431-PLAN-000402
Revision -
Effective Date: To be added upon Release
Expiration Date: To be added upon Release

Lunar Reconnaissance Orbiter Project

LRO Mission Rehearsal Test Plan

August 7, 2007

National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland

CM FOREWORD

This document is a Lunar Reconnaissance Orbiter (LRO) Project Configuration Management (CM)-controlled document. Changes to this document require prior approval of the applicable Configuration Control Board (CCB) Chairperson or designee. Proposed changes shall be submitted to the LRO CM Office (CMO), along with supportive material justifying the proposed change. Changes to this document will be made by complete revision.

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LUNAR RECONNAISSANCE ORBITER PROJECT

DOCUMENT CHANGE RECORD

Sheet: 1 of 1

REV LEVEL	DESCRIPTION OF CHANGE	APPROVED BY	DATE APPROVED
-	Baseline version of Document	D. Everett	TBD

List of TBDs/TBRs

Item No.	Location	Summary	Ind./Org.	Due Date

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1.0 INTRODUCTION

This document describes the plan for mission rehearsals that will occur pre-launch. Mission rehearsals play an important role in training and verifying operational readiness for the entire project team. While the focus is mostly on the mission operations team, through the mission rehearsals, the engineering, instrument and ground system teams all play a role. During the mission rehearsals, the project team is exposed and trained on hardware and software systems that will support the mission on-orbit.

This document will describe the different mission rehearsals being planned for LRO. The document will also capture the following information:

- General approach for planning and coordinating each rehearsal
- Objectives for each rehearsal
- Test Dependencies
- Required participation for each rehearsal
- Process for executing each rehearsal
- Capturing results and feedback

1.1 MISSION REHEARSALS DEFINITION

Currently, there are five mission rehearsals being planned for LRO. The mission rehearsals will cover different time periods during the mission. Table 1-1 provides the list of the five rehearsals and time period each rehearsal will cover.

Table 1-1: Mission Rehearsal Definition

Rehearsal	Time Period
Rehearsal #1	Routine Operations – Nominal Mission Phase
Rehearsal #2	Launch & Cruise Activities (Including LOI)
Rehearsal #3	Lunar Orbit Acquisition & Spacecraft Commissioning
Rehearsal #4	Instrument Activation
Rehearsal #5	Launch and Early Cruise Activities (Including LOI)

For each mission rehearsal, different anomalies will be inserted to test various contingency plans and verify proficiency of the team reacting to anomalous conditions. Anomalies inserted into the rehearsals can be two different types. The first type is when the anomalous condition is simulated through orbiter housekeeping data. The second type is called anomaly cards. This is used when the anomaly can not be simulated realistically or for ground system items such as primary string is down and failover to the backup systems are required.

The individual mission rehearsals will generally last between 3-5 days. The actual duration depends on availability of test platform, goals/objectives for the rehearsal, and other project activities.

1.2 MISSION REHEARSAL REQUIRED SUPPORT

After completing the five rehearsals, various timelines and team support will be exercised. Table 1-2 shows the required support from different groups on LRO for each rehearsal.

Table 1-2: Mission Rehearsal Support Matrix

	MOT	Flight Dynamics	GNSO	Project	LRO Systems	S/C Subsystems	Instrument Teams	SOCs
Rehearsal #1	X	X	X					X
Rehearsal #2	X	X	X	X	X	X	X (1)	X (3)
Rehearsal #3	X	X	X	X	X	X		
Rehearsal #4	X	X	X	X	X	X	X (2)	X (4)
Rehearsal #5	X	X	X	X	X	X	X (1)	X (3)

Notes:

(1)	Includes LEND & CRaTER Instrument Teams
(2)	Includes LOLA, LROC, DLRE, LAMP, Mini-RF
(3)	Includes LEND & CRaTER SOC Teams
(4)	Includes LOLA, LROC, DLRE, LAMP, Mini-RF

1.2.1 Mission Operations Team (MOT)

The MOT is the central focus for all mission operations on LRO. The MOT will support all rehearsals and be involved with some of the initial planning and coordinating. The MOT will perform all activities as planned during the mission. These activities include:

- Daily planning

- Trending & Analysis
- Real-time Operations
- Off-line Activities

1.2.2 Flight Dynamics

Flight Dynamics support includes support from the Flight Dynamics Facility support team and Flight Dynamics Analysis Branch. Pre-rehearsal support includes generation of mission products for planning the rehearsal. During the rehearsals, the flight dynamic teams will perform routine product generation and maneuver and slew planning support.

1.2.3 Ground Network Scheduling Office (GNSO)

GNSO support to the mission rehearsals is limited to generating contact schedules based on rehearsal view periods generated by FDF. The rehearsal contact schedules will be used throughout the rehearsal for planning.

1.2.4 Project Team

The project team includes project management/leadership. It is expected that during early mission activities, project management will be present and involved in the daily planning/problem solving efforts. Involvement of the project team will allow execution of the escalation procedures.

1.2.5 LRO Systems

The LRO systems team will support all early mission activities leading up to nominal operations. Systems will be the main conduit for polling subsystem and instrument teams during on-orbit activities. LRO Systems will also lead the pre-rehearsal planning/coordinating.

1.2.6 LRO Subsystem Teams

LRO Spacecraft Subsystem Teams will be supporting all early mission activities leading up to nominal operations. Portions of the subsystem teams will also assist in the planning and coordinating the rehearsal activities.

1.2.7 Instrument Teams

For this document, instrument team is defined as the instrument developer. In some cases, the instrument teams and Science Operations Teams are not integrated. During instrument activation and certain commissioning activities, instrument support usually includes the instrument system engineer and management. These individuals are located at GSFC during critical instrument activities and support both real-time and planning process. Location near the mission operations center is provided to the instrument teams. The location contains both the mission operations real-time telemetry display terminals and space allocation for instrument GSE

required. During the mission rehearsals, GSE interfaces will be verified with the MOC systems. Since LEND and CRaTER instruments are turned on early during cruise, those teams will support Rehearsals 2 & 5. The remaining instrument teams (LOLA, LROC, LAMP, DLRE, and Mini-RF) will support mission rehearsals 3 and 4.

1.2.8 Science Operations Centers (SOCs)

The SOCs main support will come in rehearsal #1. During rehearsal number #1, the SOCs will perform daily activities that include:

- Support planning activities with the Ops team
- Generate and deliver operations activity requests
- Receive and process instrument housekeeping and science data
- Exercise access to MOC systems for data retransmit request

During the early mission rehearsals (Rehearsals 2, 4, and 5), the SOCs will be online to receive instrument housekeeping data. Since the primary instrument contact during this phase is the onsite instrument support, the SOCs main role is receiving and processing the instrument and selected spacecraft data.

Similar to the instrument teams, the LEND and CRaTER SOCs will support rehearsals 1, 2, and 5. The LOLA, LROC, DLRE, LAMP and Mini-RF SOCs will support rehearsals 1, 3, and 4.

1.3 MISSION REHEARSAL PLANNING APPROACH

For each mission rehearsal identified in Table 1-1, a rehearsal execution team will be assembled. Members of this team may change for the different rehearsals. The rehearsal execution team primary responsible is planning and coordinating the execution of the rehearsals but the team is also responsible for monitoring the execution of the rehearsal. The team will be led by someone on the LRO mission system team as identified by the Mission System Engineer. The appointed lead for each rehearsal will assemble the remaining team members. The team members should have experience in the different engineering disciplines such as Systems, Subsystems, Instrument, Ground Systems, Science Operations, and Mission Operations.

Specific activities the team will perform are identified in Table 1-3.

Table 1-3: Rehearsal Execution Team Activities

Activity	Summary
Anomaly Identification	Generate list of possible problems/anomalies for the rehearsal.

Activity	Summary
Anomaly Planning	Generate timeline where identified anomalies will be inserted. Coordinate that the anomalies are realistically simulated. In addition, the team should identify the correct response to the anomalies.
Test Planning	Coordinate required test platforms such as flatsat and/or the orbiter
Rehearsal Sequence of Events	The rehearsal execution team will generate a rehearsal sequence of events that identifies when nominal activities are occurring and when anomalies are inserted.
Rehearsal Briefing	Perform briefing that outlines test flow, objectives, provide logistical information, etc
Monitor Rehearsals	During the rehearsals, the execution team monitors the performance of the team. This is used in the post rehearsal feedback session. The team monitors both the nominal processes as well as how the team reacts to the different anomalies.
Rehearsal De-Brief	Following each rehearsal, the execution team will collect all feedback forms, capture observations, and generate a de-brief package. The rehearsal de-brief will capture how the team reacted to the anomalies, whether the response was correct, process improvements, and general feedback.

1.3.1 Rehearsal Preparation Schedule

For each mission rehearsal, the schedule shown in Table 1-4 will serve as a general guideline for the rehearsal execution team. The rehearsal execution time will adjust based on the scope and definition of the rehearsal objectives.

Table 1-4: Typical Rehearsal Preparation Schedule

Schedule	Activity
R-90 days	Mission System Engineer identifies lead for rehearsal execution team.
R-60 days	List is compiled for possible anomalies that could be used during the rehearsal.
R-45 days	Anomalies are evaluated based on capabilities to simulate conditions. Final anomaly list is compiled.
R-30 days	Nominal sequence of events is updated and timeline is created when anomalies are inserted.

Schedule	Activity
R-10 days	Final preparations are completed, simulation products are generated and released to participates.
R-2 days	Rehearsal briefing is performed with all supporting team members.
R- day	Mission Rehearsal starts.
Rehearsal End Day + 5 days	Within 5 days following the mission rehearsal, the post-rehearsal summary is compiled from all inputs and presented to the project team.

2.0 MISSION REHEARSAL TEST SUMMARY

2.1 MISSION REHEARSAL DEPENDENCIES

Generally for most mission rehearsals, the completed flatsat with ETUs or Orbiter with Flight hardware is required. Table 2-1 provides the rehearsal dependencies which include MOC and Flight Dynamics software. This matrix will be used to adjust scheduling of the mission rehearsals if integration delays occur with individual components.

Table 2-1: Mission Rehearsal Dependency Matrix

		Rehearsal #1	Rehearsal #2	Rehearsal #3	Rehearsal #4	Rehearsal #5
Spacecraft	Flight/ETU C&DH	X	X	X	X	X
	Flight/ETU PSE	X	X	X	X	X
	Flight/ETU PDE	X	X	X	X	X
	Star Trackers	X	X	X	X	X
	Inertial Measurement Unit	X	X	X	X	X
	Reaction Wheels	X	X	X	X	X
	Goddard Dynamics Simulator	X	X	X	X	X
	FSW Build 4.0	X	X	X	X	X
	FSW Build 3.0					
	Flight/ETU S-Band TT&C	X	X	X	X	X
	Flight/ETU Ka-Band	X		X	X	
Instrument	Flight LROC	X			X	
	Flight LOLA	X			X	
	Flight LEND	X	X	X	X	X
	Flight Mini-RF	X			X	
	Flight LAMP	X			X	
	Flight DLRE	X			X	
	Flight CRaTER	X	X	X	X	X
	LROC Flatsat Simulator	X			X	
	LAMP Flatsat Simulator	X			X	
	LEND Flatsat Simulator	X	X	X	X	X
	LOLA Flatsat Simulator	X			X	
	CRaTER Flatsat Simulator	X	X	X	X	X
	Mini-RF Flatsat Simulator	X			X	
	DLRE Flatsat Simulator	X			X	
MOC	AGS Release 1					
	AGS Release 2	X	X	X	X	X
	MPS Release 1					

		Rehearsal #1	Rehearsal #2	Rehearsal #3	Rehearsal #4	Rehearsal #5
	MPS Release 2	X	X	X	X	X
	T&C Release 1					
	T&C Release 2	X	X	X	X	X
	Trending Release 1		X	X	X	X
	Trending Release 2	X	X	X	X	X
	MAS (Ops Config)	X	X	X	X	X
	DPS Release 1					
	DPS Release 2	X	X	X	X	X
	DMS Release 1					
	DMS Release 2	X	X	X	X	X
FDF	FDPC	X	X	X	X	X

2.2 MISSION REHEARSAL SCHEDULE

Table 2-2 provides the timeframe for when the individual mission rehearsals occur. The schedule will be adjusted to account for orbiter and flatsat availability.

Table 2-2: Mission Rehearsal Preliminary Schedule

Rehearsal #1	Routine Operations – Nominal Mission Phase	July 2008 (Tied to Orbiter TVac)
Rehearsal #2	Launch & Cruise Activities (Including LOI)	January 2008
Rehearsal #3	Lunar Orbit Acquisition & Spacecraft Commissioning	March 2008
Rehearsal #4	Instrument Activation	June 2008
Rehearsal #5	Launch and Early Cruise Activities (Including LOI)	August 2008

2.3 MISSION REHEARSAL #1 (ROUTINE OPERATIONS)

Mission Rehearsal #1 will be performed during orbiter thermal vacuum testing. This will provide the most realistic simulation for the instruments and spacecraft operations. The rehearsal will run for consecutive days.

2.3.1 Mission Rehearsal #1 Objectives

- Orbiter Operation
  - Demonstrate nominal day-in-life timeline
  - Execute Mini-RF Operations Opportunity
  - Anomaly detection/resolution/recovery
- Personnel
  - Roles and Responsibilities of operations team
  - Real-time and offline decision flow
  - Anomaly resolution coordination
- Ground Operations
  - Perform daily mission planning activities
  - Execute automation during off-shift hours
  - Receive and process inputs from SOCs
  - Generate daily products and distribute to ground segment elements
  - Real-time Operations
  - Team Communication using voice loops
  - Exercise planning meetings
- Staffing Plans
  - Shift Coverage is planned (monitor on 2nd and 3rd shift), actual activities will occur on 1 shift
  - Operations team, all SOCs online

2.4 MISSION REHEARSAL #2 (LAUNCH & CRUISE)

Mission Rehearsal #2 will cover all activities from launch through end of LOI. The rehearsal will run for 5 consecutive days.

2.4.1 Mission Rehearsal #2 Objectives

- Orbiter Operation
  - Demonstrate early mission timeline from launch through end of LOI
  - Re-Planning based on activities accomplished
  - Anomaly detection/resolution/recovery
- Personnel
  - Roles and Responsibilities of operations team, engineering support, and project support.
  - Real-time and offline decision flow
  - Anomaly resolution coordination
- Ground Operations
  - Generate and execute MCC plan within 24 hrs
  - Generate and verify LOI plans w/contingencies
  - Early mission data trending
  - Real-time Operations
  - Team Communication using voice loops

  - Exercise planning meetings, shift handovers, and anomaly briefings
- Staffing Plans
  - Shift Coverage is planned
  - Operations team, system & subsystem engineering team, LEND/CRaTER Engineering support, project management

2.5 MISSION REHEARSAL #3 (LUNAR ORBIT ACQUISITION & S/C COMMISSIONING)

Mission Rehearsal #3 will cover all activities from start of LOA to the end of S/C commissioning. The rehearsal will run for 4 consecutive days.

2.5.1 Mission Rehearsal #3 Objectives

- Orbiter Operation
  - Demonstrate sequence of LOA maneuvers
  - Execute plans for performing spacecraft calibrations
  - Re-Planning based on activities accomplished
  - Anomaly detection/resolution/recovery
- Personnel
  - Roles and Responsibilities of operations team, engineering support, and project support.
  - Real-time and offline decision flow
  - Anomaly resolution coordination
- Ground Operations
  - Generate LOA maneuvers
  - Early mission data trending
  - Real-time Operations
  - Team Communication using voice loops
  - Exercise planning meetings, shift handovers, and anomaly briefings
- Staffing Plans
  - Shift Coverage is planned
  - Operations team, system & subsystem engineering team, Engineering support, project management

2.6 MISSION REHEARSAL #4 (INSTRUMENT ACTIVATION)

Mission Rehearsal #4 will cover all activation for LROC, LOLA, LAMP, DLRE and Mini-RF. The rehearsal will run for 5 consecutive days. Initial activation sequence for each instrument will be exercised. Mission rehearsal will not cover any calibration activities.

2.6.1 Mission Rehearsal #4 Objectives

- Orbiter Operation
  - Demonstrate activation sequence for each instrument
  - Re-Planning based on activities accomplished
  - Anomaly detection/resolution/recovery
- Personnel
  - Roles and Responsibilities of operations team, engineering support, and project support.
  - Real-time and offline decision flow
  - Anomaly resolution coordination
- Ground Operations
  - Perform regular planning meetings
  - Simulate ground contact coverage
  - Early mission data trending
  - Real-time Operations
  - Team Communication using voice loops
  - Exercise planning meetings, shift handovers, and anomaly briefings
- Staffing Plans
  - Shift Coverage is planned
  - Operations team, system & subsystem engineering team, LROC, LOLA, LAMP, DLRE, and Mini-RF Engineering support, project management
  -

2.7 MISSION REHEARSAL #5 (LAUNCH & CRUISE)

Mission Rehearsal #5 will cover all activities from launch through end of LOI. The rehearsal will run for 5 consecutive days.

2.7.1 Mission Rehearsal #5 Objectives

- Orbiter Operation
  - Demonstrate early mission timeline from launch through end of LOI
  - Re-Planning based on activities accomplished
  - Anomaly detection/resolution/recovery
- Personnel
  - Roles and Responsibilities of operations team, engineering support, and project support.
  - Real-time and offline decision flow
  - Anomaly resolution coordination
- Ground Operations
  - Generate and execute MCC plan within 24 hrs
  - Generate and verify LOI plans w/contingencies
  - Early mission data trending
  - Real-time Operations
  - Team Communication using voice loops

  - Exercise planning meetings, shift handovers, and anomaly briefings
- Staffing Plans
  - Shift Coverage is planned
  - Operations team, system & subsystem engineering team, LEND/CRaTER Engineering support, project management

Appendix A. Abbreviations and Acronyms

Abbreviation/ Acronym	DEFINITION
AGS	Attitude Ground System
C&DH	Command & Data Handling
CCB	Configuration Control Board
CM	Configuration Management
CMO	Configuration Management Office
CRaTER	Cosmic Ray Telescope for the Effects of Radiation
DLRE	Diviner Lunar Radiometer Experiment
DMS	Data Management System
DPS	Data Processing System
ETU	Engineering Test Unit
FDF	Flight Dynamics Facility
FDPC	Flight Dynamics Product Center
FSW	Flight Software
GNSO	Ground Network Scheduling Office
GSFC	Goddard Space Flight Center
ICD	Interface Control Document
LAMP	Lyman-Alpha Mapping Project
LEND	Lunar Exploration Neutron Detector
LOA	Lunar Orbit Acquisition
LOI	Lunar Orbit Insertion
LOLA	Lunar Orbiter Laser Altimeter
LRO	Lunar Reconnaissance Orbiter
LROC	Lunar Reconnaissance Orbiter Camera
MAS	Monitor Alert System
MCC	Mid Course Correction
MOC	Mission Operations Center
MOT	Mission Operations Team
MPS	Mission Planning System
Ops	Operations
PDE	Propulsion Deployment Electronics
PSE	Power System Electronics
S/C	Spacecraft
SOCs	Science Operations Centers
T&C	Telemetry & Command
TT&C	Telemetry Tracking and Command