoidance data
# Retro-reflectors : ALL
# White Sands : no constraint on visibility
# Generated 2009-02-02 15:20:32
# START = 2009-07-08T00:00:01.00 , 2009-189-00:00:01 ,    300283266.18
#  STOP = 2009-08-05T00:00:01.00 , 2009-217-00:00:01 ,    302702466.18
# Event Start    Duration
2009-191-15:54:12, 59
2009-191-17:47:12, 84
2009-191-19:40:11, 92
2009-191-21:33:10, 90
2009-191-23:26:10, 76
2009-192-01:19:10, 39
2009-192-04:58:01, 63
2009-192-06:51:05, 82
2009-192-08:44:09, 84
2009-192-10:37:12, 72
2009-192-12:30:15, 31
2009-193-15:01:01, 36
2009-193-16:54:03, 82
2009-193-18:47:06, 96
2009-193-20:40:09, 93
```

***Figure B.3-9 Sample Lunar Laser Retro-Reflector Avoidance Event File***

### B.1.35 (LR-1) Laser Ranging Schedule Data Sample

```
7941 2008 24 00:48 2008 24 01:37 MATM
7125 2008 24 01:37 2008 24 01:47 GO1L
7125 2008 24 02:44 2008 24 03:42 GO1L
7125 2008 24 04:39 2008 24 05:36 GO1L
7125 2008 24 06:34 2008 24 07:31 GO1L
7125 2008 24 08:28 2008 24 09:26 GO1L
7125 2008 24 10:23 2008 24 11:21 GO1L
7080 2008 24 12:18 2008 24 12:20 MDOL
7825 2008 24 12:20 2008 24 13:15 STL3
7825 2008 24 14:12 2008 24 15:10 STL3
7825 2008 24 16:07 2008 24 17:04 STL3
7825 2008 24 18:02 2008 24 18:59 STL3
7941 2008 24 20:14 2008 24 20:55 MATM
7941 2008 24 21:52 2008 24 22:49 MATM
7941 2008 24 23:46 2008 25 00:44 MATM
7941 2008 25 01:41 2008 25 02:39 MATM
7125 2008 25 03:36 2008 25 04:33 GO1L
7125 2008 25 05:30 2008 25 06:28 GO1L
7125 2008 25 07:25 2008 25 08:22 GO1L
7125 2008 25 09:19 2008 25 10:17 GO1L
7125 2008 25 11:14 2008 25 12:12 GO1L
7825 2008 25 13:08 2008 25 14:06 STL3
7825 2008 25 15:03 2008 25 16:00 STL3
7825 2008 25 16:57 2008 25 17:55 STL3
7825 2008 25 18:52 2008 25 19:49 STL3
7825 2008 25 20:46 2008 25 20:59 STL3
7941 2008 25 21:20 2008 25 21:44 MATM
7941 2008 25 22:41 2008 25 23:39 MATM
7941 2008 26 00:36 2008 26 01:33 MATM
7941 2008 26 02:30 2008 26 03:28 MATM
7125 2008 26 04:25 2008 26 05:22 GO1L
7125 2008 26 06:19 2008 26 07:17 GO1L
7125 2008 26 08:14 2008 26 09:11 GO1L
```

***Figure B.3-10 Sample Laser Ranging Schedule Data File***

### B.1.36 (LROC-3) LROC Daily Command Sequence Sample

```
Absolute Time, Image Priority, Command Mnemonic
2009-015-00:23:34, 1, LRNAC, XID=0xAC, TIME=2009-015-00:23:35.33, IMAGEID=0x1214, EXTIME=0xDEAF, LINES=0xEFFD, CPNDSEL=0xAB, TESTPAT=TEST, SUM=NO_SUM, COMP=NO_COMPRESS, NACSEL=BOTH, RSTLVLL=0, RSTLVLR=0, OFFAL=0, OFFAR=0, OFFBL=0, OFFBR=0
2009-015-00:23:34, 3, LRWAC, XID=0xA2, TIME=2009-015-00:23:35.33, IMAGEID=0xAC01, EXTIME=25009, FRMS=32000, CPNDSEL=0, TESTPAT=NO_TEST, WACPWR=ON, POLAR=NO_POLAR, COMP=COMPRESS, BAND=ALL_BANDS, IFRMTIME=205
2009-015-00:24:30, 2, LRNAC, XID=0xAAAA, TIME=2009-015-00:24:32.00, IMAGEID=0x1215, EXTIME=0xDEAF, LINES=0xEFFD, CPNDSEL=0xAB, TESTPAT=TEST, SUM=NO_SUM, COMP=COMPRESS, NACSEL=BOTH, RSTLVLL=1, RSTLVLR=0, OFFAL=1, OFFAR=0, OFFBL=0, OFFBR=0
2009-015-00:26:45, 2, LRNAC, XID=0xA2, TIME=2009-015-00:26:47.23, IMAGEID=0x1216, EXTIME=0xDEAF, LINES=0xEFFC, CPNDSEL=0xAA, TESTPAT=NO_TEST, SUM=NO_SUM, COMP=COMPRESS, NACSEL=BOTH, RSTLVLL=0, RSTLVLR=2, OFFAL=0, OFFAR=2, OFFBL=0, OFFBR=0
2009-015-00:28:55, 1, LRNAC, XID=0xA2, TIME=2009-015-00:28:57.53, IMAGEID=0x1217, EXTIME=0xDEAF, LINES=0xEF00, CPNDSEL=0xAA, TESTPAT=NO_TEST, SUM=NO_SUM, COMP=COMPRESS, NACSEL=BOTH, RSTLVLL=0, RSTLVLR=0, OFFAL=0, OFFAR=0, OFFBL=1, OFFBR=1
2009-015-00:32:30, 1, LRNAC, XID=0xAAAA, TIME=2009-015-00:32:32.43, IMAGEID=0x1218, EXTIME=0, LINES=0xEDDD, CPNDSEL=0xAB, TESTPAT=NO_TEST, SUM=SUM, COMP=COMPRESS, NACSEL=BOTH, RSTLVLL=0, RSTLVLR=0, OFFAL=0, OFFAR=0, OFFBL=0, OFFBR=0
2009-015-00:35:22, 4, LRNAC, XID=0xAAAA, TIME=2009-015-00:35:24.23, IMAGEID=0x1219, EXTIME=0, LINES=0xECAA, CPNDSEL=0xAB, TESTPAT=NO_TEST, SUM=SUM, COMP=COMPRESS, NACSEL=BOTH, RSTLVLL=0, RSTLVLR=0, OFFAL=0, OFFAR=0, OFFBL=0, OFFBR=0
2009-015-00:40:12, 4, LRNAC, XID=0xAAAA, TIME=2009-015-00:40:14.13, IMAGEID=0x121A, EXTIME=0xDEAF, LINES=0xECAD, CPNDSEL=0xAA, TESTPAT=NO_TEST, SUM=NO_SUM, COMP=COMPRESS, NACSEL=NACR, RSTLVLL=0, RSTLVLR=0, OFFAL=0, OFFAR=0, OFFBL=0, OFFBR=0
2009-015-00:40:18, 1, LRNAC, XID=0xAAAA, TIME=2009-015-00:40:20.03, IMAGEID=0x121B, EXTIME=0xDEAF, LINES=0xEFFA, CPNDSEL=0xAB, TESTPAT=NO_TEST, SUM=NO_SUM, COMP=COMPRESS, NACSEL=NACL, RSTLVLL=0, RSTLVLR=0, OFFAL=0, OFFAR=0, OFFBL=0, OFFBR=0
2009-015-00:43:28, 4, LRWAC, XID=0xAAAA, TIME=2009-015-00:43:30.25, IMAGEID=0xAC02, EXTIME=65000, FRMS=32000, CPNDSEL=0, TESTPAT=NO_TEST, WACPWR=ON, POLAR=NO_POLAR, COMP=COMPRESS, BAND=ALL_BANDS, IFRMTIME=180
2009-015-00:45:00, 1, LRNAC, XID=0xAC, TIME=2009-015-00:45:03.43, IMAGEID=0x121C, EXTIME=0xDEAF, LINES=0xEFFD, CPNDSEL=0xAB, TESTPAT=NO_TEST, SUM=NO_SUM, COMP=COMPRESS, NACSEL=BOTH, RSTLVLL=0, RSTLVLR=0, OFFAL=0, OFFAR=0, OFFBL=0, OFFBR=0
2009-015-00:50:45, 1, LRNAC, XID=0xAC, TIME=2009-015-00:50:48.53, IMAGEID=0x121D, EXTIME=0xDEAF, LINES=0xEFFD, CPNDSEL=0xAB, TESTPAT=NO_TEST, SUM=NO_SUM, COMP=COMPRESS, NACSEL=BOTH, RSTLVLL=0, RSTLVLR=0, OFFAL=0, OFFAR=0, OFFBL=0, OFFBR=0
2009-015-00:55:48, 2, LRNAC, XID=0xAAAA, TIME=2009-015-00:55:52.13, IMAGEID=0x121E, EXTIME=0xDEAF, LINES=0xEFFD, CPNDSEL=0xAB, TESTPAT=NO_TEST, SUM=NO_SUM, COMP=COMPRESS, NACSEL=BOTH, RSTLVLL=0, RSTLVLR=0, OFFAL=0, OFFAR=0, OFFBL=0, OFFBR=0
2009-015-00:57:50, 2, LRNAC, XID=0xAAAA, TIME=2009-015-00:57:55.03, IMAGEID=0x121F, EXTIME=0xDEAF, LINES=0xEFFD, CPNDSEL=0xAB, TESTPAT=NO_TEST, SUM=NO_SUM, COMP=COMPRESS, NACSEL=BOTH, RSTLVLL=0, RSTLVLR=0, OFFAL=0, OFFAR=0, OFFBL=0, OFFBR=0
2009-015-01:00:05, 1, LRNAC, XID=0xAAAA, TIME=2009-015-01:00:07.43, IMAGEID=0x1220, EXTIME=0xABBB, LINES=0xEFFD, CPNDSEL=0xAA, TESTPAT=NO_TEST, SUM=NO_SUM, COMP=NO_COMPRESS, NACSEL=BOTH, RSTLVLL=0, RSTLVLR=0, OFFAL=0, OFFAR=0, OFFBL=0, OFFBR=0
2009-015-01:05:15, 5, LRNAC, XID=0xAAAA, TIME=2009-015-01:05:18.43, IMAGEID=0x1221, EXTIME=0xDEAF, LINES=1, CPNDSEL=0xAB, TESTPAT=NO_TEST, SUM=NO_SUM, COMP=COMPRESS, NACSEL=BOTH, RSTLVLL=0, RSTLVLR=0, OFFAL=0, OFFAR=0, OFFBL=0, OFFBR=0
2009-015-01:08:11, 5, LRNAC, XID=0xAAAA, TIME=2009-015-01:08:14.33, IMAGEID=0x1222, EXTIME=0xDEAF, LINES=1, CPNDSEL=0xAB, TESTPAT=NO_TEST, SUM=NO_SUM, COMP=COMPRESS, NACSEL=BOTH, RSTLVLL=0, RSTLVLR=0, OFFAL=0, OFFAR=0, OFFBL=0, OFFBR=0
2009-015-01:10:15, 1, LRWAC, XID=0xAAAA, TIME=2009-015-01:11:00.11, IMAGEID=0xAC03, EXTIME=15800, FRMS=65000, CPNDSEL=0, TESTPAT=NO_TEST, WACPWR=ON, POLAR=NO_POLAR, COMP=COMPRESS, BAND=UV1, IFRMTIME=205
2009-015-01:10:59, 1, LRNAC, XID=0xAAAA, TIME=2009-015-01:11:02.23, IMAGEID=0x1223, EXTIME=0xDAAC, LINES=0xEFFD, CPNDSEL=0xAB, TESTPAT=NO_TEST, SUM=NO_SUM, COMP=COMPRESS, NACSEL=BOTH, RSTLVLL=0, RSTLVLR=0, OFFAL=0, OFFAR=0, OFFBL=0, OFFBR=0
```

***Figure B.3-11 LROC Daily Command Sequence File***

### B.1.37 (MIRF-2) Mini-RF Load Files

```
<File Name>
<Mission>,<ID>,<Date>,<Version>,<Source>,<Pkt Size>,<Byte Swap>,<Data Size>,<Rate>
<Select Command>
<Instrument Load Command>
<Commit Command>
;
;
;
X 00 04 02 03 0A 99 6F 7A 30 FF CA 00 05 12 15 42 60 19 01 9A 9D 4A
X 00 04 02 03 0A 99 6F 7A 30 FF CA 00 05 12 15 42 60 19 01 9A 9D 4A
X 00 04 02 03 0A 99 6F 7A 30 FF CA 00 05 12 15 42 60 19 01 9A 9D 4A
X 00 04 02 03 0A 99 6F 7A 30 FF CA 00 05 12 15 42 60 19 01 9A 9D 4A
X 00 04 02 03 0A 99 6F 7A 30 FF CA 00 05 12 15 42 60 19 01 9A 9D 4A
X 00 04 02 03 0A 99 6F 7A 30 FF CA 00 05 12 15 42 60 19 01 9A 9D 4A
X 00 04 02 03 0A 99 6F 7A 30 FF CA 00 05 12 15 42 60 19 01 9A 9D 4A
X 00 04 02 03 0A 99 6F 7A 30 FF CA 00 00
```

***Figure B.3-12 Sample Mini-RF Load File***

### B.1.38 (MIRF-3) Mini-RF Command Timeline Files

```
Absolute Time, Command Mnemonic
2009-115-14:20:00, MRACTIVATE, BOARD=ALL
2009-115-14:21:10, MRNOOP
2009-115-14:21:15, MRCOLLECT, DURATION=0.5, BAND=S, OPTION=CAL_NOISE, APID=0x8C, INDEX=20, OPI=OPI, VCHAN_ATT=0, HCHAN_ATT=10, BURSTS=1, EXP_ID=3, RPF_FACT=2, PTP_INT=1, PTP_FACT=1, COMPRS=2
2009-115-14:21:16, MRCOLLECT, DURATION=0.5, BAND=S, OPTION=CAL_CHIRP, APID=140, INDEX=25, OPI=OPI, VCHAN_ATT=25, HCHAN_ATT=20, BURSTS=1, EXP_ID=3, RPF_FACT=2, PTP_INT=1, PTP_FACT=1, COMPRS=2
2009-115-14:21:17, MRCOLLECT, DURATION=0.5, BAND=S, OPTION=TX_ONLY, APID=140, INDEX=25, OPI=OPI, VCHAN_ATT=25, HCHAN_ATT=20, BURSTS=1, EXP_ID=3, RPF_FACT=2, PTP_INT=1, PTP_FACT=1, COMPRS=2
2009-115-14:21:18, MRCOLLECT, DURATION=0.5, BAND=S, OPTION=BIT_TX_LEAK, APID=140, INDEX=25, OPI=OPI, VCHAN_ATT=25, HCHAN_ATT=20, BURSTS=1, EXP_ID=3, RPF_FACT=2, PTP_INT=1, PTP_FACT=1, COMPRS=2
2009-115-14:21:19, MRCOLLECT, DURATION=240, BAND=S, OPTION=NORMAL, APID=0x8C, INDEX=20, OPI=OPI, VCHAN_ATT=25, HCHAN_ATT=10, BURSTS=2000, EXP_ID=3, RPF_FACT=2, PTP_INT=1, PTP_FACT=1, COMPRS=0x0C
2009-115-14:26:00, MRNOOP
2009-115-14:27:00, MRDEACTIVATE
```

***Figure B.3-13 Sample Mini-RF Command Timeline File***

## Mission Operations Center Products

### B.1.39 (MOC-7) Daily Command Load Report Sample

```
                           LRO ATS DAILY LOAD REPORT
                               HEADER INFORMATION

Mission:                                        LRO
MPS Version:                                    2.0
Command DB Version:                             2
Load File:                                      SC_2009077_0000_A_V01.ATS
Load Creation Time:                             2008-022-18:32:48
Load Start Time (First Cmd):                    2009-077-00:00:00
Load Stop Time (Last Cmd):                      2009-078-00:00:00
ATS Buffer                                      A
ATS Buffer Size (Bytes):                        80000
Load Uplink Size (Bytes); Includes Overhead: 16372
Load Data Size with No Fill (Bytes):            16244
Number of ATS Commands:                         274
Number of Critical Commands:                    0
Estimated Time of Uplink @ 4 Kbps (Minutes): 0.734
Number of Ka-Band Supports:                     2

                           LRO ATS DAILY LOAD REPORT
                                COMMAND SUMMARY

Subsystem/Instrument                            Number of Commands
--------------------                            ------------------
DL_COMMAND                                      12
SWCF_COMMANDS                                   26
SWEVS_COMMANDS                                  26
SWFM_COMMANDS                                   117
SWIM_COMMANDS                                   20
SWOM_COMMANDS                                   13
SWSC_COMMANDS                                   30
SWTO_COMMANDS                                   58

TOTAL                                           274

                           LRO ATS DAILY LOAD REPORT
                                  FILE INPUTS

Input File                                      File Name
----------                                      ---------
EVENT FILE                                      FDF13_2009077_2009084_N01.FDP
EVENT FILE                                      SLRO2009077d03O.075999999.FDP
CMD FILE                                        MPS_CMD_XML_20071206_FIXEDDLRE_MPSR2_V02.COMMAND

                           LRO ATS DAILY LOAD REPORT
                            ERROR/CONSTRAINT SUMMARY

No Errors

-------------- -------------- ---------------------- ------------------     --------------------------------     ----------------------
       ------------------------------------------------------------         -----------
SOURCE         COMMAND NUMBER COMMAND EXECUTION TIME COMMAND_MNEMONIC                                              PARENT_SEQUENCE_ID    COMMAND_DESCRIPTION
       CRITICALITY
                                                     SUBMNEMONIC_NAME       SUBMNEMONIC_VALUE

-------------- -------------- ---------------------- ------------------     --------------------------------     ----------------------
       ------------------------------------------------------------         -----------
SWIM_COMMANDS  1              2009-077-00:00:00      SWIMBASEFILENM                                                SWIMBASELEND_ACT      IM Set Base Filename

                                                        INST                LEND

                                                        BFILENAME           /SSR2/LEND/LEND_2009077_

SWIM_COMMANDS  2              2009-077-00:00:00      SWIMBASEFILENM                                                SWIMBASECRATER_ACT    IM Set Base Filename
```

***Figure B.4-1 Sample Daily Command Load Report File***

### B.1.40 (MOC-62) RTS Command Load Report Sample

```
                              LRO RTS LOAD REPORT
                               HEADER INFORMATION

Mission:                                       LRO
MPS Version:                                   2.0
Command DB Version:                            1
Load File:                                     SC_170_SWREOPENASN_V01.RTS
Load Creation Time:                            2008-018-14:35:55
RTS Slot:                                      170
RTS Buffer Size (Bytes):                       300
Load Data Size with No Fill (Bytes):           94
Number of RTS Commands:                        7
Number of Critical Commands:                   0
Estimated Time of Uplink @ 4 Kbps (Minutes):   0.02

                              LRO RTS LOAD REPORT
                                COMMAND SUMMARY

SUBSYSTEM/INSTRUMENT                           NUMBER_OF_COMMANDS
====================                           ==================
SWDS_COMMANDS                                  2
SWIM_COMMANDS                                  1

TOTAL                                          7

                              LRO RTS LOAD REPORT
                            ERROR/CONSTRAINT SUMMARY

ERROR/CONSTRINT                                EXPLANATION
===============                                ===========
No errors

==============      ===============     =================== =================    ======================================= ===========
COMMAND_NUMBER      RELATIVE_OFFSET     COMMAND_MNEMONIC                                COMMAND_DESCRIPTION                       CRITICALITY
                                        SUBMNEMONIC_NAME    SUBMNEMONIC_VALUE
==============      ===============     =================== =================    ======================================= ===========
1                   0                   LRO_SWDSDISABLEDEST                      DS disable destination
*                                       FILEID              1
2                   1000                LRO_SWDSENABLEDEST                       DS enable destination
*                                       FILEID              1
3                   0                   LRO_SWIMREOPENFILE                       IM Re-open Data Files (already enabled)
*                                       INST                DEBUG
4                   0                   LRO_SWIMREOPENFILE                       IM Re-open Data Files (already enabled)
*                                       INST                CRATER
5                   1000                LRO_SWIMREOPENFILE                       IM Re-open Data Files (already enabled)
*                                       INST                LEND
6                   0                   LRO_SWIMREOPENFILE                       IM Re-open Data Files (already enabled)
*                                       INST                LOLA
7                   0                   LRO_SWIMREOPENFILE                       IM Re-open Data Files (already enabled)
*                                       INST                LROC
```

***Figure B.4-2 Sample RTS Command Load Report File***

### B.1.41 (MOC-2) SCLK SPICE Clock Correlation File Sample

```
KPL/SCLK

LRO SCLK File
===========================================================================

   This file is a SPICE spacecraft clock (SCLK) kernel containing
   information required for converting LRO spacecraft on-board clock
   times to other time systems (UTC, ET, etc) and vice versa.


Production/History of this SCLK file
--------------------------------------------------------

   This file was generated by the NAIF utility program MAKCLK from the
   LRO SCLKvSCET file /export/home/whcalk/Desktop/clock_corr_data/LRO_SCLKvSCET (see the comment sections
   ``SCLKvSCET file SFDU Header'' and ``MAKCLK Setup file'' below for
   the SCLKvSCET SFDU header and MAKCLK setup file).


Usage
--------------------------------------------------------

   This file must be loaded into the user's SPICE-based application by
   a call to the SPICELIB FURNSH subroutine (furnsh_c in CSPICE,
   cspice_furnsh in ICY):

      CALL FURNSH  ( 'frame_kernel_name' )
      furnsh_c     ( "frame_kernel_name" );
      cspice_furnsh, "frame_kernel_name"

   in order to use the SPICELIB SCLK family of subroutines to convert
   LRO spacecraft on-board clock to ET and vice versa.


SCLK Format
--------------------------------------------------------

   The on-board clock, the conversion for which is provided by this
   SCLK file, consists of two fields:

      SSSSSSSSSS:FFFFF

   where:

      SSSSSSSSSS -- count of on-board seconds

      FFFFF      -- count of fractions of a second with one
                    fraction being 1/65536 of a second


References
--------------------------------------------------------

   1.   SCLK Required Reading Document

   2.   MAKCLK User's Guide Document

   3.   SFOC SCLKvSCET SIS Document


Inquiries
--------------------------------------------------------

   If you have any questions regarding this file contact

      Howard Calk, LRO Engineering (William.H.Calk@nasa.gov; 301-286-4843)


SCLKvSCET file SFDU Header
--------------------------------------------------------

     MISSION-NAME=LRO;
     SPACECRAFT-NAME=LRO;
     DATA-SET-ID=SCLK-SCET;
     FILE-NAME=lro_clkcor2009037_v00.tsc;
     PRODUCT-CREATION-TIME=2008-04-16T17:43:36;
     PRODUCT-VERSION-ID=02;
     PRODUCER-ID=SCT;
     APPLICABLE-START-TIME=1980-001T00:00:00;
```

***Figure B.4-3 Sample SCLK SPICE Clock Correlation File (page 1 of 2)***

```
     MISSION-NAME=LRO;
     SPACECRAFT-NAME=LRO;
     DATA-SET-ID=SCLK-SCET;
     FILE-NAME=LRO-SCLKSCET-EXAMPLE.00018;
     PRODUCT-CREATION-TIME=2008-05-01T17:45:50;
     PRODUCT-VERSION-ID=18;
     PRODUCER-ID=SCT;
     APPLICABLE-START-TIME=1980-001T00:00:00;
     APPLICABLE-STOP-TIME=2010-001T00:00:00;
     MISSION-ID=UNK;
     SPACECRAFT-ID=85;


MAKCLK Setup file
--------------------------------------------------------

     SCLKSCET_FILE          = /export/groups/ops/current/naif/sclk/input/LRO_SCLKvSCET
     OLD_SCLK_KERNEL        = /export/groups/naif/current/lro_template.tsc
     FILE_NAME              = /export/groups/naif/current/sclk/lro_clkcor_2008179_v00.tsc
     NAIF_SPACECRAFT_ID     = -85
     LEAPSECONDS_FILE       = /export/groups/naif/data/lsk/naif0008.tls
     PARTITION_TOLERANCE    = 656
     LOG_FILE               = /export/groups/ops/current/naif/sclk/input/LRO_SCLKvSCET.log


Kernel DATA
--------------------------------------------------------

\begindata


SCLK_KERNEL_ID           = ( @2008-06-27/20:37:49.00 )

SCLK_DATA_TYPE_85        = ( 1 )
SCLK01_TIME_SYSTEM_85    = ( 2 )
SCLK01_N_FIELDS_85       = ( 2 )
SCLK01_MODULI_85         = ( 4294967296 65536 )
SCLK01_OFFSETS_85        = ( 0 0 )
SCLK01_OUTPUT_DELIM_85   = ( 1 )

SCLK_PARTITION_START_85  = ( 0.0000000000000E+00 )

SCLK_PARTITION_END_85    = ( 2.8147497671065E+14 )

SCLK01_COEFFICIENTS_85   = (

    0.0000000000000E+00     3.1579264184000E+07     1.0000000000000E+00
    1.5485503275008E+13     2.6786929218400E+08     1.0000000000000E+00 )

\begintext
```

***Figure B.4-4 Sample SCLK SPICE Clock Correlation File (page 2 of 2)***

### B.1.42 (MOC-40) SPICE FK – Frame Kernel Sample

The following several examples provide more details into the LRO Frames kernel. The actual file is larger than can be adequately provided here. If the reader wishes to see the complete Frames kennel sample please contact the author

```
KPL/FK

LRO Frame Definitions Kernel -- DRAFT
===============================================================================

   This frame kernel contains the LRO spacecraft and science instrument
   frame definitions. This frame kernel also contains name - to - NAIF
   ID mappings for LRO science instruments and s/c structures (see the
   last section of the file.)


Version and Date
-------------------------------------------------------

   Version 0.2 draft -- May 06, 2008 -- Ralph Casasanta, Boris Semenov

      Modified HGA and SA IDs for the CK identifier to indicate we use
      the main object structure and not to the articulating booms.
      NOTE: Still does not contain a description for any of the frames.

   Version 0.1 draft -- November 14, 2007 -- Boris Semenov

      Added HGA and SA definitions and changed their IDs and
      relationship. Fixed frame ID that is a part of the keyword name
      in numerous fixed offset frames. Added name-ID mapping keywords.
      Minor revisions to the comments. Still does not contain a
      description for any of the frames.

   Version 0.0 draft -- November 14, 2007 -- Eric B. Holmes

      Initial Release. Contains Euler angles from LRO I-Kernel
      files. Does not contain a description for any of the frames.
```

```
LRO Frames
--------------------------------------------------------------------------------

   The following LRO frames are defined in this kernel file:

      Frame Name                     Relative to               Type     NAIF ID
   =========================    =========================    =======   =======

   Spacecraft Bus and Spacecraft Structure Frames:
   ------------------------------------------------
      LRO_SC_BUS                rel.to J2000                 CK        -85000

      LRO_HGA                   rel.to SC_BUS                CK        -85020

      LRO_SA                    rel.to SC_BUS                CK        -85030


      LRO_STARP                 rel.to SC_BUS                FIXED     -85010
      LRO_STARS                 rel.to SC_BUS                FIXED     -85011

      LRO_MIMU                  rel.to SC_BUS                FIXED     -85012

   Instrument Frames:
   ------------------
      LRO_CRATER                rel.to SC_BUS                FIXED     -85100

      LRO_DLRE                  rel.to SC_BUS                FIXED     -85200

      LRO_LAMP                  rel.to SC_BUS                FIXED     -85300

      LRO_LEND                  rel.to SC_BUS                FIXED     -85400

      LRO_LOLA                  rel.to SC_BUS                FIXED     -85500

      LRO_LROCNACA              rel.to SC_BUS                FIXED     -85600
      LRO_LROCNACB              rel.to SC_BUS                FIXED     -85610
      LRO_LROCWAC               rel.to SC_BUS                FIXED     -85620

      LRO_MINIRF                rel.to SC_BUS                FIXED     -85700
```

```
Diviner Lunar Radiometer Experiment Frame
-----------------------------------------

   The DLRE instrument frame is defined by the instrument design as
   follows:

      *  +X axis is [TBD];

      *  +Y axis is [TBD];

      *  +Z axis is [TBD];

      *  the origin of this frame is at [TBD];

   The orientation of this frame is fixed with respect to the
   spacecraft frame. The rotation angles provided in the frame
   definition below are extracted from [5].

   \begindata

      FRAME_LRO_DLRE              = -85200
      FRAME_-85200_NAME           = 'LRO_DLRE'
      FRAME_-85200_CLASS          = 4
      FRAME_-85200_CLASS_ID       = -85200
      FRAME_-85200_CENTER         = -85
      TKFRAME_-85200_SPEC         = 'ANGLES'
      TKFRAME_-85200_RELATIVE     = 'LRO_SC_BUS'
      TKFRAME_-85200_ANGLES       = ( 0.0, 0.0, 0.0 )
      TKFRAME_-85200_AXES         = ( 1,   2,   3   )
      TKFRAME_-85200_UNITS        = 'DEGREES'

   \begintext
```

***Figure B.4-5 Sample SPICE FK – Frame Kernel***

### B.1.43 (MOC-41- MOC-44) SPICE CK File Comments Sample

```
*****************************************************************

LRO Predicted Spacecraft Orientation CK File
===========================================================================


Orientation Data in the File
--------------------------------------------------------

     This file contains actual orientation data for the
     Lunar Reconnaissance Orbiter (LRO) spacecraft frame,
     'LRO_SPACECRAFT', relative to the Earth Mean Equator and Equinox of
     date, 'J2000', frame. The NAIF ID code for the
     'LRO_SPACECRAFT' frame is -85000.


Status
--------------------------------------------------------

     This file is a regular operational actual C-Kernel file created
     by the LRO AGS. It contains quaternions extracted from the telemtry
     downlinked from the spacecraft by the LRO MOC.


Pedigree
--------------------------------------------------------

     This CK file was generated by an automated process. This process
     extracts spacecraft orientation quaternions from the telemetry using the
     LRO MTASS and writes them to a CK file using MSOPCK program.


Approximate Time Coverage
--------------------------------------------------------

     This file is a type 3 CK file (segment) which provides linear
     interpolation between orientation data points extracted from telemetry.
     Sunch interpolation is not applied to the whole coverage of
     a segment but only inside intervals where enough orientation
     telemetry data were available and orientation data points were close to
     each other in time for such interpolation to make sense.

     A table containing the complete list of valid interpolation intervals
     in each segment of the file is provided at the end of these comments.

     The start time and stop time of the total coverage for every segment
     in the file are given in the header of the interval table for that segment.


Usage Note
--------------------------------------------------------

     In order to use this file an LRO SCLK file, containing
     coefficients mapping LRO on-board time to ET, and the standard LSK file,
     providing UTC to ET mapping, must be loaded into a user program.


Contacts
--------------------------------------------------------

     If you have any question regarding this data contact the LRO MOC:

        Richard Saylor
        301-286-1354
        richard.s.saylor@nasa.gov

********************************************************************************
MSOPCK SETUP FILE: D:\LRO_FDS\Data\Utilities\ck\setupdef_25-Sep-2008.txt
********************************************************************************
\begindata
```

***Figure B.4-6 Sample SPICE CK File Comments (Page 1 of 2)***

```
LSK_FILE_NAME = 'D:\LRO_FDS\Data\SupportFiles\naif0009.tls.pc'
SCLK_FILE_NAME = 'D:\LRO_FDS\Data\SupportFiles\lro_clkcor2008300_v00.tsc'
INTERNAL_FILE_NAME = 'LRO BODY ATTITUDE - DEFINITIVE FROM AGS'
CK_TYPE = 3
CK_SEGMENT_ID = 'LRO BODY ATTITUDE - SEGMENT SIM 29'
INSTRUMENT_ID = -85000
REFERENCE_FRAME_NAME = 'J2000'
ANGULAR_RATE_PRESENT = 'MAKE UP/NO AVERAGING'
MAXIMUM_VALID_INTERVAL = 65
INPUT_TIME_TYPE = 'UTC'
INPUT_DATA_TYPE = 'MSOP QUATERNIONS'
QUATERNION_NORM_ERROR = 0.00010
COMMENTS_FILE_NAME = 'D:\LRO_FDS\Data\SupportFiles\lro_comments_defin.txt'
PRODUCER_ID = 'LRO AGS'
\begintext

*****************************************************************************
RUN-TIME OBTAINED META INFORMATION:
*****************************************************************************

PRODUCT_CREATION_TIME = 2000-09-25T19:17:05
START_TIME = 2009-09-24T05:53:27.214
STOP_TIME = 2009-09-24T22:06:06.984

*****************************************************************************
INTERPOLATION INTERVALS IN THE FILE SEGMENTS:
*****************************************************************************

SEG.SUMMARY: ID -85000, COVERG: 2009-09-24T05:53:27.214 2009-09-24T17:48:34.785
--------------------------------------------------------------------------------
2009-09-24T05:53:27.214 2009-09-24T07:05:33.816
2009-09-24T12:00:00.085 2009-09-24T12:01:38.289
2009-09-24T13:29:00.183 2009-09-24T17:48:34.785

SEG.SUMMARY: ID -85000, COVERG: 2009-09-24T17:48:34.785 2009-09-24T22:06:06.984
--------------------------------------------------------------------------------
2009-09-24T17:48:34.785 2009-09-24T22:06:06.984

*****************************************************************************
```

***Figure B.4-6 Sample SPICE CK File Comments (Page 2 of 2)***

### B.1.44 (MOC-30) Mini-RF Operations Opportunity Sample

ADD,2009-062-14:00:00,2009-062-14:30:00

DELETE,2009-063-14:00:00,2009-062-14:30:00

ADD,2009-063-14:15:00,2009-063-14:25:00

ADD,2009-064-14:00:00,2009-062-14:30:00

***Figure B.4-7 Sample Mini- Operations Opportunity File***

### B.1.45 (MOC-46 thru MOC-60) Meta-Summary Report Sample

The Meta-Summary Report is valid for the set of science instrument housekeeping and measurement data products that the WS1-SDPS element delivers to the MOC and that the MOC then distributes to the various science centers. The following sets of figures provide the various representation of the Meta Summary Reports.

Transaction ID:: 0.24_1
Source file name:: /export/dyer/files/core
Destination file name:: /export/dyer/dest/d_core
Transaction started:: 2007-213-155409
Class:: 2
File size:: 4730
Temp file name:: /home/dyer/itos/rh/test/output/cfdp/tempfiles/temp00075
Transaction completed:: 2007-213-155410
CFDP File checksum:: 2431491781
MD5 File checksum:: bcbdf2dfb48fe5a858319bfabed7e170
File transfer status:: Successful
File complete percentage:: 100.0000

***Figure B.4-8 Sample Meta-Summary Report (No Gaps)***

Transaction ID:: 0.23_1
Source file name:: /export/dyer/files/f550M
Destination file name:: /export/dyer/dest/d_f550M
Transaction started:: 2007-213-202627
Class:: 2
File size:: 576716800
Temp file name:: /home/dyer/itos/sunk/test/output/cfdp/tempfiles/temp00001
Transaction completed::2007-213-20:26:42
CFDP File checksum:: 2431491781
MD5 File checksum:: bcbdf2dfb48fe5a858319bfabed7e170
File transfer status:: Unsuccessful, cancel requested.
File complete percentage:: 86.3637
Number of gaps in file:: 2
File completion map:: missing bytes = 1742, offset = 485849026
File completion map:: missing bytes = 78640848, offset = 496217410

***Figure B.4-9 Sample Meta-Summary Report (Missing Data Segments)***

Transaction ID:: 0.23_1
Source file name:: /export/dyer/files/f550M
Destination file name:: /export/dyer/dest/d_f550M
Transaction started:: 2007-213-202627
Class:: 2
File size:: 576716800
Temp file name:: /home/dyer/itos/sunk/test/output/cfdp/tempfiles/temp00001
Transaction completed:: 2007-213-202642
CFDP File checksum:: 2431491781
MD5 File checksum:: bcbdf2dfb48fe5a858319bfabed7e170
File transfer status:: Unsuccessful, cancel requested.
File complete percentage:: 86.3637
Number of gaps in file:: 2
File completion map:: missing bytes = 1742, offset = 485849026
File completion map:: missing bytes = 78640848, offset = 496217410
Processed File size:: 498074150
Processed File MD5 checksum:: bcbdf2dfb48fe5a858319bf3fae4f321
Processed complete percentage:: 86.3637
File deletion map:: deleted bytes = 1762, offset = 485849016
File deletion map:: deleted bytes = 78640888, offset = 496217370

***Figure B.4-10 Sample Meta-Summary Report (Deleted Data Segments)***

Transaction ID:: 0.24_1
Source file name:: /export/dyer/files/core
Destination file name:: /export/dyer/dest/d_core
Transaction started:: 2010-056-155409
Class:: 2
File size:: 4730
Temp file name:: /home/dyer/itos/rh/test/output/cfdp/tempfiles/temp00075
Transaction completed:: 2010-056-155412
CFDP File checksum:: 2431491781
MD5 File checksum:: bcbdf2dfb48fe5a858319bfabed7e170
File transfer status:: Successful
File complete percentage:: 100.0000
File size no fill: 4600
MD5 File Checksum no fill:: bcbdf2dfb48fe5a858319bfabed7c200

***Figure B.4-11 Sample LROC Science Meta-Summary Report (No Missing Data Segments)***

B.1.46 (MOC-63) Propulsion System Data File Sample

ASCII Report
Input Definition File: C:\itps\Data\IDF\MOC63_PROPDATA.idf
Report Date: 04/07/2008
DMDB file(s): C:\itps\Data\dmdb\LRODB_033108.dmdb
Decom start: 2008/303/10:15:00
Decom stop: 2008/303/13:00:00

| Year | S/C Time | CDHEPRESSTNKTEMP | CDLPRXDCR |
|---|---|---|---|
| 2008 | 303-10:15:00.387 | 2290 | -0.35021 |
| 2008 | 303-10:15:02.387 | 2290 | -0.264795 |
| 2008 | 303-10:15:04.387 | 2291 | -0.35021 |
| 2008 | 303-10:15:06.387 | 2290 | -0.35021 |
| 2008 | 303-10:15:08.387 | 2290 | -0.264795 |
| 2008 | 303-10:15:10.387 | 2289 | -0.264795 |
| 2008 | 303-10:15:12.387 | 2290 | -0.35021 |
| 2008 | 303-10:15:14.387 | 2291 | -0.264795 |
| 2008 | 303-10:15:16.387 | 2290 | -0.264795 |
| 2008 | 303-10:15:18.387 | 2290 | -0.35021 |
| 2008 | 303-10:15:20.387 | 2291 | -0.264795 |
| 2008 | 303-10:15:22.387 | 2291 | -0.264795 |
| 2008 | 303-10:15:24.386 | 2290 | -0.264795 |
| 2008 | 303-10:15:26.387 | 2289 | -0.264795 |
| 2008 | 303-10:15:28.387 | 2291 | -0.264795 |
| 2008 | 303-10:15:30.387 | 2290 | -0.264795 |
| 2008 | 303-10:15:32.387 | 2290 | -0.264795 |
| 2008 | 303-10:15:34.387 | 2290 | -0.35021 |
| 2008 | 303-10:15:36.387 | 2290 | -0.264795 |
| 2008 | 303-10:15:38.387 | 2290 | -0.35021 |
| 2008 | 303-10:15:40.387 | 2290 | -0.35021 |
| 2008 | 303-10:15:42.387 | 2291 | -0.35021 |
| 2008 | 303-10:15:44.387 | 2291 | -0.264795 |

***Figure B.4-12 Sample Propulsion System Data File***

### B.1.47 (MOC-65) Definitive Spacecraft Body Frame Attitude File

```
C      Spacecraft_Body_Attitude_File
C      Satellite_ID LRO
C      StartTime 2009 077    0.000
C      StopTime 2009 078    0.000
C      CoordinateFrame MJ2000
C YYYY DDD  SSSSS.SSS  Component_1(q1)  Component_2(q2)  Component_3(q3)  Component_4(q4)
2009 077    0.000 0.14162258260076 0.69448852253506 0.14179631907482 0.69103005727782
2009 077   60.000 0.14550229481938 0.67503262855665 0.13780592750426 0.71004898347289
2009 077  120.000 0.14927210288513 0.65505225744127 0.13371031800777 0.72852311574830
2009 077  180.000 0.15293221511306 0.63456213491401 0.12951635025360 0.74643696956339
2009 077  240.000 0.15647792940289 0.61357816522457 0.12522528606863 0.76377687874042
2009 077  300.000 0.15990109124417 0.59211743819900 0.12083385318790 0.78053043523193
2009 077  360.000 0.16319771186450 0.57019682517940 0.11634367055144 0.79668452835495
2009 077  420.000 0.16636727219537 0.54783264998274 0.11176085648371 0.81222584871032
2009 077  480.000 0.16940846521380 0.52504174729127 0.10709061362663 0.82714178711289
2009 077  540.000 0.17231960896500 0.50184126994758 0.10233759036915 0.84142041200638
2009 077  600.000 0.17509869213434 0.47824887853210 0.09750595194378 0.85505031871298
2009 077  660.000 0.17774297493537 0.45428289551004 0.09259860074252 0.86802072835196
2009 077  720.000 0.18025027375009 0.42996174028738 0.08761917495865 0.88032131683927
2009 077  780.000 0.18261823824457 0.40530437548894 0.08257089004223 0.89194225731692
2009 077  840.000 0.18484546398546 0.38032964026980 0.07745872815774 0.90287411337818
...
2009 077 86340.000 0.01664355144104 -0.97649799529991 -0.19872492062869 0.08175000484285
2009 078    0.000 0.01111257185095 -0.97839109106203 -0.19910965609696 0.05461436190471
```

***Figure B.4-13 Sample Definitive Spacecraft Body Frame Attitude File***

## B.1.48 (MOC-66) Spacecraft HGA Motion File

```
C      HGA_Motion_File
C      Satellite_ID LRO
C      StartTime 2009 077    0.000
C      StopTime 2009 078    0.000
C      CoordinateFrame MJ2000
C YYYY DDD  SSSSS.SSS  X_Direction  Y_Direction  Z_Direction
2009 077     0.000      0.18915604      0.87204921      0.45138694
2009 077    60.000      0.18900540      0.87196680      0.45160920
2009 077   120.000      0.18884157      0.87188689      0.45183196
2009 077   180.000      0.18866461      0.87180981      0.45205455
2009 077   240.000      0.18847464      0.87173589      0.45227629
2009 077   300.000      0.18827180      0.87166544      0.45249650
2009 077   360.000      0.18805627      0.87159877      0.45271451
2009 077   420.000      0.18782828      0.87153615      0.45292966
2009 077   480.000      0.18758808      0.87147787      0.45314129
2009 077   540.000      0.18733598      0.87142420      0.45334875
2009 077   600.000      0.18707232      0.87137539      0.45355141
2009 077   660.000      0.18679747      0.87133166      0.45374866
2009 077   720.000      0.18651183      0.87129324      0.45393989
2009 077   780.000      0.18621585      0.87126034      0.45412451
2009 077   840.000      0.18590999      0.87123315      0.45430197
...
2009 077 86340.000     -0.02139602      0.89652109      0.44248407
2009 078     0.000     -0.02129603      0.89654289      0.44244471
```

***Figure B.4-14 Sample Spacecraft HGA Motion File***

## B.1.49 (MOC-67) Spacecraft Solar Array Motion File

```
C      Spacecraft_Solar_Array_Motion_File
C      Satellite_ID LRO
C      StartTime 2009 077    0.000
C      StopTime 2009 078    0.000
C      CoordinateFrame MJ2000
C YYYY DDD  SSSSS.SSS  X_Direction  Y_Direction  Z_Direction
2009 077    0.000       0.99908734     -0.03925970      -0.01682746
2009 077   60.000       0.99908786     -0.03924884      -0.01682205
2009 077  120.000       0.99908837     -0.03923799      -0.01681665
2009 077  180.000       0.99908889     -0.03922713      -0.01681125
2009 077  240.000       0.99908941     -0.03921628      -0.01680585
2009 077  300.000       0.99908993     -0.03920542      -0.01680046
2009 077  360.000       0.99909044     -0.03919456      -0.01679509
2009 077  420.000       0.99909096     -0.03918370      -0.01678972
2009 077  480.000       0.99909147     -0.03917283      -0.01678437
2009 077  540.000       0.99909199     -0.03916196      -0.01677903
2009 077  600.000       0.99909251     -0.03915108      -0.01677371
2009 077  660.000       0.99909302     -0.03914020      -0.01676840
2009 077  720.000       0.99909354     -0.03912931      -0.01676312
2009 077  780.000       0.99909405     -0.03911841      -0.01675786
2009 077  840.000       0.99909457     -0.03910750      -0.01675262
...
2009 077 86340.000       0.99967882      -0.02330287      -0.00996166
2009 078    0.000       0.99967912     -0.02329176      -0.00995698
```

***Figure B.4-15 Sample Spacecraft Solar Array Motion File***

## B.1.50 (MOC-68) OBC Generated Attitude Data File

```
ASCII Report, , , , , , , , , , , , , , , , , ,
Input Definition File:  C:\itps\Data\IDF\MOC68_240.idf, , , , , , , , , , , , , , , ,
Report Date:  04/07/2008, , , , , , , , , , , , , , , , ,
DMDB file(s): C:\itps\Data\dmdb\LRODB_033108.dmdb , , , , , , , , , , , , , , , ,
Decom start:  2008/303/10:15:00, , , , , , , , , , , , , , , ,
Decom stop:  2008/303/13:00:00, , , , , , , , , , , , , , , ,
, , , , , , , , , , , , , , , , , ,
, , , , , , , , , , , , , , , , , ,
Year, S/C Time, SWACATTQ1, SWACATTQ2, SWACATTQ3, SWACATTQ4, SWACTARGETQ1, SWACTARGETQ2, SWACTARGETQ3, SWACTARGETQ4, SWACUSEDATTQSRC, SWACSELTQTYPE,
SWACATTERR1, SWACATTERR2, SWACATTERR3, SWACSELRATE1, SWACSELRATE2, SWACSELRATE3, SWACRATEERRMAG, SWACATTERRMAG
2008, 303-10:15:00.166, 0.259326, 0.064751, -0.451063, 0.851528, 0.259333, 0.064755, -0.45106, 0.851527, 2, 1, 0.000009, 0.000015, 0.000003, -0.000073, -0.000079, -0.000073, 0.00013, 0.000018
2008, 303-10:15:01.167, 0.259325, 0.06475, -0.451065, 0.851527, 0.259333, 0.064755, -0.45106, 0.851527, 2, 1, 0.000009, 0.000019, 0.000007, -0.000021, -0.000025, -0.000021, 0.000039, 0.000022
2008, 303-10:15:02.167, 0.259342, 0.064752, -0.451054, 0.851528, 0.259333, 0.064755, -0.45106, 0.851527, 2, 1, -0.000017, -0.000007, -0.000014, -0.000075, -0.000075, -0.000079, 0.000132, 0.000023
2008, 303-10:15:03.167, 0.259337, 0.064751, -0.45106, 0.851526, 0.259333, 0.064755, -0.45106, 0.851527, 2, 1, -0.000011, 0.000002, -0.000001, -0.000008, -0.000019, -0.000019, 0.000028, 0.000011
2008, 303-10:15:04.166, 0.259342, 0.064752, -0.451058, 0.851525, 0.259333, 0.064755, -0.45106, 0.851527, 2, 1, -0.000019, -0.000006, -0.000004, 0.000042, 0.000042, 0.000038, 0.00007, 0.00002
2008, 303-10:15:05.167, 0.259365, 0.064754, -0.451043, 0.851526, 0.259333, 0.064755, -0.45106, 0.851527, 2, 1, -0.000054, -0.000036, -0.000032, 0.000017, 0.00001, 0.000012, 0.000023, 0.000072
2008, 303-10:15:06.167, 0.259354, 0.064751, -0.451055, 0.851524, 0.259333, 0.064755, -0.45106, 0.851527, 2, 1, -0.000041, -0.000016, -0.000011, 0.000029, 0.000019, 0.000019, 0.000039, 0.000045
2008, 303-10:15:07.164, 0.259345, 0.064749, -0.451064, 0.851522, 0.259333, 0.064755, -0.45106, 0.851527, 2, 1, -0.000029, -2.56E-07, 0.000007, -0.000056, -0.000063, -0.00006, 0.000104, 0.000029
2008, 303-10:15:08.167, 0.259355, 0.064749, -0.451058, 0.851522, 0.259333, 0.064755, -0.45106, 0.851527, 2, 1, -0.000044, -0.000012, -0.000004, -0.000008, -0.000012, -0.000012, 0.00002, 0.000046
2008, 303-10:15:09.167, 0.259372, 0.064751, -0.451048, 0.851522, 0.259333, 0.064755, -0.45106, 0.851527, 2, 1, -0.000072, -0.000036, -0.000023, 0.000048, 0.000044, 0.00004, 0.000076, 0.000084
2008, 303-10:15:10.167, 0.259373, 0.064749, -0.451051, 0.85152, 0.259333, 0.064755, -0.45106, 0.851527, 2, 1, -0.000076, -0.000033, -0.000017, 0.000056, 0.00005, 0.000046, 0.000088, 0.000084
2008, 303-10:15:11.167, 0.259374, 0.064748, -0.451054, 0.851518, 0.259333, 0.064755, -0.45106, 0.851527, 2, 1, -0.00008, -0.000029, -0.000012, -0.000065, -0.000075, -0.000075, 0.000124, 0.000086
2008, 303-10:15:12.166, 0.259394, 0.064747, -0.45104, 0.851519, 0.259333, 0.064755, -0.45106, 0.851527, 2, 1, -0.000113, -0.000053, -0.000039, -0.000002, -0.00001, -0.000012, 0.000016, 0.000131
2008, 303-10:15:13.167, 0.259396, 0.064744, -0.451043, 0.851518, 0.259333, 0.064755, -0.45106, 0.851527, 2, 1, -0.00012, -0.000048, -0.000035, 0.000025, 0.000021, 0.000015, 0.000036, 0.000134
2008, 303-10:15:14.167, 0.259416, 0.064744, -0.451029, 0.851519, 0.259333, 0.064755, -0.45106, 0.851527, 2, 1, -0.000153, -0.000073, -0.000061, -0.000029, -0.000038, -0.00004, 0.000062, 0.00018
2008, 303-10:15:15.167, 0.259429, 0.064743, -0.451023, 0.851518, 0.259333, 0.064755, -0.45106, 0.851527, 2, 1, -0.000174, -0.000087, -0.000074, 0.000044, 0.000044, 0.000044, 0.000076, 0.000208
2008, 303-10:15:16.167, 0.259435, 0.064739, -0.45102, 0.851518, 0.259333, 0.064755, -0.45106, 0.851527, 2, 1, -0.000187, -0.000087, -0.00008, 0.00005, 0.00004, 0.000046, 0.000079, 0.000221
2008, 303-10:15:17.167, 0.259448, 0.064737, -0.45101, 0.85152, 0.259333, 0.064755, -0.45106, 0.851527, 2, 1, -0.00021, -0.0001, -0.000103, -0.000002, -0.000012, 0.000002, 0.000013, 0.000254
2008, 303-10:15:18.167, 0.259417, 0.06473, -0.451033, 0.851518, 0.259333, 0.064755, -0.45106, 0.851527, 2, 1, -0.000167, -0.00005, -0.000062, -0.000015, -0.000015, -0.000004, 0.000021, 0.000185
2008, 303-10:15:19.167, 0.259413, 0.064727, -0.451035, 0.851518, 0.259333, 0.064755, -0.45106, 0.851527, 2, 1, -0.000163, -0.00004, -0.000058, -0.000046, -0.00005, -0.000046, 0.000082, 0.000178
2008, 303-10:15:20.167, 0.259406, 0.064725, -0.451042, 0.851516, 0.259333, 0.064755, -0.45106, 0.851527, 2, 1, -0.000154, -0.000025, -0.000045, -0.000144, -0.000144, -0.000144, 0.000249, 0.000162
2008, 303-10:15:21.166, 0.259425, 0.064725, -0.451031, 0.851516, 0.259333, 0.064755, -0.45106, 0.851527, 2, 1, -0.000186, -0.00005, -0.000067, 0.000015, 0.00001, 0.000004, 0.000018, 0.000203
2008, 303-10:15:22.167, 0.259437, 0.064727, -0.451025, 0.851516, 0.259333, 0.064755, -0.45106, 0.851527, 2, 1, -0.000203, -0.000066, -0.000076, 0.000044, 0.00004, 0.000029, 0.000066, 0.000227
2008, 303-10:15:23.167, 0.259433, 0.064728, -0.451027, 0.851516, 0.259333, 0.064755, -0.45106, 0.851527, 2, 1, -0.000197, -0.000063, -0.000072, -0.000012, -0.000008, -0.000008, 0.000017, 0.000219
2008, 303-10:15:24.167, 0.259429, 0.064728, -0.451028, 0.851517, 0.259333, 0.064755, -0.45106, 0.851527, 2, 1, -0.000188, -0.000059, -0.000072, 0.000023, 0.000029, 0.000035, 0.000051, 0.00021
2008, 303-10:15:25.166, 0.259403, 0.064726, -0.451042, 0.851517, 0.259333, 0.064755, -0.45106, 0.851527, 2, 1, -0.000147, -0.000025, -0.000046, -0.000038, -0.000031, -0.000023, 0.000054, 0.000156
2008, 303-10:15:26.167, 0.259391, 0.064726, -0.451047, 0.851518, 0.259333, 0.064755, -0.45106, 0.851527, 2, 1, -0.000129, -0.000012, -0.000036, 0.000021, 0.000027, 0.000031, 0.000046, 0.000134
2008, 303-10:15:27.164, 0.259366, 0.064724, -0.451064, 0.851517, 0.259333, 0.064755, -0.45106, 0.851527, 2, 1, -0.000091, 0.000024, -0.000004, -0.000015, -0.00001, -0.000015, 0.000023, 0.000094
```

***Figure B.4-16 Sample OBC Generated Attitude Data File***

### B.1.51 (MOC-72) LRO Thruster Data File

```
ASCII Report
Input Definition File: C:\itps\Data\IDF\MOC72_THRUSTER.idf
Report Date: 04/07/2008
DMDB file(s): C:\itps\Data\dmdb\LRODB_033108.dmdb
Decom start: 2008/303/10:15:00
Decom stop: 2008/303/13:00:00


Year, S/C Time, SWACDHTIMEINMODE, SWACDVTIMEINMODE, SWACDHSYSANGMOMERRMAG, SWACDVSENTPULSEAT1,
SWACDVSENTPULSEAT2, SWACDVSENTPULSEAT3, SWACDVSENTPULSEAT4, SWACDVSENTPULSEAT5, SWACDVSENTPULSEAT6,
SWACDVSENTPULSEAT7, SWACDVSENTPULSEAT8, SWACDVSENTPULSENT1, SWACDVSENTPULSENT2, SWACDVSENTPULSENT3,
SWACDVSENTPULSENT4, SWACDVTHRONTIMEAT1, SWACDVTHRONTIMEAT2, SWACDVTHRONTIMEAT3, SWACDVTHRONTIMEAT4,
SWACDVTHRONTIMEAT5, SWACDVTHRONTIMEAT6, SWACDVTHRONTIMEAT7, SWACDVTHRONTIMEAT8, SWACDVTHRONTIMENT1,
SWACDVTHRONTIMENT2, SWACDVTHRONTIMENT3, SWACDVTHRONTIMENT4,
2008, 303-10:15:00.166, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
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2008, 303-10:28:36.167, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
2008, 303-10:28:37.167, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
2008, 303-10:28:38.167, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
2008, 303-10:28:39.167, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
2008, 303-10:28:40.167, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
2008, 303-10:28:41.167, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
2008, 303-10:28:42.167, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
2008, 303-10:28:43.167, 0, 0.6, 0, 200, 0, 200, 0, 92, 0, 200, 0, 0, 0, 0, 0, 0.6, 0, 0.6, 0, 0.584, 0, 0.6, 0, 0, 0, 0, 0,
2008, 303-10:28:44.167, 0, 1.6, 0, 92, 0, 90, 0, 81, 0, 200, 0, 0, 0, 0, 0, 1.542, 0, 1.514, 0, 1.422, 0, 1.6, 0, 0, 0, 0, 0,
2008, 303-10:28:45.167, 0, 2.6, 0, 92, 0, 90, 0, 82, 0, 200, 0, 0, 0, 0, 0, 2.462, 0, 2.414, 0, 2.23, 0, 2.6, 0, 0, 0, 0, 0,
2008, 303-10:28:46.167, 0, 3.6, 0, 93, 0, 91, 0, 83, 0, 200, 0, 0, 0, 0, 0, 3.388, 0, 3.324, 0, 3.056, 0, 3.6, 0, 0, 0, 0, 0,
2008, 303-10:28:47.164, 0, 4.6, 0, 93, 0, 91, 0, 83, 0, 200, 0, 0, 0, 0, 0, 4.318, 0, 4.234, 0, 3.886, 0, 4.6, 0, 0, 0, 0, 0,
2008, 303-10:28:48.167, 0, 5.6, 0, 93, 0, 92, 0, 84, 0, 200, 0, 0, 0, 0, 0, 5.248, 0, 5.148, 0, 4.726, 0, 5.6, 0, 0, 0, 0, 0,
2008, 303-10:28:49.167, 0, 6.6, 0, 93, 0, 92, 0, 85, 0, 200, 0, 0, 0, 0, 0, 6.178, 0, 6.068, 0, 5.57, 0, 6.6, 0, 0, 0, 0, 0,
2008, 303-10:28:50.167, 0, 7.6, 0, 94, 0, 92, 0, 85, 0, 200, 0, 0, 0, 0, 0, 7.116, 0, 6.988, 0, 6.42, 0, 7.6, 0, 0, 0, 0, 0,
2008, 303-10:28:51.167, 0, 8.6, 0, 94, 0, 93, 0, 86, 0, 200, 0, 0, 0, 0, 0, 8.056, 0, 7.912, 0, 7.278, 0, 8.6, 0, 0, 0, 0, 0,
2008, 303-10:28:52.167, 0, 9.6, 0, 94, 0, 93, 0, 87, 0, 200, 0, 0, 0, 0, 0, 8.996, 0, 8.842, 0, 8.142, 0, 9.6, 0, 0, 0, 0, 0,
2008, 303-10:28:53.166, 0, 10.6, 0, 94, 0, 93, 0, 87, 0, 200, 0, 0, 0, 0, 0, 9.936, 0, 9.772, 0, 9.012, 0, 10.6, 0, 0, 0, 0, 0,
2008, 303-10:28:54.167, 0, 11.6, 0, 200, 0, 94, 0, 88, 0, 200, 0, 0, 0, 0, 0, 10.924, 0, 10.708, 0, 9.89, 0, 11.6, 0, 0, 0, 0, 0,
2008, 303-10:28:55.167, 0, 12.6, 0, 200, 0, 94, 0, 89, 0, 200, 0, 0, 0, 0, 0, 11.924, 0, 11.648, 0, 10.772, 0, 12.6, 0, 0, 0, 0, 0,
2008, 303-10:28:56.167, 0, 13.6, 0, 200, 0, 94, 0, 89, 0, 200, 0, 0, 0, 0, 0, 12.924, 0, 12.588, 0, 11.662, 0, 13.6, 0, 0, 0, 0, 0,
2008, 303-10:28:57.166, 0, 14.6, 0, 200, 0, 200, 0, 90, 0, 200, 0, 0, 0, 0, 0, 13.924, 0, 13.576, 0, 12.56, 0, 14.6, 0, 0, 0, 0, 0,
2008, 303-10:28:58.167, 0, 15.6, 0, 200, 0, 200, 0, 91, 0, 200, 0, 0, 0, 0, 0, 14.924, 0, 14.576, 0, 13.464, 0, 15.6, 0, 0, 0, 0, 0,
```

***Figure B.4-17 Sample LRO Thruster Data File***

B.1.52 (MOC-74) Predictive LRO Spacecraft Body Attitude File

```
                         MOC74_2008320_20083287_v01.a
stk.v.7.0

BEGIN Attitude


NumberofAttitudePoints    129601

ScenarioEpoch         24 Nov 2008 10:20:00.0
CentralBody Earth
CoordinateAxes J2000
AttitudeTimeQuaternions
0.000000 0.239141 0.098590 -0.224468 0.939524
2.000000 0.239125 0.098579 -0.224470 0.939529
4.000000 0.239109 0.098568 -0.224472 0.939534
6.000000 0.239093 0.098556 -0.224474 0.939538
8.000000 0.239077 0.098545 -0.224476 0.939543
10.000000 0.239061 0.098534 -0.224478 0.939548
12.000000 0.239045 0.098523 -0.224480 0.939553
14.000000 0.239029 0.098512 -0.224481 0.939558
16.000000 0.239013 0.098501 -0.224483 0.939562
18.000000 0.238997 0.098490 -0.224485 0.939567
20.000000 0.238981 0.098478 -0.224487 0.939572

....

259196.000000 0.227984 0.046795 -0.208213 0.949990
259198.000000 0.227984 0.046795 -0.208213 0.949990
259200.000000 0.227984 0.046795 -0.208212 0.949990
END Attitude
```

***Figure B.4-18 Sample Predictive LRO Spacecraft Body Attitude File***

### B.1.53 (MOC-64) Laser Ranging Go-NOGO Flag Sample File

LRO 0911401 0059 5 nogo maneuver

OR

LRO 0911401 0059 5 go

***Figure B.4-19 Sample Laser Ranging Go-NOGO Flag File***

B.1.54 (MOC-69) LRO-Provided Separation Data Sample File

# MOC-69 product Best Estimated Launch Vehicle Separation Data
# 25 April 2009, 1441 GMT
#
Date of launch vehicle separation = 04242009 (MMDDYYYY)
Time of launch vehicle separation = 123516 (HHMMSS)
Semi-major Axis = 123456.54321(Km)
Eccentricity = 0.2346(Unitless)
Inclination = 93.2345(Degrees)
Right Ascension of Ascending Node = 270.0345 (Degrees)
Argument of perigee = 123.8765 (Degrees)
True Anomaly = 88.2345 (Degrees)
# Orbiter Separation Data (S/C Body Frame)
Separation Rate X Axis = 2.3456 (m/sec)
Separation Rate Y Axis = 0.09356 (m/sec)
Separation Rate Z Axis = 0.00009 (m/sec)
Sun Vector X Axis = 0.3435 (Unitless)
Sun Vector Y Axis = 0.889 (Unitless)
Sun Vector Z Axis = 0.302798 (Unitless)

***Figure B.4-20 Sample LRO-Provided Separation Data File***

## B.1.55 (MOC-71) Data Recorder Model Report Sample File

MOC-71 Data Recorder Model

```
Instruments
-----------
VR1: LROC/MINI-RF
VR2: CRaTER/DLRE/LAMP/LEND/LOLA
VR3: Spacecraft Houskeeping

Capacity
--------
VR1: 390.32 Gbits
VR2:  14.00 Gbits
VR3:   8.00 Gbits
```

| WOTIS Ka Band Passes | MINUTES | RATE(Mbps) |
|---|---|---|
| 2009267.190900 - 2009267.194000 | 31.00 | 100 |
| 2009268.111548 - 2009268.115704 | 41.27 | 100 |
| 2009268.130453 - 2009268.135148 | 46.92 | 100 |
| 2009268.145936 - 2009268.154437 | 45.02 | 100 |
| 2009269.122146 - 2009269.130440 | 42.90 | 100 |
| 2009269.141314 - 2009269.145740 | 44.43 | 100 |
| 2009269.160700 - 2009269.165110 | 44.17 | 100 |
| 2009269.175810 - 2009269.183855 | 40.75 | 100 |

```
Average LROC NAC Image Size:     2.3042 Gbits
Average LROC WAC Image Size:     0.0000 Gbits

Size of last SSR1 Telemetry:   363.3926 Gbits
Time of last SSR1 Telemetry:   2009077.195705
```

| | | Commanding (Gbits) | | | | Available Memory (Gbits) | | | |
|---|---|---|---|---|---|---|---|---|---|
| ASC. Node Time | Orbit Number | MRF | LROCNAC | LROCWAC | KBandDL(Gbits) | LROC IMAGES AVALABLE | VR1(390.32) | VR2(14.00) | VR3(8.00) |
| 2009267.002441 | 2570 | - | - | - | - | 157 | 363.3926 ( 93%) | - | - |
| 2009267.021744 | 2571 | - | 23.3948 | - | - | 147 | 339.9978 ( 87%) | - | - |
| 2009267.041048 | 2572 | - | 23.3948 | - | - | 137 | 316.6029 ( 81%) | - | - |
| 2009267.060351 | 2573 | - | 16.3764 | - | - | 130 | 300.2266 ( 76%) | - | - |
| 2009267.075654 | 2574 | - | 25.7343 | - | - | 119 | 274.4923 ( 70%) | - | - |
| 2009267.094958 | 2575 | - | 21.0553 | - | - | 109 | 253.4369 ( 64%) | - | - |
| 2009267.114301 | 2576 | - | 21.0553 | - | - | 100 | 232.3816 ( 59%) | - | - |
| 2009267.133605 | 2577 | - | 23.3948 | - | - | 90 | 208.9867 ( 53%) | - | - |
| 2009267.152909 | 2578 | - | 21.0553 | - | - | 81 | 187.9314 ( 48%) | - | - |
| 2009267.172214 | 2579 | - | 25.7343 | - | - | 70 | 162.1971 ( 41%) | - | - |
| 2009267.191519 | 2580 | - | 23.3948 | - | 33.3105 | 65 | 150.1128 ( 38%) | 14.0000 | 8.0000 |
| 2009267.210824 | 2581 | - | 28.0738 | - | 130.1660 | 99 | 230.2051 ( 58%) | 14.0000 | 8.0000 |
| 2009267.230129 | 2582 | - | 32.7528 | - | - | 85 | 197.4523 ( 50%) | - | - |
| 2009268.005435 | 2583 | - | 28.0738 | - | - | 73 | 169.3785 ( 43%) | - | - |
| 2009268.024740 | 2584 | - | 30.4133 | - | - | 60 | 138.9652 ( 35%) | - | - |
| 2009268.044046 | 2585 | - | 25.7343 | - | - | 49 | 113.2309 ( 29%) | - | - |
| 2009268.063351 | 2586 | - | 32.7528 | - | - | 34 | 80.4782 ( 20%) | - | - |
| 2009268.082657 | 2587 | - | 18.7159 | - | - | 26 | 61.7623 ( 15%) | - | - |
| 2009268.102003 | 2588 | - | 21.0553 | - | - | 17 | 40.7070 ( 10%) | - | - |
| 2009268.121309 | 2589 | - | 23.3948 | - | 217.6172 | 92 | 212.9293 ( 54%) | 14.0000 | 8.0000 |
| 2009268.140615 | 2590 | - | 25.7343 | - | 247.4121 | 169 | 390.3200 (100%) | 14.0000 | 8.0000 |
| 2009268.155921 | 2591 | - | 25.7343 | - | 237.3926 | 169 | 390.3200 (100%) | 14.0000 | 8.0000 |
| 2009268.175227 | 2592 | - | 23.3948 | - | - | 159 | 366.9252 ( 94%) | - | - |
| 2009268.194533 | 2593 | - | 21.0553 | - | - | 150 | 345.8698 ( 88%) | - | - |
| 2009268.213839 | 2594 | - | 18.7159 | - | - | 141 | 327.1540 ( 83%) | - | - |

***Figure B.4-21 Sample Data Recorder Model Report File***