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L A N D S A T Data Continuity Mission
LDCM

DRAFT

LDCM Project

Space to Ground Segments Interface Requirements Document

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Revision – 0.d

Signature Page

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Document Revision History

This document is controlled by the LDCM Project Management. Changes require prior approval of the LDCM Project Manager, LDCM observatory Manager, and the LDCM Mission Assurance Manager. Proposed changes shall be submitted to LDCM Mission Systems Engineer.

RELEASE	DATE	BY	DESCRIPTION
–			Initial Version

List of TBD's/TBC's/TBR's

This document contains information that is complete as possible. Items that are not yet defined are annotated with TBD (To Be Determined). Where final numerical values or data are not available, best estimates are given and annotated TBC (To Be Confirmed). If there is an inconsistency between two requirements then the best estimate is given and annotated with a TBR (To Be Resolved). The following table summarizes the TBD/TBC/TBR items in the document and supplements the revision history.

ITEM	REFERENCE	DESCRIPTION

Table of Contents

1 Introduction

1.1 Purpose

The purpose of this document is to specify the functional and performance interface requirements for Landsat Data Continuity Mission (LDCM) systems. This document also provides the basis for subsequent development of corresponding Interface Control Documents (ICDs) and Data Format Control Books (DFCBs).

1.2 Scope

LDCM system interfaces covered in this document are intended to support system design, development, test and operation of the LDCM observatory. Consequently, this IRD:

- Identifies required interfaces between the LDCM Space Segment (SS), Launch Segment, Flight Operations Segment (FOS), and other necessary entities,
- Specifies interfaces for selected elements within the segments,
- Establishes data exchange, functional and performance requirements related to these interfaces; and
- Generally assigns responsibilities for interface implementation.

The focus of this draft is on interfaces related to the LDCM procurement. Subsequent versions will complete the system wide view.

1.3 Document Organization

Section 1 of this document provides an overview and introduction to the IRD. Section 2 presents a brief overview of the mission. Section 3 provides an overview of the interfaces in the system. Section 4 describes the LDCM observatory interface requirements. Section 5 describes the Mission Operations Element interface requirements.

1.4 Reference Documents

- LDCM Space Segment Requirements Document (SSRD)
- LDCM Mission Operations Element Requirements Document (MOERD)
- LDCM Operations Concept Document (OCD)
- NASA Space Network User's Guide (SNUG), June 2002
- NASA Ground Network User's Guide, Revision 1, February 2005
- CCSDS 732.0-B-1, Recommendations for Advanced Orbiting Systems – Space Data Link Protocol
- CCSDS 231.0-B-1, Telecommand Synchronization and Channel Coding

- CCSDS 232.0-B-1, Telecommand Space Data Link Protocol
- CCSDS 232.1-B-1, Communications Operations Procedure-1
- CCSDS 131.0-B-1, TM Synchronization and Channel Coding
- CCSDS 401.0-B-16, Radio Frequency and Modulation Systems
- GSFC-STD-9100, Goddard Technical Standard, Low Density Parity Check Code for Rate 7/8
- NPR 2810.1A, NASA Policy Guideline, Security of Information Technology
- 452-ICD-SN/CSM, Interface Control Document between the Space Network and Customers for Service Management

2 Mission Overview

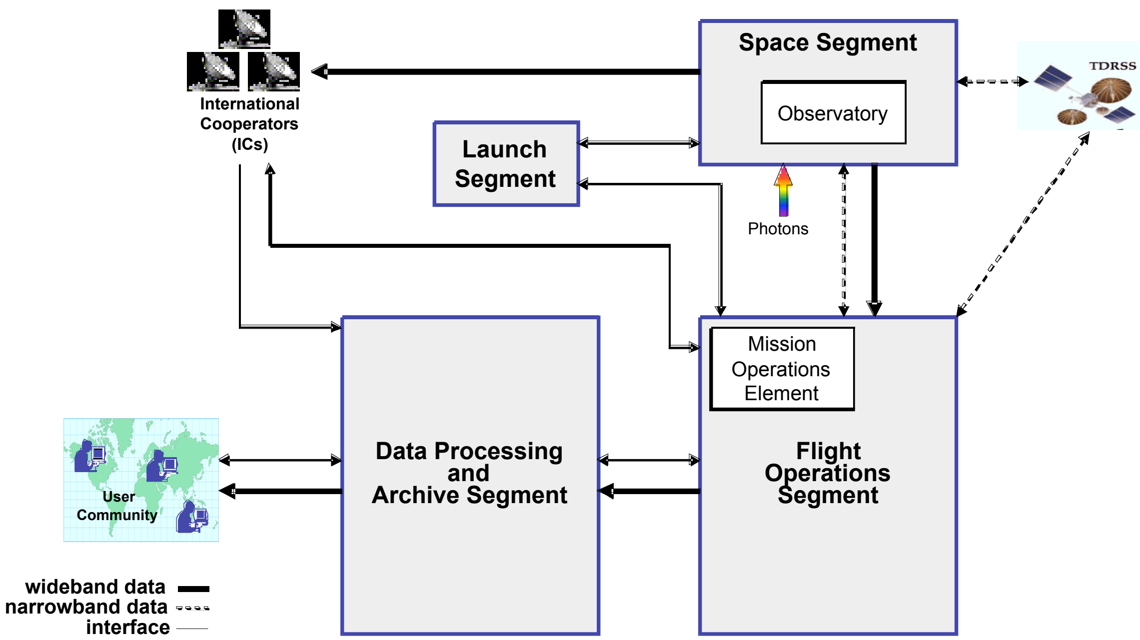

Figure 2-1. LDCM System Architecture

Figure 2-1 presents a top level view of the LDCM system. The system is made up of segments. Each segment is composed of Elements, most of which are not shown in the figure. The Mission Operations Element is shown because portions of that Element are related to the procurement and are highlighted in section 5.

The LDCM system is the latest mission in a program started in 1972 with Landsat 1. The LDCM collects global multispectral data, maintains it in an archive, and makes those data available to users around the world.

The Space Segment consists of the LDCM observatory. The observatory includes the instrument(s), on board data storage, high rate and low rate communications and associated systems. The Space Segment collects image data of the Earth and transmits to the Flight Operations Segment LDCM Ground Network Element and to a series of LDCM International Cooperators (ICs) worldwide. The NASA Space Network (SN) is also used to transmit communications between the Space Segment and Flight Operations Segment. The Launch Segment is the launch vehicle and associated systems and infrastructure used to place the observatory in the proper orbit. The Flight Operations Segment operates the observatory, provides space to ground communications and plans all the observatory activities and data collection. The Data Processing and Archive Segment archives all LDCM data, performs calibration related functions, produces products and makes them available to the user community. A more detailed description of the segments and elements can be found in the LDCM Operations Concept Document.

3 System Interfaces Overview

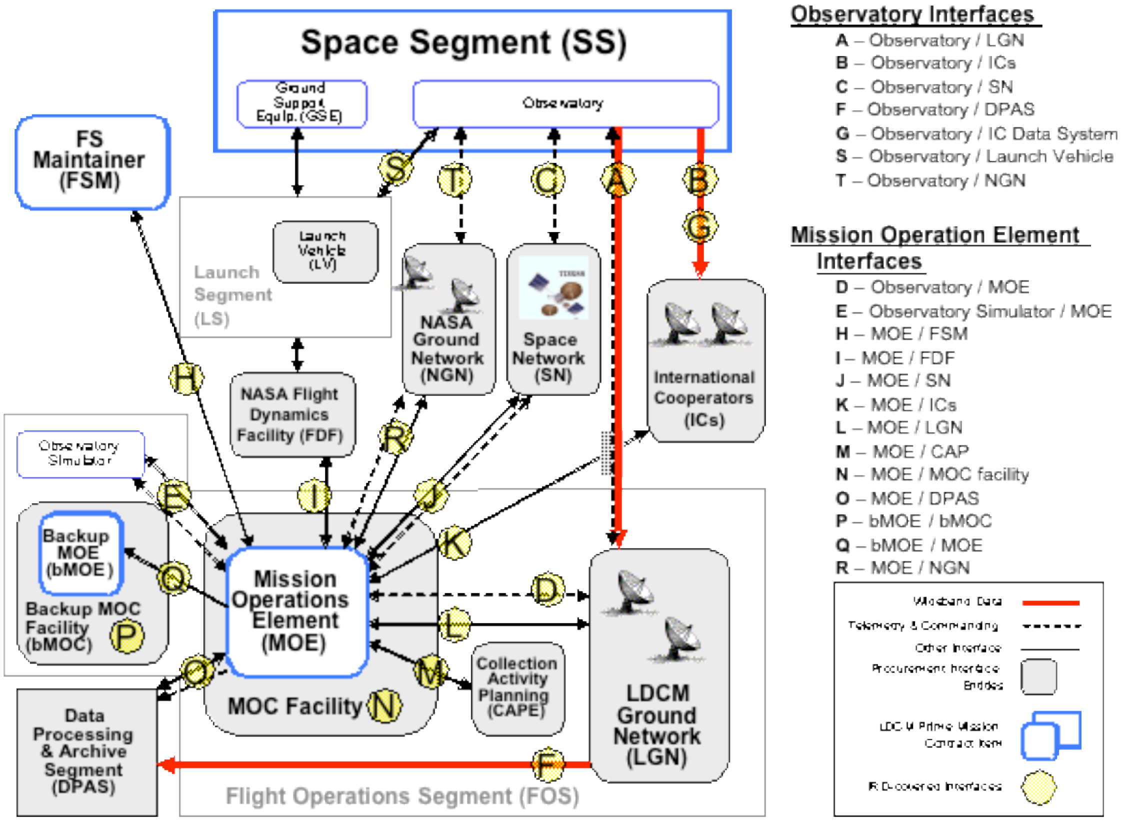

Figure 3-1. LDCM IRD Interfaces

Identified in Figure 3-1, are the LDCM interfaces included in this document. While general data flow is also depicted, more detailed operational threads are covered in the LDCM Operations Concept Document. Several are noted here for clarity.

This document includes the following radio frequency (RF) interfaces:

- the observatory / LGN interface,
- the observatory / IC Ground Station interface,
- the observatory / SN interface, and
- the observatory / NGN interface.

Several interfaces address commanding and telemetry operations and/or the transmission of mission data:

- the observatory / MOE interface,
- the observatory Simulator / MOE interface,
- the observatory / DPAS interface, and
- the observatory / IC Data System interface.

Several Flight Operations Segment (FOS) interfaces are also shown in the figure above:

- the MOE / LGN interface,
- the MOE / CAPE interface,
- the MOE / DPAS interface
- the MOE / MOC Facility interface,
- the MOE/bMOE interface, and
- the bMOE/bMOC Facility interface.

Important external FOS interfaces include:

- the Flight Software Maintainer (FSM) / MOE interface,
- the MOE/ FDF interface,
- the MOE / SN interface,
- the MOE / NGN interface, and
- the MOE / ICs interface.

4 LDCM Observatory Interface Requirements

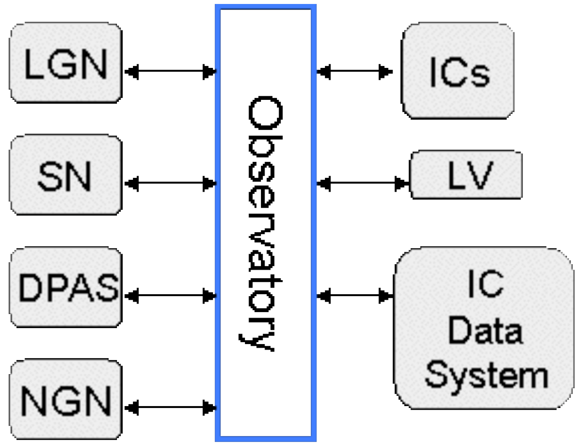

Figure 4-1. LDCM Observatory Interfaces

This section details element level interfaces between the LDCM Space Segment observatory and the elements shown in Figure 4-1. The observatory interfaces to LGN, IC Ground Stations, NSN and SN focus on physical interface aspects. The observatory interfaces to MOE DPAS and IC Data System are logical interfaces.

Spectrum Utilization
The observatory RF interfaces shall comply with the National Telecommunications and Information Administration (NTIA) and International Telecommunications Union (ITU) for spectrum utilization/sharing.

AOS Service
Space/Ground interfaces shall use CCSDS Recommendations for Advanced Orbiting Systems - Space Data Link Protocol 732.0-B-1 for all telemetry and science data streams.

4.1 Observatory / LDCM Ground Network Interface

The observatory shall interface to the LDCM Ground Network (LGN).

4.1.1 LGN Capabilities

The observatory interface to LGN shall be compatible with the following LGN capabilities:

The LDCM Ground Network will include two (2) ground stations at the following locations.

- Sioux Falls, South Dakota – primary site
- Fairbanks, Alaska (TBC19) – secondary site
- A third location (TBD03) will be chosen for a backup capability

Receive Antenna diameter
9m

X-band center frequency range
8025 MHz to 8400 MHz.

S-band center frequency range
2200 MHz – 2290 MHz receive
2025 MHz – 2108 MHz transmit

Minimum S-band transmit Equivalent Isotropic Radiated Power (EIRP)
54 dBW, measured at the uplink antenna interface.

Noise specifications for X-band and S-band
Minimum Clear-Sky X-band G/T at 5 degrees elevation: 31 dB•K (TBC05)
Minimum Clear-Sky S-band G/T at 5 degrees elevation: 20 dB•K (TBC06)

Minimum elevation angle
5 degrees

Polarization
S-band: Left-hand Circularly Polarized (LHCP) or Right-hand Circularly Polarized (RHCP).
X-band: Left-hand Circularly Polarized (LHCP) or Right-hand Circularly Polarized (RHCP).

Modulation
X-band:
Staggered/offset-keyed Quadrature phase-shift keying (SQPSK) or four-dimensional 8-ary phase-shift keying trellis-coded modulation (4D 8-PSK TCM).

S-band:
Command uplinks: PCM/PM on carrier, PCM/PSK/PM on sub-carriers up to 32KHz, or BPSK.
Telemetry downlinks: PCM/PM/Bi-phase, BPSK, SQPSK

Randomization
CCSDS-131.0-B-1 TM Synchronization/Channel Coding and CCSDS 231.0-B-1, Telecommand Synchronization/Channel Coding are supported.

S-band Uplink Sweep Range:
± 160 KHz about the center frequency

S-band Uplink Sweep Rate:
5 - 35 KHz/sec.

Maximum rate for S-band uplink transition to a fixed carrier:
10 KHz/sec.

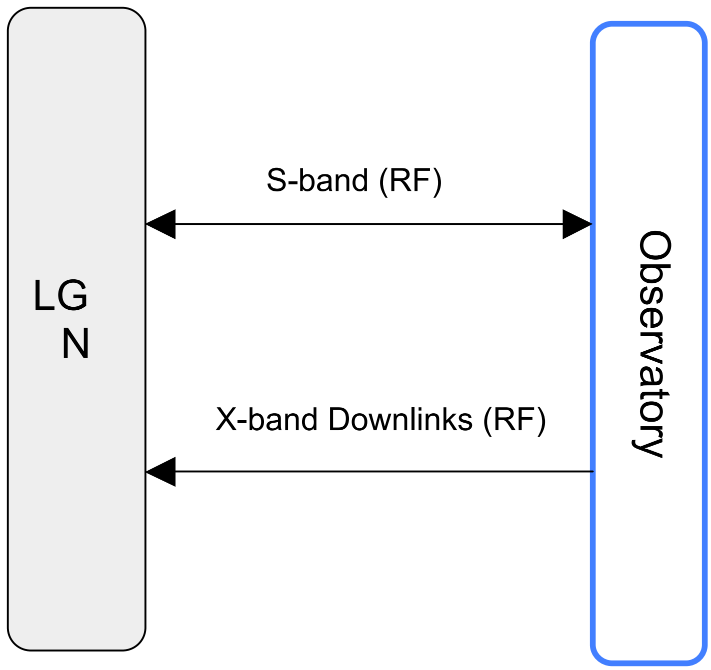

Figure 4-2. Observatory / LGN Interfaces

As shown in Figure 4-2, the observatory/LGN interface is used to transmit/receive Radio Frequency (RF) S-band data and to transmit X-band data to LGN. S-band data includes commanding and telemetry communications that originate from or end in the MOE. X-band data includes mission data, ancillary data, and stored telemetry communications that end in the DPAS or MOE.

4.1.2 Observatory / LGN – S-band

The observatory shall downlink S-band data to the LGN.

The LGN will receive S-band data downlinks from the observatory.

The LGN will uplink S-band data to the observatory.

The observatory shall receive S-band data uplinks from the LGN.

The observatory shall maintain S-band communication links with at least 3db link margin at the end of observatory design life.

The observatory shall have an S-band transmission bit error rate (BER) of less than 1E-8 after demodulation and application of all error correction code at the end of observatory design life.
Rationale: This requirement applies to all established S-band stations

The observatory shall have link availability of 99% or greater at all elevation angles above 5 degrees when in contact with an LGN station.
Rationale: This applies to all links.

The observatory shall provide selectable randomization of the S-band downlink in accordance with CCSDS-131.0-B-1.

The observatory shall support selectable randomization of the S-band uplink in accordance with CCSDS-231.0-B-1

The observatory shall utilize modulations consistent with CCSDS 401.0-B-16.

The observatory shall utilize error-correction coding compliant with CCSDS 131.0-B-1 on S-band downlinks.
Rationale: assuming the standard products (PTP) for S-band; LGN already supports CCSDS standard

The observatory shall process S-band uplink coded for error correction following CCSDS 231.0-B-1.

4.1.3 Observatory / LGN – X-band

The observatory shall downlink X-band data to the LGN.

The LGN will receive X-band data downlinks from the observatory.

The observatory shall maintain X-band LGN station communication links with at least 3db link margin at the end of observatory design life.

The observatory shall have link availability of 99% or greater at all elevation angles above 5 degrees when in contact with an LGN station.
Rationale: This applies to all LGN station and Space Network links.

The observatory shall have an X-band transmission bit error rate (BER) of less than 1E-10 (TBC18) after demodulation and application of all error correction code at the end of observatory design life.
Rationale: This requirement applies to all established X-band stations (LGN and ICs).

The observatory shall provide selectable randomization of the X-band downlink in accordance with CCSDS-131.0-B-1.

The observatory shall utilize modulations consistent with CCSDS 401.0-B-16.

The observatory shall encode X-band downlink data for error-correction using Low-Density Parity Check (LDPC) coding in accordance with GSFC-STD-9100.
Rationale: advantageous coding for X-band

4.2 Observatory / IC Ground Stations

As shown in Figure 4-3, the observatory to IC Ground Station interface includes X-band RF downlinks to the ICs. X-band data to the ICs includes real-time mission data and real-time ancillary data.

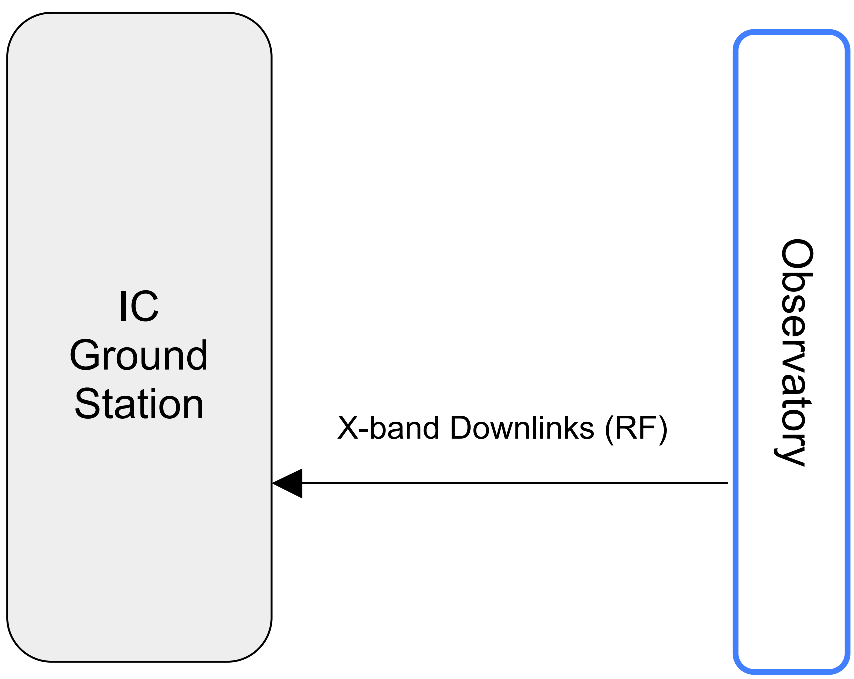

Figure 4-3. Observatory / IC Ground Station Interfaces

4.2.1 IC Ground Station Capabilities

The observatory interface to IC Ground Stations shall be compatible with the following station capabilities:

Antenna Size
9 m

X-band center frequency range
8025 MHz to 8400 MHz

Noise specifications for X-band
Minimum Clear-Sky X-band G/T at 5 degrees elevation: 31 dB•K (TBC10)

Minimum elevation angle
5 degrees

Polarizations
LHCP or RHCP

Modulation
SQPSK or 8PSK

4.2.2 Observatory / IC Ground Station - X-band

The observatory shall send real-time X-band downlinks to the IC Ground Stations.

The IC Ground Stations will receive observatory X-band real-time downlinks.

The observatory shall maintain IC ground station X-band communication links with at least 3db link margin at the end of observatory design life.

The observatory shall have link availability of 99% or greater at all elevation angles above 5 degrees when in contact with an IC ground station.
Rationale: This applies to all station links.

The observatory shall have an X-band transmission bit error rate (BER) of less than 1E-10 (TBC19) after demodulation and application of all error correction code at the end of observatory design life.
Rationale: This requirement applies to all established X-band stations

The observatory shall encode X-band downlink data for error-correction using Low-Density Parity Check (LDPC) coding in accordance with GSFC-STD-9100.
Rationale: advantageous coding for X-band

The observatory shall utilize modulations consistent with CCSDS 401.0-B-16.

4.3 Observatory / Space Network Interface

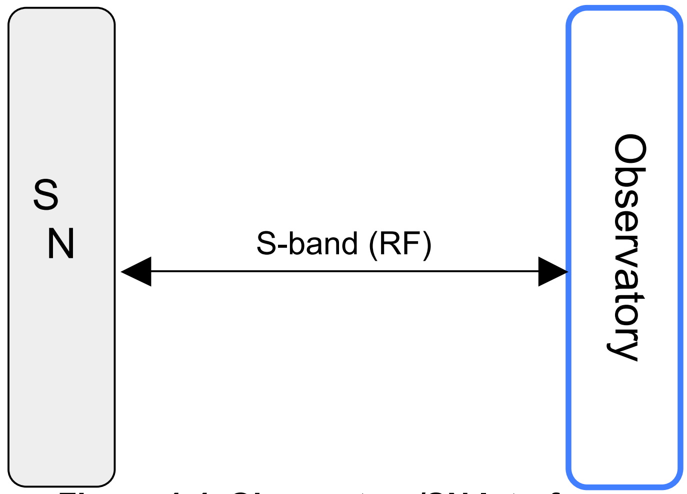

Figure 4-4. Observatory/SN Interfaces

As shown in Figure 4-4, the LDCM observatory will interface to the NASA Space Network via RF S-band communications. LDCM will use the SN during launch and early orbit phases and during emergencies or anomaly investigations for telemetry and commanding only.

The observatory shall interface to the SN as defined in the Space Network User's Guide.

The SN will interface to the observatory as defined in the Space Network User's Guide.

The SN will send S-band communications to the observatory.

The observatory shall receive S-band communications from the SN.

The observatory shall send S-band communications to the SN.

The SN will receive S-band communications from the observatory.

4.4 Observatory / NASA Ground Network Interface

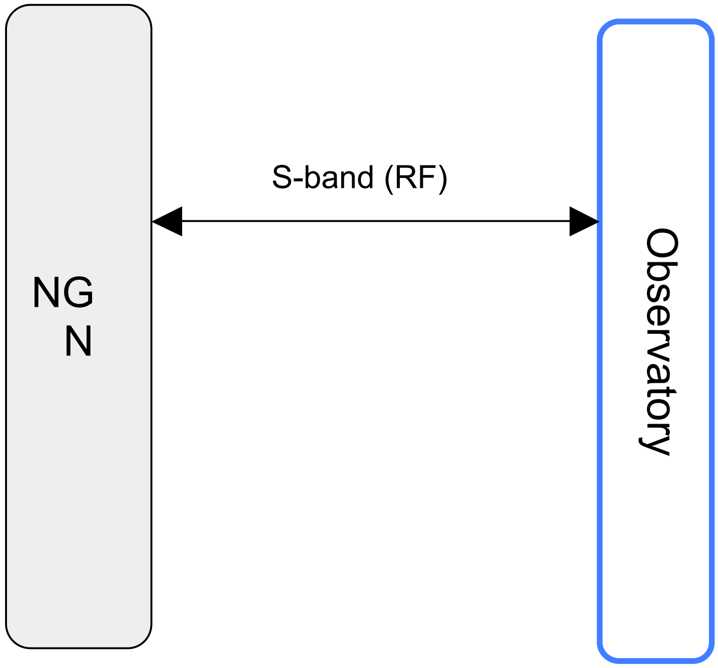

Figure 4-5. Observatory / NGN Interfaces

As shown in Figure 4-5, the observatory/NGN interface is used to transmit/receive Radio Frequency (RF) S-band data to NGN. S-band data includes commanding and telemetry communications that originate from or end in the MOE. LDCM will utilize the NGN as a backup capability during launch and early orbit operations.

The observatory shall have the capability to interface to the following NASA Ground Network ground stations:

- Norway - SGS
- Wallops, Virginia - WGS
- McMurdo, Antarctica - MGS
- Poker Flat, Alaska - AGS

The observatory shall be compatible with the NGN capabilities defined in the Ground Network User's Guide.

The observatory shall downlink S-band data to the NGN.

The NGN will receive S-band data downlinks from the observatory.

The NGN will uplink S-band data to the observatory.

The observatory shall receive S-band data uplinks from the NGN.

The observatory shall maintain S-band communication links with at least 3db link margin at the end of observatory design life.

The observatory shall have an S-band transmission bit error rate (BER) of less than 1E-8 after demodulation and application of all error correction code at the end of observatory design life.
Rationale: This requirement applies to all established S-band stations

The observatory shall have link availability of 99% or greater at all elevation angles above 5 degrees when in contact with an NGN station.
Rationale: This applies to all station links.

The observatory shall utilize error-correction coding consistent with CCSDS 131.0-B-1 on S-band downlinks.
Rationale: assuming the standard products (PTP) for S-band; GN already supports CCSDS standard

The observatory shall process S-band uplink coded for error correction following CCSDS 231.0-B-1.

4.5 Observatory / DPAS

The observatory / DPAS interface (Figure 4-6) includes the transmission of mission and ancillary data. All communications across this interface will pass through the LGN.

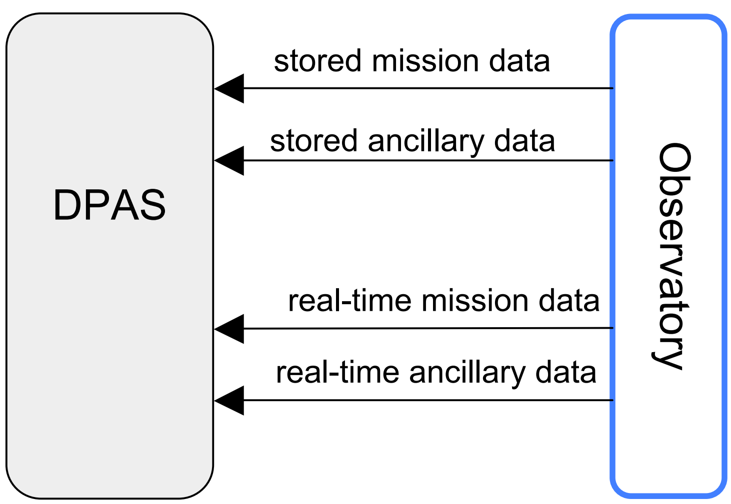

Figure 4-6. LDCM Observatory / DPAS Interfaces

The observatory shall send real-time mission data to the DPAS.

The DPAS will receive real-time mission data from the observatory.

The observatory shall send stored mission data to the DPAS.

The DPAS will receive stored mission data from the observatory.

The observatory shall send real-time ancillary data to the DPAS.

The DPAS will receive real-time ancillary data from the observatory.

The observatory shall send stored ancillary data to the DPAS.

The DPAS will receive stored ancillary data from the observatory.

4.6 Observatory / IC Data System

The observatory / IC Data System interface includes the transmission of mission and ancillary data. All communications across this interface will pass through the IC Ground Stations.

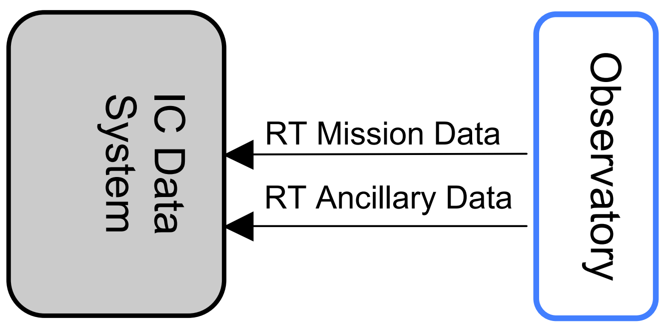

Figure 4-7. Observatory / IC Data System Interfaces

As shown in Figure 4-7, ICs only receive Real-time (RT) mission data via RF communications from the observatory.

The observatory shall send real-time mission data to the IC data system.

The IC data system will receive real-time mission data from the observatory.

The observatory shall send real-time ancillary data to the IC data system.

The IC data system will receive real-time ancillary data from the observatory.

4.7 Observatory / Launch Vehicle

The LDCM Observatory shall interface with NASA/KSC provided launch vehicle as defined in the Delta II [TBC] to LDCM Mission Interface Control Document. (See Figure 4-8.)

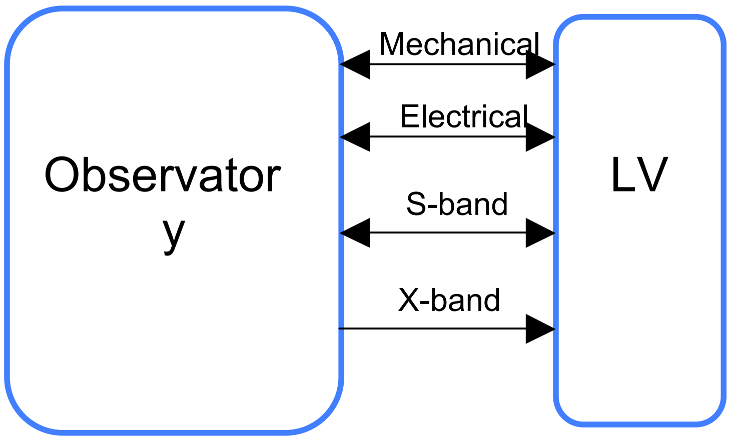

Figure 4-8. LDCM Observatory / LV Interfaces

The LDCM observatory shall mechanically and electrically interface with a Delta II launch vehicle.

The LDCM observatory shall be capable of sending S-band telemetry through the launch vehicle interface umbilical.

The LDCM observatory shall be capable of sending X-band data telemetry through the launch vehicle interface umbilical.

The LDCM observatory shall be capable of receiving S-band command data through the launch vehicle interface umbilical.

The LDCM observatory shall receive electrical power through the launch vehicle interface umbilical.

5 Mission Operations Element Interface Requirements

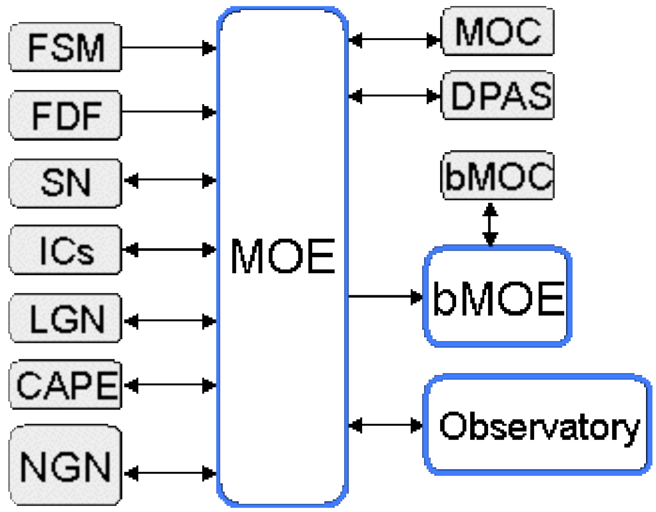

Figure 5-1. Mission Operations Element Interfaces

This section details the Mission Operations Element interfaces shown in Figure 5-1.

5.1 Mission Operations Element / Observatory Interface

The interface requirements in this section will include all commands from the MOE to the observatory and all telemetry from the observatory to the MOE. See Figure 5-2. All communications passed across the observatory / MOE interface will pass through the LGN or the SN.

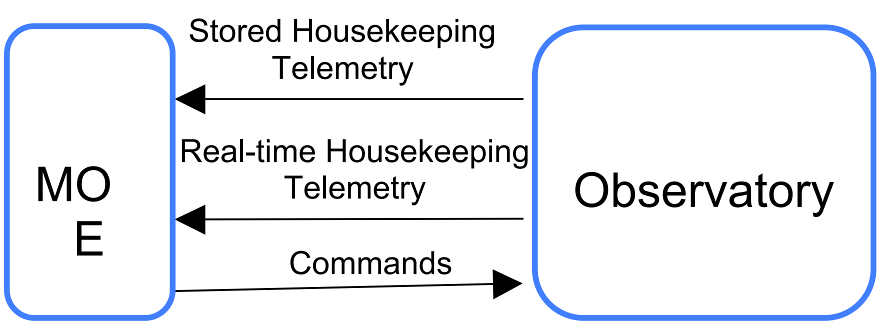

Figure 5-2. LDCM MOE / Observatory Interfaces

5.1.1 Commanding

The observatory shall process commands compliant with CCSDS 232.0-B-1 Telecommand Space Data Link Protocol and CCSDS 232.1-B-1 Command Operations Procedure-1.

The MOE shall generate commands compliant with CCSDS 232.0-B-1 Telecommand Space Data Link Protocol and CCSDS 232.1-B-1 Command Operations Procedure-1.

The MOE shall send commands to the observatory.

The observatory shall receive commands from the MOE.

5.1.2 Telemetry

The observatory shall send real-time housekeeping telemetry to the MOE.

The MOE shall receive real-time housekeeping telemetry from the observatory.

The observatory shall send stored housekeeping telemetry to the MOE.

The MOE shall receive stored housekeeping telemetry from the observatory.

5.2 Mission Operations Element / Flight Software Maintainer Interface

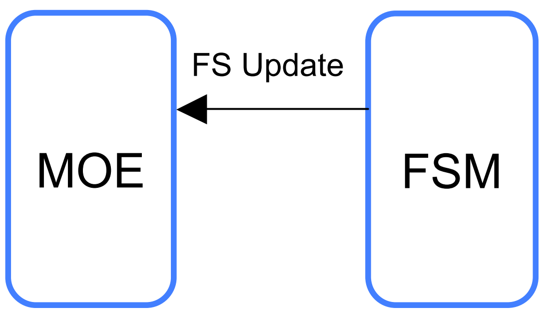

Figure 5-3. MOE / FSM Interfaces

Illustrated in Figure 2-1, the MOE/Flight Software Maintainer (FSM) interface covers the modifications to flight software that are made by the FS Maintainer (FSM), namely, the LDCM Prime Mission Contractor.

The FSM shall send flight software updates to the MOE.

The MOE shall receive flight software updates from the FSM.

5.3 Mission Operations Element / Flight Dynamics Facility

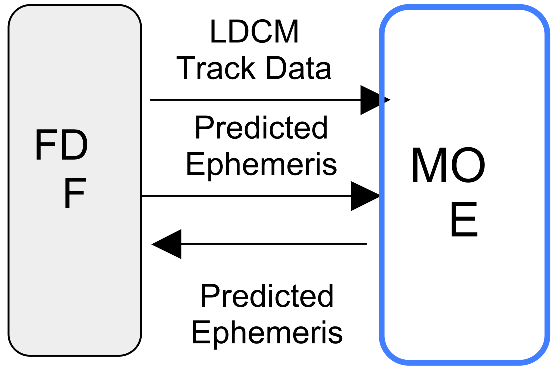

Figure 5-4. LDCM MOE / FDF Interfaces

Figure 5-4 illustrates necessary data exchanges within the MOE/FDF interface. The GSFC Flight Dynamics Facility provides expertise for early orbit determination activities, SN contacts, and anomaly resolution. LDCM will utilize the Flight Dynamics Facility to support launch and early orbit flight dynamics activities and to support anomaly resolution.

The FDF will send LDCM acquisition and tracking data to the MOE.
Rationale: for anomaly resolution, FDF provides tracking data for LGN stations
The MOE shall receive LDCM early orbit track data.

The FDF will send predicted ephemeris to the MOE.
Rationale: during launch and early orbit

The MOE shall receive predicted ephemeris from FDF.
Rationale: during launch and early orbit; allows MOE to make contact with observatory

The MOE shall send predicted ephemeris to the FDF.
Rationale: supports Earth Science Mission Operation (ESMO) a.m. constellation coordination activities

The FDFD shall receive predicted ephemeris from the MOE.
Rationale: FDF supports the Earth Science Mission Operations (ESMO) office for a.m. constellation coordination

5.4 Mission Operations Element / Space Network

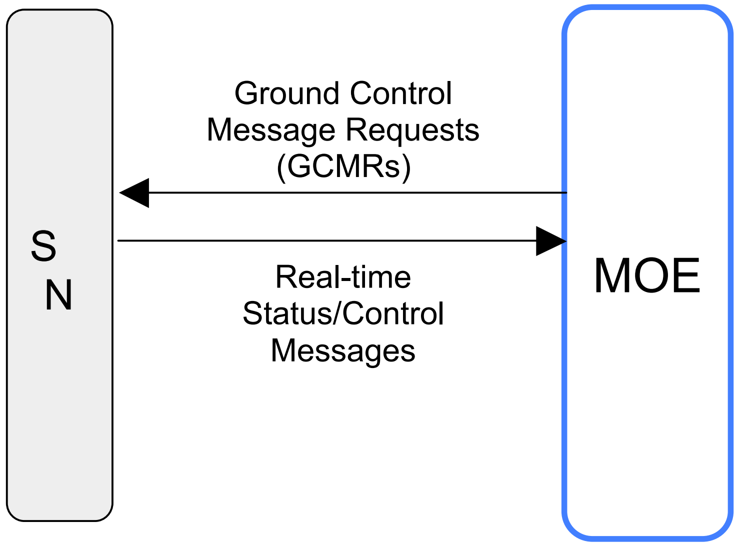

Figure 5-5. LDCM MOE / SN Interfaces

Figure 5-5 illustrates necessary data exchanges within the MOE/SN interface. Note that some data flowing through SN between the observatory and MOE is represented in the MOE to observatory logical interface section.

The MOE shall send forward and return link service Ground Control Message Requests (GCMRs) to the SN, consistent with the Interface Control Document between the Space Network and Customers for Service Management.

The SN will receive forward and return link service Ground Control Message Requests (GCMRs) from the MOE, consistent with the Interface Control Document between the Space Network and Customers for Service Management.

The SN will send real-time network status/control messages to the MOE, consistent with the Interface Control Document between the Space Network and Customers for Service Management.

The MOE shall receive real-time network status/control messages from the SN, consistent with the Interface Control Document between the Space Network and Customers for Service Management.

The MOE shall introduce no more than a 1-second (TBR12) delay in all communications to the SN.

The SN will introduce no more than a 1-second (TBR13) delay in all communications to the MOE.

The LDCM MOC will interface to the SN for scheduling purposes using a Government-provided, SN-compatible scheduling system. The SN-compatible schedule system will be separate from the MOE. Scheduling information will be transferred between the SN and MOC consistent with the Interface Control Document between the Space Network and Customers for Service Management.

5.5 Mission Operations Element / International Cooperator's Ground Stations

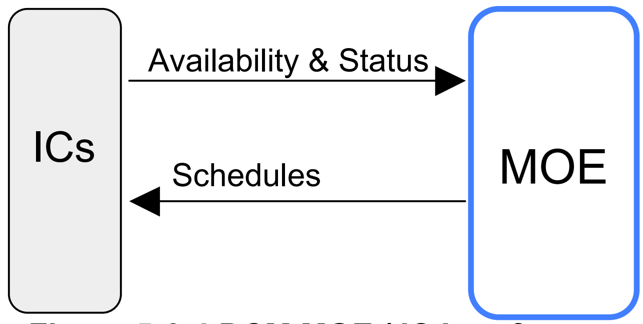

Figure 5-6. LDCM MOE / IC Interfaces

Figure 5-6 illustrates necessary data exchanges within the MOE/ICs interface. Availability & Status includes station status (planned and emergency outage notifications). Schedules include the following information specific to each individual IC:

- As-planned (next 72 hrs planned resource activities, pass content),
- As-scheduled (next 24 hrs – allocated resource activities, pass content),
- As-executed (prior 24 hrs – what activities got done yesterday, pass content),
- Time-critical requests (within 6-hours TBR14)

Note the "pass content" includes the scene ids collected in that time period.

The ICs will report availability and ground station status to the MOE.

The MOE shall receive availability and status from the ICs.
Rationale: for planning/scheduling purposes

The MOE shall send Schedules to the ICs.

The ICs will receive Schedules from the MOE.

5.6 Mission Operations Element / LDCM Ground Network

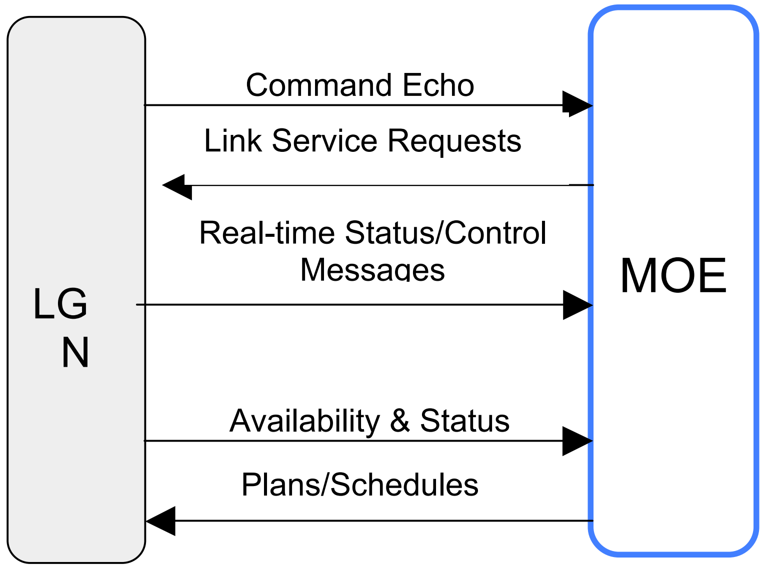

Figure 5-7. LDCM MOE / LGN Interfaces

Figure 5-7 illustrates necessary data exchanges within the MOE/LGN interface. Availability includes station and network status (planned and emergency outage notifications). Schedules include the following information, specific to each individual LGN ground station:

- As-planned (72 hrs planned resource activities, pass content),
- As-scheduled (24 hr – allocated resource activities, pass content),
- As-executed (24 hr -- what activities got done yesterday, pass content),
- Time-critical requests (within 6-hours TBR14)

Note the "pass content" includes the scene ids collected in that time period.

Link service requests establish link services prior to communication through the LGN. Command echo consists of a reflection of the commands received from the MOE and sent to the observatory. Status and control messages provide information about LGN commanding and telemetry functions.

The LGN will report availability and ground station status to the MOE.

The MOE shall receive availability and status from the LGN.
Rationale: for planning and scheduling purposes

The MOE shall send Plans and Schedules to the LGN.
Rationale: advanced notice of planned/scheduled contacts

The LGN will receive Plans and Schedules from the MOE.

The MOE shall send forward and return link service requests to the LGN.
Rationale: establishing the link prior to commanding or telemetry reception

The LGN will receive forward and return link service requests from the MOE.

The LGN will send real-time network status/control messages to the MOE.

The MOE shall receive real-time network status/control messages from the LGN.

The LGN will send command echo to the MOE.

The MOE shall receive command echo from the LGN.

The MOE shall introduce no more than a 1-second (TBR15) delay in all communications to the LGN.

The LGN will introduce no more than a 1-second (TBR16) delay in all communications to the MOE.

5.7 Mission Operations Element / NASA Ground Network

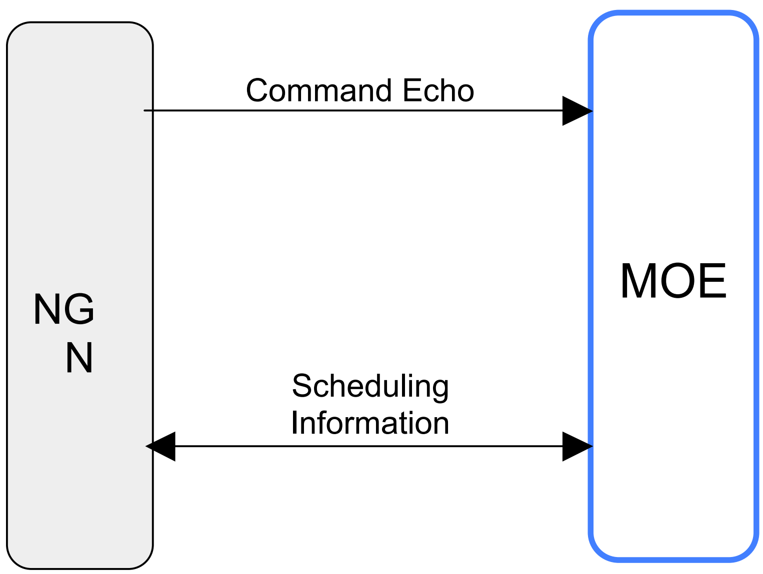

Figure 5-8. LDCM MOE / NGN Interfaces

Figure 5-78 illustrates necessary data exchanges within the MOE/NASA Ground Network (NGN) interface. Command echo consists of a reflection of the commands received from the MOE and sent to the observatory. Scheduling information necessary to schedule NGN resources is defined in the Ground Network User's Guide.

The NGN will send command echo to the MOE.

The MOE shall receive command echo from the NGN.

The MOE shall send scheduling data/information to the NGN as defined in the Ground Network User's Guide.

The NGN will receive scheduling data/information from the MOE as defined in the Ground Network User's Guide.

The MOE shall receive scheduling data/information from the NGN as defined in the Ground Network User's Guide.

The NGN will send scheduling data/information to the MOE as defined in the Ground Network User's Guide.

The MOE shall introduce no more than a 1-second (TBR20) delay in all communications to the NGN.

The NGN will introduce no more than a 1-second (TBR21) delay in all communications to the MOE.

5.8 Mission Operations Element / Collection Activity Planning Element

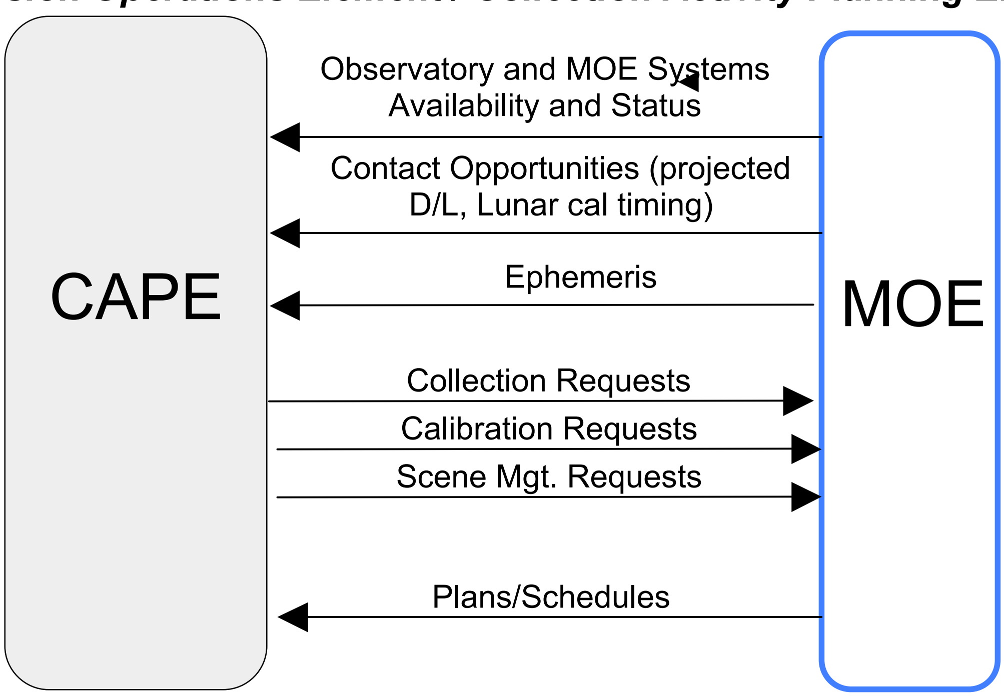

Figure 5-9. LDCM MOE / CAPE Interfaces

Figure 5-9 illustrates necessary data exchanges within the MOE/CAPE interface. Observatory Availability consists of observatory constraint information necessary to perform image collection planning. This will include resource availability and status that could impact the observatory's availability for image collection such as planned and emergency outage information for the observatory or its resources. MOE System Status includes planned and emergency outage information for the MOC systems and resources – planned and emergency outage information.

The MOE also determines downlink opportunities, uplink opportunities, and Lunar Calibration Opportunities. These are used by CAPE to perform image collection planning and formulate Collection Requests. MOE returns Plans/Schedules, which includes the following:

- As-planned (72 hrs planned resource activities, pass content),
- As-scheduled (24 hr – allocated resource activities, pass content),
- As-executed (24 hr -- what activities got done yesterday, pass content),
- Time-critical requests (within 6-hours TBR14)

Note the "pass content" includes the scene ids collected in that time period.

MOE shall send observatory availability to CAPE.
Rationale: for image collection planning

CAPE will receive observatory availability from MOE.

MOE shall send MOE system status information to CAPE.

CAPE will accept system status information from MOE.

MOE shall send observatory contact opportunities (including projected downlink opportunities, uplink opportunities, and lunar calibration opportunities) to CAPE.

CAPE will receive observatory contact opportunities from MOE.

CAPE will send to MOE the following requests:

- Collection Requests
    - Identifies WRS-2 scene IDs
    - Identifies WRS-2 Scene IDs for RT downlink to ICs
    - Identifies any WRS-2 scenes as Priority
    - Covers 72 hr (TBC17) period
- Calibration Requests
    - Specifies lunar calibration instruction (e.g. period of time to image, instrument(s) mode/settings, etc.)
    - Identifies preferred Lunar Cal. contact time.
    - Other non-routine calibration requests

- Scene Management Requests
    - Can specify scene IDs to Re-Downlink from the observatory
    - Can specify scene IDs to Delete from the observatory
    - Can Specify scene IDs to Save on the observatory

The MOE shall receive from CAPE Collection Requests, Calibration Requests, and Scene Management Requests.

The MOE shall send plans and schedules to CAPE.

The CAPE will receive plans and schedules from the MOE.

5.9 Mission Operations Element / Data Processing and Archive Segment

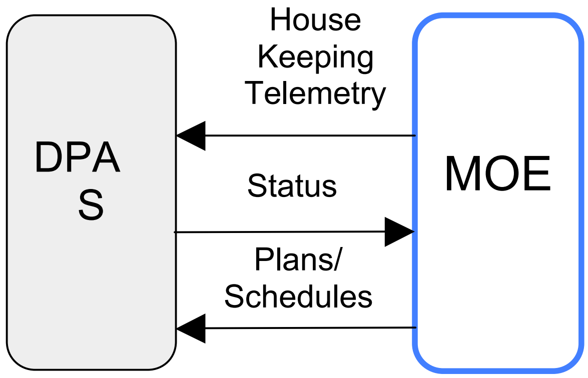

Figure 5-10. LDCM MOE / DPAS Interfaces

Figure 5-10 illustrates necessary data exchanges within the MOE/DPAS interface. The housekeeping data flow contains both real-time and stored telemetry converted to calibrated values that are stored within the DPAS for use in image data processing or instrument calibration. DPAS status includes anything that affects its ability to receive imagery such as planned and emergency outage information. As before, Plans/Schedules from the MOE to DPAS include the following:

- As-planned (72 hrs planned resource activities, pass content),
- As-scheduled (24 hr – allocated resource activities, pass content),
- As-executed (24 hr -- what activities got done yesterday, pass content),
- Time-critical requests (within 6-hours TBR14)

The MOE shall send housekeeping data to the DPAS.

The DPAS will receive housekeeping data from the MOE.

The DPAS will send DPAS availability and status to the MOE.

The MOE shall receive DPAS availability and status from the DPAS.

The MOE shall send plans and schedules to DPAS.

The DPAS will receive plans and schedules from the MOE.

5.10 Mission Operations Element / Mission Operations Center Facility

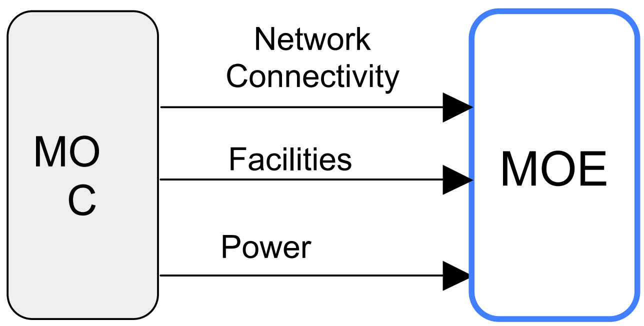

Figure 5-11. LDCM MOE / MOC Facility Interfaces

Figure 5-11 illustrates necessary connectivity and data exchanges within the MOE/MOC interface. Detailed interface requirements will be further defined in the MOE Requirements Facility Implementation Plan.

The MOC facility will supply U.S. standard single-phase, dual-phase and three-phase electrical power to the MOE.

The MOE shall receive U.S. standard single-phase, dual-phase and three-phase electrical power from the MOC facility.

The MOC facility will supply conditioned facility space to the MOE.

The MOC facility will supply network connectivity to the MOE.

The MOE shall receive network connectivity from the MOE.

The MOC facility will provide an external master time signal reference to the MOE.

The MOE shall receive an external master time signal reference from the MOC facility.

5.11 Backup Mission Operations Element / Backup Mission Operations Center

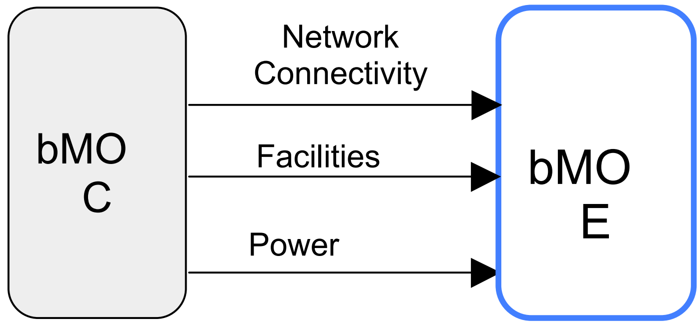

Figure 5-12. LDCM bMOE / BMOC Interfaces

Figure 5-12 illustrates necessary connectivity and data exchanges within the bMOE/bMOC interface. Detailed interface requirements will be further defined in the MOE Requirements Facility Implementation Plan.

The bMOC facility will supply U.S. standard single-phase, dual-phase and three-phase electrical power to the bMOE.

The bMOE shall receive U.S. standard single-phase, dual-phase and three-phase electrical power from the bMOC facility.

The bMOC facility will supply conditioned facility space to the bMOE.

The bMOC facility will supply network connectivity to the bMOE.

The bMOE shall receive network connectivity from the bMOE.

The bMOC facility will provide an external master time signal reference to the bMOE.

The bMOE shall receive an external master time signal reference from the bMOC facility.

5.12 Backup Mission Operations Element / Mission Operations Element Interfaces

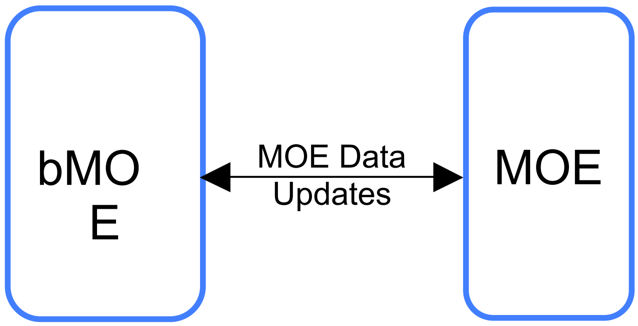

Figure 5-13. LDCM MOE / bMOE Interfaces

Figure 5-13 illustrates necessary data exchanges for the Backup MOC (bMOC) and Backup MOE (bMOE) interfaces. Essentially all MOE Data is kept current at the bMOC should switch-over be necessary. Note that the bMOE also has all the other interfaces that the MOE has. These are not replicated here; refer to the sections addressing MOE interfaces.

The MOE shall send current MOE Data to the bMOE.

The bMOE shall receive current MOE Data from the MOE.

The bMOE shall send current bMOE data to the MOE.

The MOE shall receive current bMOE data from the bMOE.

5.13 Mission Operations Element / Observatory Simulator

The observatory simulator resides in the LDCM Mission Operations Center (MOC). The simulator emulates the observatory for testing and training purposed. The observatory simulator / MOE interface is very similar to the observatory/ MOE interface, except that the communications are directly between the simulator and the MOE and do not pass through the LGN or SN.

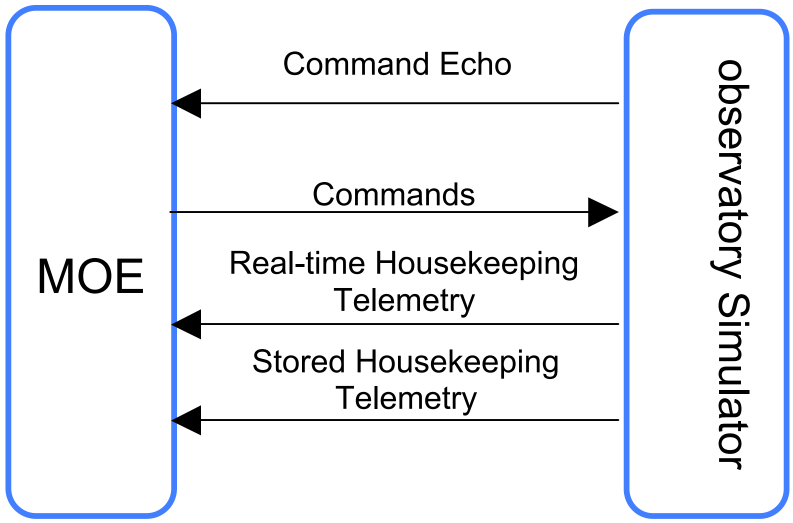

Figure 5-14. LDCM MOE / Simulator Interfaces

Figure 5-14 illustrates data exchange within the Simulator/MOE interface.

5.13.1 Commanding

The observatory simulator shall process commands compliant with CCSDS 232.0-B-1 Telecommand Space Data Link Protocol and CCSDS 232.1-B-1 Command Operations Procedure-1.

The MOE shall generate commands compliant with CCSDS 232.0-B-1 Telecommand Space Data Link Protocol and CCSDS 232.1-B-1 Command Operations Procedure-1.

The MOE will send commands to the observatory simulator.

The observatory simulator shall receive commands from the MOE.

The observatory simulator shall send command echo to the MOE.

The MOE shall receive command echo from the observatory simulator.

5.13.2 Telemetry

The observatory simulator shall send real-time housekeeping telemetry to the MOE.

The MOE will receive real-time housekeeping telemetry from the observatory simulator.

The observatory simulator shall send stored housekeeping telemetry to the MOE.

The MOE will receive stored housekeeping telemetry from the observatory simulator.

Appendix A: Requirement Traceability Matrix