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Lunar Reconnaissance Orbiter Project

LRO Mission Operations Test Plan

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**Goddard Space Flight Center
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1.0 INTRODUCTION

This document will describe the overall approach and plan for mission operations testing. The test describe within this document will primary be used for operations training, system verification, procedure verification, and maintain operations proficiency. This document will not contain information on mission rehearsals. Mission Rehearsal details are captured in a separate document, LRO Mission Rehearsal Test Plan (431-PLAN-000402).

There are two types of mission operation tests that will be described within this document. The first type is mission simulations and the second type is Operations Readiness Tests (ORTs).

1.1 MISSION SIMULATIONS OVERVIEW

Mission Simulations is a term that describes a large variety of operations testing. In general, mission simulations will involve the entire mission elements and components, but not necessarily at the same time. The primary goals of mission simulations are:

1. Verify operations timeline
2. Execute and verify operations procedures and scripts
3. Verify ground system configuration and operations concepts
4. Perform stress testing on hardware and software components
5. Provide training opportunities for the Mission Operations Team (MOT) and mission engineering team.

Mission simulations will be performed up through launch. Individual simulations are identified within this document. A simulation test will range from a few hours to several days, the duration is determined by the goals and mission time period.

Mission simulations are the natural complement to mission rehearsals. Mission simulations are similar to the mission rehearsals but generally require less time to prepare and execute. Simulations are also generally more focused on particular areas of the operations concept, but there are some simulations that will cover large portions of the mission timeline. Another different between simulations and rehearsals are anomalies, the simulations tend to focus on following the nominal timeline, verifying the timing and sequence of activities. This is sometime difficult to verify during rehearsals since rehearsals contain ground and flight segment anomalies.

1.2 OPERATIONS READINESS TEST OVERVIEW

ORTs main purpose is to maintain operator proficiency and to re-verify configuration after formal mission readiness testing is complete. ORTs are executed between different ground elements and generally involve data flows using a test file. The primary participates in ORTs are:

- Deep Space Network (DSN)
- Universal Space Network (USN)
- White Sands (WS1)
- Space Network (SN)
- Mission Operations Center (MOC)
- Flight Dynamics Facility (FDF)
- Instrument Science Operations Centers (SOCs)

Individual ORTs will typically involve just one interface. These are not meant to serve as end-to-end tests. By limiting ORTs to a single interface, it allows these tests to be schedule often and the test durations are reduced. A typical ORT will generally last between 1-2 hours.

For all ORTs, the MOC is involved and the MOT at the MOC executes the test according to the ORT plan.

2.0 MISSION SIMULATIONS

A mission simulation matrix was developed to identify the different simulations being planned for LRO. The matrix identifies the simulation, brief description, and required participants for the test. The simulation matrix is illustrated in Table 2-1.

Table 2-1: Mission Operations Simulation Test Matrix

LRO Mission Operations Simulation Test Matrix					Matrix Version: 1.0			
Test #	Test Title	Test Duration	Shift (Yes/No)	Test Platform	Required Participates			
					MOC-MOT	FDf	SOcs	System Team
LRO-SIM-01	Daily Operations	8 hours	No	Ops Sim	X			
LRO-SIM-02	Daily Operations w/SOCs	12 hours	No	Flatsat	X	X	X	
LRO-SIM-03	Day-in-the-Life	12 hours	No	Orbiter	X	X	X	X
LRO-SIM-04	LOI Timeline	4 hours	No	Flatsat	X	X		X
LRO-SIM-05	Early Mission Timeline	8 hours	No	Flatsat	X	X		X
LRO-SIM-06	Instrument Activation	12 hours	No	Flatsat	X			X
LRO-SIM-07	Extended Early Mission Sim	5 days	Yes	Flatsat	X	X		X
LRO-SIM-08	Extended Nominal Operations	4 days	Yes	Flatsat	X	X	X	X
LRO-SIM-09	Monthly SK-Calibrations	10 hours	No	Flatsat	X	X		X
LRO-SIM-10	Spacecraft Commissioning #1	8 hours	No	Data Files	X			X
LRO-SIM-11	Spacecraft Commissioning #2	8 hours	No	Data Files	X			X
LRO-SIM-12	Spacecraft Commissioning #3	8 hours	No	Data Files	X			X
LRO-SIM-13	Initial Acquisition	2 hours	No	Data Files	X			
LRO-SIM-14	Extended Daily Operations #2	4 days	Yes	Flatsat	X	X	X	X
LRO-SIM-15	Extended Early Mission Sim #2	5 days	Yes	Flatsat	X	X		X
LRO-SIM-16	Mini-RF Operations	8 hours	No	Flatsat	X	X	X	
LRO-SIM-17	Yaw Flip Maneuvers	4 hours	No	Flatsat	X	X		
LRO-SIM-18	Contingency Simulation #1	8 hours	No	Flatsat	X			X
LRO-SIM-19	Contingency Simulation #2	8 hours	No	Flatsat	X			X
LRO-SIM-20	Contingency Simulation #3	8 hours	No	Orbiter	X			X
LRO-SIM-21	Contingency Simulation #4	8 hours	No	Orbiter	X			X
LRO-SIM-22	Instrument Calibration Sim	12 hours	No	Flatsat	X			X
LRO-SIM-23	MOI Simulation	12 hours	No	Flatsat	X	X		X
LRO-SIM-24	LOA Simulation	12 hours	No	Flatsat	X	X		X
LRO-SIM-25	LOI Contingency #1	8 hours	No	Flatsat	X	X		X
LRO-SIM-26	LOI Contingency #2	8 hours	No	Flatsat	X	X		X
LRO-SIM-27	LOI Contingency #3	8 hours	No	Orbiter	X	X		X
LRO-SIM-28	LOI Contingency #4	8 hours	No	Orbiter	X	X		X
LRO-SIM-29	Nominal Operations	3 days	Yes	Flatsat	X	X	X	X
LRO-SIM-30	Extended Early Mission Sim #3	4 days	Yes	Flatsat	X	X		X
Estimated Simulation Test Time:		804	hours					

2.1 MISSION SIMULATION APPROACH

The general timelines and plans for each simulation will follow the mission concept of operations and detailed timelines. Before each simulation, a general briefing message will be generated that captures any unique items planned for the simulations. The message will be sent to all simulation participants. It is the responsible of either the system team or GS&O lead that preparations are ready for each test.

2.2 SIMULATION SCHEDULE

All mission simulations will occur after the MOC receives the launch capable software release. The actual dates for each simulation will be maintained in the GS&O Integrated Schedule. Current plan has operation simulations starting in January 2008. As the orbiter and FlatSat schedule continues to firm up, individual dates will be selected for each mission simulation. The earlier simulations will be primarily for preparing for mission rehearsals.

2.3 SIMULATION RESULTS

Following each mission simulation, a test result report will be written and submitted to the project library. The test report will contain the following information:

- Main objectives and brief description of the test
- Objectives accomplished
- List of issues or DRs discovered during the test
- Lessons Learned that should be applied to future tests and rehearsals
- Test Participants
- Test hours

The test report will be written by the test director for each simulation. Results from each simulation will be compiled and summarized periodically during monthly status reports and at the Flight Operations Readiness Review (FORR).

3.0 LRO OPERATIONS READINESS TEST

An Operations Readiness Test matrix was developed to identify the nominal plan. Based on the results of each ORT, the baseline plan will be evaluated and additional ORTs may be scheduled. The tests identified in Table 3-1 illustrates the minimum tests being planned.

Table 3-1: LRO Operations Readiness Test Matrix

<i>LRO Operations Readiness Test Matrix</i>				<i>Matrix Version: 1.0</i>						
Test #	Test Title	Test Duration	Test Platform	Required Participates						
				MOC-MOT	USN	DSN	WS1	SN	FDf	SOCs
LRO-ORT-01	MOC-USN #1	2 hours	Data Files	X	X					
LRO-ORT-02	MOC-DSN #1	2 hours	Data Files	X		X				
LRO-ORT-03	MOC-WS1 #1	2 hours	Data Files	X			X			
LRO-ORT-04	MOC-SN #1	2 hours	Data Files	X				X		
LRO-ORT-05	MOC-SN #2	2 hours	Data Files					X		
LRO-ORT-06	MOC-SN #3	2 hours	Data Files					X		
LRO-ORT-07	MOC-SOC #1	3 hours	Flatsat	X					X	X
LRO-ORT-08	MOC-SOC #2	3 hours	Flatsat	X					X	X
LRO-ORT-09	MOC-USN #2	2 hours	Data Files	X	X					
LRO-ORT-10	MOC-DSN #2	2 hours	Data Files	X		X				
LRO-ORT-11	MOC-WS1 #2	2 hours	Data Files	X			X			
LRO-ORT-12	MOC-USN #3	2 hours	Data Files	X	X					
LRO-ORT-13	MOC-DSN #3	2 hours	Data Files	X		X				
LRO-ORT-14	MOC-WS1 #3	2 hours	Data Files	X			X			
LRO-ORT-15	MOC-USN #4	2 hours	Data Files	X	X					
LRO-ORT-16	MOC-DSN #4	2 hours	Data Files	X		X				
LRO-ORT-17	MOC-WS1 #4	2 hours	Data Files	X			X			
Estimated ORT Test Hours:		36 hours								

3.1 ORT TEST DETAILS

An initial list of objectives for each ORT has been identified and illustrated in Table 3-2. Prior to each ORT, the objectives will be reviewed and modified based on previous ORT results.

Table 3-2: Individual ORT Objectives

ORT Test ID	Test Objectives
LRO-ORT-01	Data File Required: VC0, VC1 frames MOT perform Pre-Pass Briefing Establish Telemetry, Command and Status Packet Connections Flow Real-Time VC0 & VC1 data MOC Receives and Displays VC0 MOC Processes VC1 CFDP files MOC performs real-time commanding – Stations verifies receipt of commands.
LRO-ORT-02	Data File Required: VC0, VC1 frames MOT perform Pre-Pass Briefing Establish Telemetry, Command and Status Packet Connections Flow Real-Time VC0 & VC1 data MOC Receives and Displays VC0 MOC Processes VC1 CFDP files MOC performs real-time commanding – Stations verifies receipt of commands.
LRO-ORT-03	Data File Required: <ul style="list-style-type: none"> • VC0, VC1 frames (S-Band) • VC2, VC3 frames (Ka-Band) MOT perform Pre-Pass Briefing Establish Telemetry, Command and Status Packet Connections Flow Real-Time VC0 & VC1 data MOC Receives and Displays VC0 MOC Processes VC1 CFDP files MOC performs real-time commanding – Stations verifies receipt of commands. WS1 flows real-time VC2 & VC3 to MUE Station DPS processes Ka-Band files and forwards CFDP PDUs and data files to the MOC.
LRO-ORT-04	Data File Required: VC0 frames MOT perform Pre-Pass Briefing Establish Telemetry and Command connections Flow Real-Time VC0 data MOC Receives and Displays VC0 MOC performs real-time commanding – Stations verifies receipt of commands. Perform handover activities

ORT Test ID	Test Objectives
LRO-ORT-05	Data File Required: VC0 frames MOT perform Pre-Pass Briefing Establish Telemetry and Command connections Flow Real-Time VC0 data MOC Receives and Displays VC0 MOC performs real-time commanding – Stations verifies receipt of commands. Perform handover activities
LRO-ORT-06	Data File Required: VC0 frames MOT perform Pre-Pass Briefing Establish Telemetry and Command connections Flow Real-Time VC0 data MOC Receives and Displays VC0 MOC performs real-time commanding – Stations verifies receipt of commands. Perform handover activities
LRO-ORT-07	Data File Required (All from Flatsat) Generate data files on Flatsat Forward FDF products to SOCs MOC commands Flatsat and dumps Stored Files Files are forwarded to SOCs
LRO-ORT-08	Data File Required (All from Flatsat) Generate data files on Flatsat Forward FDF products to SOCs MOC commands Flatsat and dumps Stored Files Files are forwarded to SOCs
LRO-ORT-09	Data File Required: VC0, VC1 frames MOT perform Pre-Pass Briefing Establish Telemetry, Command and Status Packet Connections Flow Real-Time VC0 & VC1 data MOC Receives and Displays VC0 MOC Processes VC1 CFDP files MOC performs real-time commanding – Stations verifies receipt of commands.
LRO-ORT-10	Data File Required: VC0, VC1 frames MOT perform Pre-Pass Briefing Establish Telemetry, Command and Status Packet Connections Flow Real-Time VC0 & VC1 data MOC Receives and Displays VC0 MOC Processes VC1 CFDP files MOC performs real-time commanding – Stations verifies receipt of commands.

ORT Test ID	Test Objectives
LRO-ORT-11	<p>Data File Required:</p> <ul style="list-style-type: none"> • VC0, VC1 frames (S-Band) • VC2, VC3 frames (Ka-Band) <p>MOT perform Pre-Pass Briefing Establish Telemetry, Command and Status Packet Connections Flow Real-Time VC0 & VC1 data MOC Receives and Displays VC0 MOC Processes VC1 CFDP files MOC performs real-time commanding – Stations verifies receipt of commands. WS1 flows real-time VC2 & VC3 to MUE Station DPS processes Ka-Band files and forwards CFDP PDUs and data files to the MOC.</p>
LRO-ORT-12	<p>Data File Required: VC0, VC1 frames</p> <p>MOT perform Pre-Pass Briefing Establish Telemetry, Command and Status Packet Connections Flow Real-Time VC0 & VC1 data MOC Receives and Displays VC0 MOC Processes VC1 CFDP files MOC performs real-time commanding – Stations verifies receipt of commands.</p>
LRO-ORT-13	<p>Data File Required: VC0, VC1 frames</p> <p>MOT perform Pre-Pass Briefing Establish Telemetry, Command and Status Packet Connections Flow Real-Time VC0 & VC1 data MOC Receives and Displays VC0 MOC Processes VC1 CFDP files MOC performs real-time commanding – Stations verifies receipt of commands.</p>
LRO-ORT-14	<p>Data File Required:</p> <ul style="list-style-type: none"> • VC0, VC1 frames (S-Band) • VC2, VC3 frames (Ka-Band) <p>MOT perform Pre-Pass Briefing Establish Telemetry, Command and Status Packet Connections Flow Real-Time VC0 & VC1 data MOC Receives and Displays VC0 MOC Processes VC1 CFDP files MOC performs real-time commanding – Stations verifies receipt of commands. WS1 flows real-time VC2 & VC3 to MUE Station DPS processes Ka-Band files and forwards CFDP PDUs and data files to the MOC.</p>

ORT Test ID	Test Objectives
LRO-ORT-15	Data File Required: VC0, VC1 frames MOT perform Pre-Pass Briefing Establish Telemetry, Command and Status Packet Connections Flow Real-Time VC0 & VC1 data MOC Receives and Displays VC0 MOC Processes VC1 CFDP files MOC performs real-time commanding – Stations verifies receipt of commands.
LRO-ORT-16	Data File Required: VC0, VC1 frames MOT perform Pre-Pass Briefing Establish Telemetry, Command and Status Packet Connections Flow Real-Time VC0 & VC1 data MOC Receives and Displays VC0 MOC Processes VC1 CFDP files MOC performs real-time commanding – Stations verifies receipt of commands.
LRO-ORT-17	Data File Required: <ul style="list-style-type: none"> • VC0, VC1 frames (S-Band) • VC2, VC3 frames (Ka-Band) MOT perform Pre-Pass Briefing Establish Telemetry, Command and Status Packet Connections Flow Real-Time VC0 & VC1 data MOC Receives and Displays VC0 MOC Processes VC1 CFDP files MOC performs real-time commanding – Stations verifies receipt of commands. WS1 flows real-time VC2 & VC3 to MUE Station DPS processes Ka-Band files and forwards CFDP PDUs and data files to the MOC.

3.2 ORT PLANNING APPROACH

Majority of the ORTs are designed to test the MOC with the ground network interfaces. For these tests, the GS&O team will coordinate and develop test briefing messages with the GSFC Network Operations Management (NOM). The NOM will be responsible for distributing the briefing messages and coordinating with each network.

For ORTs that include the SOCs, the GS&O team will generate the test briefing message and coordinate the detail plans with the SOCs. There are limited ORTs with the SOCs and FDF mostly since these elements and teams participate in mission simulations and rehearsals.

3.3 SIMULATION SCHEDULE

All mission ORTs will occur after mission readiness testing is complete. In general, all ORTs will be performed within the last two months of the mission. The actual dates for each ORT will be maintained in the GS&O Integrated Schedule. The current schedule and changes to test dates will be highlighted at the Bi-Weekly GS&O Status Meetings.

3.4 ORT RESULTS

Following each ORT, a summary report will be written and submitted to the project library. The report will contain the following information:

- Main objectives and brief description of the test
- Objectives accomplished
- List of issues or DRs discovered during the test
- Lessons Learned that should be applied to future tests
- Test Participants
- Test hours

The test report will be written by the test director for each simulation.

Appendix A. Abbreviations and Acronyms

Abbreviation/ Acronym	DEFINITION
CCB	Configuration Control Board
CFDP	CCSDS File Delivery Protocol
CM	Configuration Management
CMO	Configuration Management Office
DPS	Data Processing System
DR	Discrepancy Report
DSN	Deep Space Network
FDF	Flight Dynamics Facility
FORR	Flight Operations Readiness Review
GS&O	Ground System & Operations
LOI	Lunar Orbit Insertion
LRO	Lunar Reconnaissance Orbiter
MOC	Mission Operations Center
MOT	Mission Operations Team
MUE	Mission Unique Equipment
NOM	Network Operations Manager
ORT	Operations Readiness Test
PDU	Packet Data Unit
SK	Station-Keeping
SN	Space Network
SOC	Science Operations Center
TBD	To Be Determined
TBR	To Be Resolved
USN	Universal Space Network
VC	Virtual Channel